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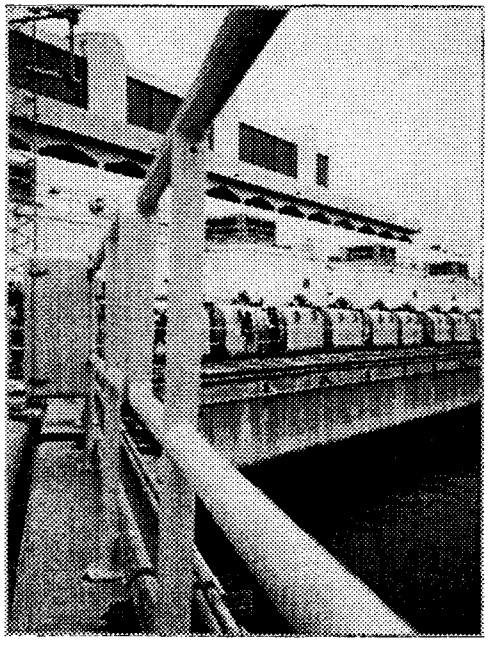

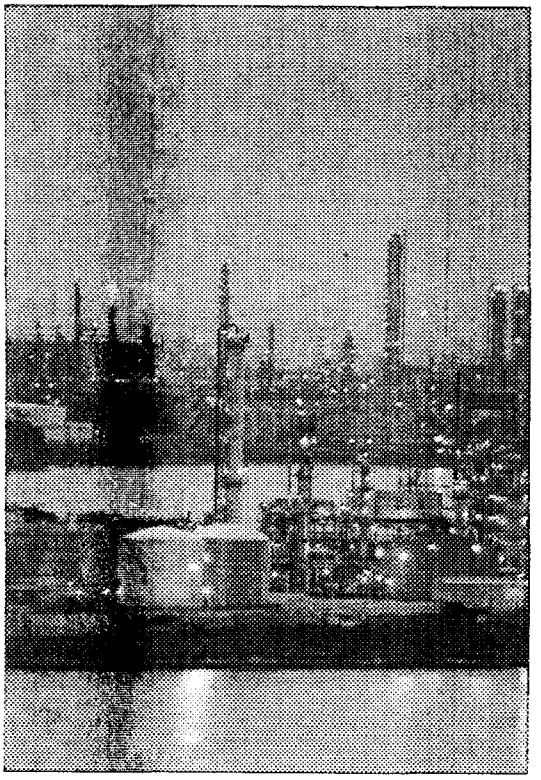

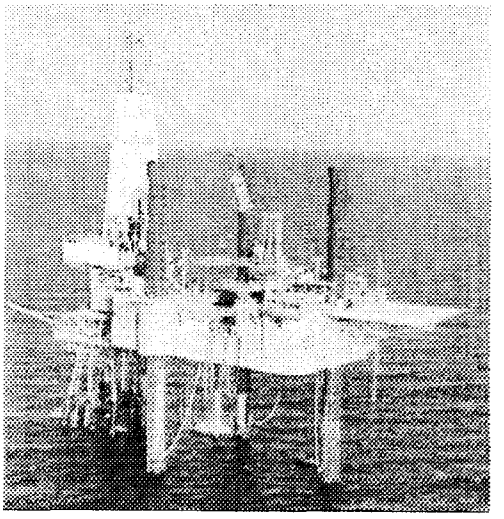

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Chapter 1: Summary of the Proposed Rule

1.0 APPLICABILITY OF THE PROPOSED RULE

The proposed 316(b) rule for Phase III would apply to two groups of facilities that use cooling water intake structures to withdraw water from waters of the U.S. First, it would apply to existing facilities not already regulated by EPA's "Phase II" regulation that withdraw above a certain flow threshold (see below). Based on the co-proposed flow thresholds, the proposed rule would, in effect, only apply to existing manufacturing and industrial facilities. *Phase III existing facilities* are defined in § 125.101 and § 125.102 of the proposed rule, and include existing manufacturing and industrial facilities (including but not limited to chemical, metal, pulp and paper, and petroleum refining facilities) that meet the criteria specified below. Under the proposed rule, these facilities would be subject to similar requirements to the final 316(b) rule for Phase II, with Phase III requirements specified in Part 125, Subpart K. Second, the proposed rule would apply to new offshore oil and gas extraction facilities, with requirements specified in Part 125, Subpart N.

Existing facilities must meet all of the following criteria to be considered a "Phase III existing facility" subject to the uniform national requirements of proposed rule:

- The facility is a point source that has or is required to have a NPDES permit under section 402 of the Clean Water Act;
- The facility is an existing facility other than a Phase II existing facility;
- The facility uses at least 25 percent of water withdrawn exclusively for cooling purposes, measured on an average annual basis; and
- The facility uses, or proposes to use, cooling water intake structures, including a cooling water intake structure operated by an independent supplier, with a total design intake flow equal to or greater than the proposed threshold in million gallons per day (MGD) to withdraw cooling water from waters of the United States.

The proposed rules describe three regulatory options based on design intake flow and source waterbody type that define which facilities would be Phase III existing facilities subject to uniform national requirements:

- The facility has a total design intake flow of 50 MGD or more, and withdraws from any source waterbody type;
- The facility has a total design intake flow of 200 MGD or more, and withdraws from any source waterbody type;
- The facility has a total design intake flow of 100 MGD or more, and withdraws water from an ocean, estuary, tidal river or stream, or Great Lake.

If a facility is a point source that uses a cooling water intake structure and has, or is required to have, an NPDES permit, but does not meet the appropriate threshold based on design intake flow/source waterbody typeor the 25% cooling purposes threshold, it would be subject to permit conditions implementing section 316(b) of the Clean Water Act set by the permit director on a case-by-case basis, using best professional judgment (BPJ). For example, under the 100 MGD coastal and Great Lakes option, facilities withdrawing from a freshwater river or stream would not be subject to national requirements, but rather to site-specific best professional judgment (BPJ)-based limits.

The proposed Phase III rule also would make new offshore oil and gas extraction facilities subject to requirements similar to those under the final Phase I new facility regulation (40 CFR 125 Subpart I). Requirements for new offshore oil and gas extraction facilities are proposed in a new Subpart N. For purposes of this proposed rule, new offshore oil and gas extraction facilities are those facilities that are subject to the Oil and Gas Extraction Point Source Category Effluent Guidelines (i.e., 435.10 Offshore Subcategory or 435.40 Coastal Subcategory), and meet the definition of "new offshore oil and gas extraction facility" in proposed Subpart N, § 125.133.

2.0 AFFECTED SUBCATEGORIES

The national requirements of the proposed rule may apply to existing facilities in the following sectors: chemical and allied products, primary metals, paper and allied products, petroleum and coal products, and other industries. In addition, facilities not covered by the national requirements would continue to be subject to permit requirements that implement section 316(b) requirements on case-by-case, BPJ basis. The following is a list of industries potentially affected by Phase III section 316(b) through either national requirements or BPJ-based limits. A detailed description of the industry sectors subject to the proposed rule is found in Chapter 2 of the TDD.

Industries Potentially Affected by Section 316(b) Phase III
Operators of steam electric generating point source dischargers that employ cooling water intake structures.
Agricultural production
Metal mining
Oil and gas extraction
Mining and quarrying of nonmetallic minerals
Food and kindred products
Tobacco products
Textile mill products
Lumber and wood products, except furniture
Paper and allied products
Chemical and allied products
Petroleum refining and related industries
Rubber and miscellaneous plastics products
Stone, clay, glass, and concrete products
Primary metal industries
Fabricated metal products, except machinery and transportation equipment
Industrial and commercial machinery and computer equipment
Transportation equipment
Measuring, analyzing, and controlling instruments; photographic, medical, and optical goods; watches and clocks
Electric, gas, and sanitary services
Educational services
Engineering, accounting, research, management and related services

3.0 OVERVIEW OF THE PROPOSED REQUIREMENTS

As in Phase I and II, section 316(b) requirements for Phase III existing facilities would be implemented through the NPDES permit program. The proposed 316(b) rule for phase III existing facilities would establish performance standards similar to those that exist in the Phase II rule for Phase II existing facilities. The performance standards would consist of ranges of reductions in impingement mortality and/or entrainment (e.g., reduce impingement mortality by 80 to 95 percent and/or entrainment by 60 to 90 percent). These performance standards reflect the best technology available for minimizing adverse environmental impacts determined on a national categorical basis. The type of performance standard applicable to a particular facility (i.e., reductions in impingement mortality only or impingement mortality and entrainment) would be based on several factors, including the facility's location (i.e., source waterbody), and the proportion of the waterbody withdrawn. The proposed rule would establish requirements for new offshore oil and gas extraction facilities that are similar to requirements established under the 316(b) Phase I rule for other new facilities. These requirements are described below.

3.1 Phase III Existing Facilities

As noted above, performance requirements would vary under the proposed rule depending upon the location (waterbody) of the facility and the proportion of the waterbody withdrawn for cooling. Exhibit 1-1 presents the proposed performance standard requirements for Phase III existing facilities.

Exhibit 1-1. Performance Standard Requirements

Waterbody Type	Design Intake Flow	Type of Performance Standard
Freshwater River or Stream	5% or less of mean annual flow	Impingement mortality only
	Greater than 5% of mean annual flow	Impingement mortality and entrainment
Tidal river, Estuary, Ocean, or Great Lakes	N/A	Impingement mortality and entrainment
Lakes or Reservoirs	Increase in design intake flow must not disrupt thermal stratification except where it does not adversely affect the management of fisheries.	Impingement mortality only

As in the Phase II final rule, the proposed Phase III rule identifies five alternatives a Phase III existing facility may use to achieve compliance with the requirements for best technology available for minimizing adverse environmental impacts associated with cooling water intake structures. Four of these alternatives are based on meeting the applicable performance standards and the fifth allows the facility to request a site-specific determination of best technology available for minimizing adverse environmental impacts under certain circumstances. Application requirements would vary based on the compliance alternative selected and, for some facilities, include development of a Comprehensive Demonstration Study (see, section VII, Implementation, of the preamble to the proposed Phase III rule).

Under the first proposed compliance alternative (at § 125.103(a)(1)(i) and (ii)), a Phase III existing facility may demonstrate to the Director that it has already reduced its flow commensurate with a closed-cycle recirculating system, or that it has already reduced its design intake velocity to 0.5 feet per second or less. If a facility can demonstrate to the Director that it has reduced, or will reduce, flow commensurate with a closed-cycle recirculating system, the facility is deemed to have met the performance standards to reduce impingement mortality and entrainment (see § 125.103(a)(1)(i)). Those facilities would not be required to submit a Comprehensive Demonstration Study with their NPDES application. If the facility can demonstrate to the Director that is has reduced, or will reduce maximum through-screen design intake velocity to 0.5 feet per second or less, the facility is deemed to have met the performance standards to reduce impingement mortality only. Facilities that meet the velocity requirements would only need to submit application studies related to determining entrainment reduction, if subject to the performance standards for entrainment.

Under § 125.103(a)(2) and (3), a Phase III existing facility may demonstrate to the Director either that its current cooling water intake structure configuration meets the applicable performance standards or that it has selected design and construction technologies, operational measures, and/or restoration measures that, in combination with any existing design and construction technologies, operational measures, and/or restoration measures, meet the specified performance standards in § 125.103(b) and/or the requirements in § 125.103(c).

Under § 125.103(a)(4), a Phase III existing facility may demonstrate to the Director that it has installed and is properly operating and maintaining a rule-specified and approved design and construction technology in accordance with § 125.108(a). Submerged cylindrical wedgewire screen technology is proposed as a rule-specified design and construction technology that may be used in instances in which a facility's cooling water intake structure is located in a freshwater river or stream and meets other criteria specified at § 125.108(a). In addition, under the fourth compliance alternative, a facility or other interested person may submit a request to the Director for approval of a different technology. If the Director approves the technology, the proposed rule states that it may be used by all facilities with similar site conditions under his or her jurisdiction if allowed under the State's administrative procedures. Under the proposed rule, a Director may only approve an alternative technology following public notice and opportunity for comment on the approval of the technology (§ 125.108(b)).

Under the fifth proposed compliance alternative (at § 125.103(a)(5) (i) or (ii)), if the Director determines that a facility's costs of compliance would be significantly greater than the costs considered by the Administrator for a like facility to meet the applicable performance standards, or that the costs of compliance would be significantly greater than the benefits of meeting the applicable performance standards at the facility, the Director must make a site-specific determination of best technology available for minimizing adverse environmental impact. Under this alternative, a facility would either compare its projected costs of compliance using a particular technology or technologies to the costs the Agency considered for a like facility in establishing the applicable performance standards, or compare its projected costs of compliance with the projected benefits at its site of meeting the applicable performance standards of this proposed rule. If in either case costs are significantly greater, the technology selected by the Director must achieve an efficacy level that comes as close as practicable to the applicable performance standards without resulting in significantly greater costs.

Additionally, the proposed rule states that during the first permit term, a facility that chooses compliance alternatives in § 125.103(a)(2), (3), (4), or (5) may request that compliance with the requirements of this rule be determined based on the implementation of a Technology Installation and Operation Plan indicating how the facility will install and ensure the efficacy, to the extent practicable, of design and construction technologies and/or operational measures, and/or a Restoration Plan (§ 125.103(d)). The Technology Installation and Operation Plan must be developed and submitted to the Director in accordance with § 125.104(b)(4)(ii). The Restoration Plan must be developed in accordance with § 125.104(b)(5). During subsequent permit terms, if the facility has been in compliance with the construction, operational, maintenance, monitoring, and adaptive management requirements in its Technology Installation and Operation Plan and/or Restoration Plan during the preceding permit term, the facility may request that compliance during subsequent permit terms be based on its remaining in compliance with its Technology Installation and Operation Plan and/or Restoration Plan, revised in accordance with applicable adaptive management requirements if the applicable performance standards are not being met.

Similar to the Phase II requirements, Phase III existing facilities would be required to submit three sets of data at least 180 days prior to expiration of a facility's existing permit by all facilities regardless of compliance alternative selected (see § 122.21(r)(2)(3) and (5)). These are:

- Source Water Physical Data: a narrative description and scaled drawings showing the physical configuration of all source waterbodies used by the facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports its determination of the waterbody type where each cooling water intake structure is located; identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods used to conduct any physical studies to determine the intake's area of influence and the results of such studies; and locational maps.
- Cooling Water Intake Structure Data: a narrative description of the configuration of each of the facility's cooling water intake structures and where it is located in the waterbody and in the water column; latitude and longitude in degrees, minutes, and seconds for each of its cooling water intake structures; a narrative description of the operation of each of its cooling water intake structures, including design intake flows, daily hours of operation, number of days of the year in operation, and seasonal changes, if applicable; a flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and engineering drawings of the cooling water intake structure.
- Cooling Water System Data: a narrative description of the operation of each cooling water system, its relationship to the cooling water intake structures, proportion of the design intake flow that is used in the system, the number of days of the year the system is in operation, and seasonal changes in the operation of the system, if applicable; and engineering calculations and supporting data to support the narrative description.

In addition to the specified data facilities would be required to submit, some facilities would also be required to conduct a Comprehensive Demonstration Study. Specific requirements for the Comprehensive Demonstration Study would vary based on the compliance alternative selected. Exhibit 1-2 summarizes the Comprehensive Demonstration Study requirements for each proposed compliance alternative. Specific details of each Comprehensive Demonstration Study component are provided in section VII of this preamble.

Exhibit 1-2. Summary of Comprehensive Demonstration Study Requirements for Compliance Alternatives

Compliance Alternative (§ 125.103(a))	**Comprehensive Demonstration Study Requirements (§ 125.103(a))**
1 - Demonstrate facility has reduced flow commensurate with closed-cycle recirculating system	None
1 - Demonstrate facility has reduced design intake velocity to ≤ 0.5 feet per second	No requirements relative to impingement mortality reduction. If subject to entrainment performance standard, the facility must only address entrainment in the applicable components of its Comprehensive Demonstration Study, based on the compliance option selected for entrainment reduction.
2 - Demonstrate that existing design and construction technologies, operational measures, and/or restoration measures meet the performance standards	Proposal for Information Collection Source Waterbody Flow Information Impingement Mortality and/or Entrainment Characterization Study (as appropriate) Technology and Compliance Assessment Information - Design and Construction Technology Plan - Technology Installation and Operation Plan Restoration Plan (if appropriate) Verification Monitoring Plan
3 - Demonstrate that facility has selected design and construction technologies, operational measures, and/or restoration measures that will, in combination with any existing design and construction technologies, operational measures, and/or restoration measures, meet the performance standards	Proposal for Information Collection Source Waterbody Flow Information Impingement Mortality and/or Entrainment Characterization Study (as appropriate) Technology and Compliance Assessment Information - Design and Construction Technology Plan - Technology Installation and Operation Plan Restoration Plan (if appropriate) Verification Monitoring Plan

Exhibit 1-2. Summary of Comprehensive Demonstration Study Requirements for Compliance Alternatives (continued)

Compliance Alternative (§ 125.103(a))	Comprehensive Demonstration Study Requirements (§ 125.103(a))
4 - Demonstrate that facility has installed and properly operates and maintains an approved technology	Technology Installation and Operation Plan Verification Monitoring Plan
Demonstrate that a site-specific determination of BTA is appropriate	Proposal for Information Collection Source Waterbody Flow Information Impingement Mortality and/or Entrainment Characterization Study (as appropriate) Technology Installation and Operation Plan Restoration Plan (if appropriate) Information to Support Site Specific Determination of BTA including: -Comprehensive Cost Evaluation Study (cost-cost test and cost-benefit test); -Valuation of Monetized Benefits of Reducing IM&E (cost-benefit test only); -Site-Specific Technology Plan (cost-cost test and cost-benefit test); Verification Monitoring Plan

3.2 New Offshore Oil and Gas Extraction Facilities

Under the proposed Subpart N, new offshore oil and gas extraction facilities that withdraw more than 2 MGD would have to comply with the requirements in § 122.21(r) and proposed § 125.134. These requirements address fixed and non-fixed (mobile) facilities with and without sea chests and are similar to requirements in the Phase I rule for new facilities. Under this proposal, new offshore oil and gas extraction facilities that are fixed facilities and withdraw more than 2 MGD and that do not employ sea chests as cooling water intake structures would have to comply with the requirements in § 125.134(b)(2) through (8). The same facilities with sea chests must comply with all of the same requirements except § 125.134(b)(5) for entrainment requirements. Proposed requirements at § 125.134(b) address intake flow velocity, proportional flow restrictions for facilities on tidal rivers or estuaries, specific impact concerns (e.g., threatened or endangered species, critical habitat, migratory or sport or commercial species), required information submission, monitoring, and recordkeeping.

Under the proposed Subpart N, new offshore oil and gas extraction facilities that are non-fixed facilities would be required to submit appropriate Track 1 application requirements under § 122.21(r) and § 125.136(b). This includes source water physical data, cooling water intake structure data, velocity information, source waterbody flow information, and a design and construction technology plan.

Facilities would also have the opportunity to request alternative requirements under proposed § 125.135 and provide data to determine if compliance with the proposed requirements would result in compliance costs wholly out of proportion to those EPA considered in establishing the requirement, or would result in significant adverse impacts on local air quality, local water resources other than impingement or entrainment, or local energy markets.

Source Water Physical Data (§ 122.21(r)(2))

The requirements are the same as those described above for Phase III existing facilities. Track I fixed facilities would submit all of the data except for proposed § 122.21(r)(2)(iv), only required by non-fixed facilities: a narrative description and/or locational maps providing information on predicted locations within the waterbody during the permit term in sufficient detail for the Director to determine the appropriateness of additional impingement requirements under § 125.134(b)(4). Non-fixed facilities would only be required to submit § 122.21(r)(2)(iv) of the § 122.21(r)(2) requirements.

Cooling Water Intake Structure Data (§ 122.21(r)(3))

The requirements are the same as those described above for Phase III existing facilities for fixed facilities; non-fixed facilities would only submit (§ 122.21(r)(3)(i) and (ii), narrative description of the configuration of each cooling water intake structure, and the latitude and longitude for each cooling water intake structure.

Source Water Baseline Biological Characterization Data (§ 122.21(r)(4))

Under the proposed Subpart N, new offshore oil and gas extraction fixed facilities would be required to submit source water baseline biological characterization data as required for other new facilities under Phase I. The data would be used to characterize the biological community in the vicinity of the cooling water intake structure and to characterize the operation of the cooling water intake structure. The data would include existing data (if available) supplemented with new field studies as necessary. Detailed data requirements are at § 122.21(r)(4). Under the proposed rule, facilities may choose to conduct regional studies to collect this information as approved by the Director. EPA recognizes that many offshore oil and gas extraction facilities are regulated under NPDES general permits and that regional studies are typically conducted as part of the general permit requirements. Under this proposed rule, the regional study would include annual monitoring requirements.

Velocity Information

The proposed rule would require that new offshore oil and gas extraction facilities submit velocity information consistent with Subpart N requirements found at § 125.136(b)(1). The information would be used to demonstrate to the Director that the facility is complying with the requirement to meet a maximum through-screen design intake velocity of no more than 0.5 feet per second at the cooling water intake structure. The following information would be required to be submitted: 1) a narrative description of the design, structure, equipment, and operation used to meet the velocity requirement; and 2) design calculations showing that the velocity requirement would be met at minimum ambient source water surface elevations (based on best professional judgment using available hydrological data) and maximum head loss across the screens or other device.

Source Waterbody Flow Information

The proposed rule would also require that new offshore oil and gas extraction facilities submit source waterbody flow information consistent with Phase I requirements at § 125.136(b)(2). The information would be used to demonstrate to the Director that the facility's cooling water intake structure meets the proportional flow requirements at § 125.134(b)(3). These requirements include specific provisions for facilities located on estuaries or tidal rivers to provide greater protection for these sensitive waters. Specifically, the proposed rule requires that the total design intake flow over one tidal cycle of ebb and flow must be no greater than one (1) percent of the volume of the water column within the area centered about the opening of the intake with a diameter defined by the distance of one tidal excursion at the mean low water level. Calculations and guidance on determining the tidal excursion is found in the preamble to the final Phase I rule at section VII.B.1.d

Design and Construction Technology Plan

The proposed rule also would require that new offshore oil and gas extraction facilities submit a design and construction technology plan at § 125.136(b)(3). The design and construction technology plan would demonstrate that the facility has selected and will implement the design and construction technologies necessary to minimize impingement mortality and/or entrainment. The design and construction technology plan would require delineation of the hydrologic zone of influence for the cooling water intake structure; a description of the technologies implemented (or to be implemented) at the facility; the basis for the selection of that technology; the expected performance of the technology, and design calculations, drawings and estimates to support the technology description and performance. The Agency recognizes that the selection of a specific technology or a group of technologies will depend on the individual facility and waterbody conditions.

Chapter 2: Description of the Industry

Today's proposed rule would apply national requirements to two general groups of facilities that use cooling water intake structures to withdraw water from waters of the U.S. First, it would apply to existing facilities not already regulated by EPA's "Phase II" regulation that withdraw above a certain flow threshold. Based on the co-proposed thresholds, the proposed rule would in effect only apply to existing manufacturing and industrial facilities. Based on the co-proposed thresholds, the national requirements would not apply to existing electric generators not covered under Phase II, existing offshore oil and gas extraction facilities, and existing seafood processing vessels. Second, the proposed rule would apply to new offshore oil and gas extraction facilities. Although EPA considered proposing requirements for new seafood processing vessels and offshore liquified natural gas terminals, EPA has opted not to do so, for reasons described in the proposed preamble and these development documents. This section presents information characterizing all of the categories of facilities that EPA considered in developing this proposed rule, even if EPA did not ultimately propose national requirements for such facilities under the proposed rule. EPA has generally categorized all of these industries into two groups: land-based facilities and offshore facilities.

I. LAND-BASED INDUSTRIES

This category includes existing electric generators not covered under the Phase II rule (those with a design intake flow (DIF) less than 50 million gallons per day (MGD)) and all existing manufacturers. This section will describe these facilities, their source waterbodies, their intakes, and their intake technologies. Much of the data in this section is derived from the industry questionnaire data.

1.0 DESCRIPTION OF THE INDUSTRIES

In 1997, EPA estimated that over 400,000 facilities could potentially be subject to a cooling water intake regulation. Given the large number of facilities potentially subject to regulation, EPA decided to focus its data collection efforts on six industrial categories that, as a whole, are estimated to account for over 99 percent of all cooling water withdrawals. These six sectors are: Utility Steam Electric, Nonutility Steam Electric, Chemicals & Allied Products, Primary Metals Industries, Petroleum & Coal Products, and Paper & Allied Products.

EPA's data collection efforts (via the 1998 industry questionnaire) focused on the electric generators (both utility and nonutility steam electric) and the four manufacturing industry groups that were identified as significant users of cooling water. EPA maintains, however, that a manufacturing facility that is not classified within one of those four groups may also be subject to requirements under today's proposed rule if it meet the requisite criteria. These industries are shown below, as described by the Standard Industrial Classification (SIC) system.

Electric Services

This industry sector is classified under SIC Major Group 49. This major group includes establishments engaged in the generation, transmission, and/or distribution of electricity or gas or steam.

Chemical and Allied Products

This industry sector is classified under SIC Major Group 28. This major group includes establishments producing basic chemicals and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: (1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and (3) finished chemical products to be used for ultimate consumption, such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.

Primary Metals Industries

This industry sector is classified under SIC Major Group 33. This major group includes establishments engaged in smelting and refining ferrous and nonferrous metals from ore, pig, or scrap; in rolling, drawing, and alloying metals; in manufacturing castings and other basic metal products; and in manufacturing nails, spikes, and insulated wire and cable.

Paper and Allied Products

This industry sector is classified under SIC Major Group 26. This major group includes establishments primarily engaged in the manufacture of pulps from wood and other cellulose fibers, the manufacture of paper and paperboard, and the manufacture of paper and paperboard into converted products.

Petroleum and Coal Products

This industry sector is classified under SIC Major Group 29. This major group includes establishments primarily engaged in petroleum refining, manufacturing paving and roofing materials, and compounding lubricating oils and greases from purchased materials.

Other Industries

EPA sent industry questionnaires to individual facilities from a number of other industries outside of the four listed above and incorporated that data into the analysis for Phase III. In 2004, EPA also collected information on land-based liquefied natural gas (LNG) facilities.

1.1 Estimated Numbers of Land-based Facilities in Scope of 316(b)

EPA estimates that approximately 683 land-based facilities in the six industrial categories would be subject to regulation under 316(b). These facilities combine to account for a design intake flow of over 40 billion gallons per day of cooling water from approximately 908 cooling water intake structures. See Exhibit 2-1 below. For comparison, the numbers of in-scope facilities for Phase I and Phase II are also included.

Exhibit 2-1. Cooling Water Use in Surveyed Industries

	Estimated Number of Facilities	Estimated Design Intake Flow (MGD)
Phase I (new electric generators and manufacturers)	121 (over 20 years)	N/A
Phase II (existing electric generators >50 MGD)	554	367,752
Facility Potentially Regulated Under Phase III (existing electric generators <50 MGD and all existing manufacturers)	683	40,441
Existing electric generators <50 MGD	118	2,374
Existing manufacturers <50 MGD	410	7,931
Existing manufacturers >50 MGD	155	30,136

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include facilities identified as baseline closures.

1.2 Source Waterbodies

Facilities potentially regulated under Phase III can be found on all waterbody types, but are predominantly located on freshwater rivers and streams. Exhibit 2-2 below illustrates the distribution of facilities by waterbody type.

Exhibit 2-2. Distribution of Source Waterbodies for Phase III Facilities

Source of Surface Water	Estimated Number of Facilities	Percent of Facilities
Freshwater River or Stream	496	72.6
Lake or Reservoir	60	8.8
Great Lakes	77	11.3
Estuary or Tidal River	39	5.7
Ocean	11	1.6
Total	683	100

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include those facilities identified as baseline closures.

1.3 Design Intake Flows

Exhibit 2-3 below illustrates the range of design intake flows in facilities considered for regulation under the proposed Phase III rule. Of these facilities, only existing manufacturing facilities would be subject to the national requirements, as the lowest co-proposed flow threshold is 50 MGD. Therefore, power producers and manufacturers under 50 MGD would not be subject to the national requirements under Phase III. Power producers with a design intake flow of 50 million gallons per day (MGD) or greater are covered under Phase II.

Exhibit 2-3. Design Intake Flows at Facilities Potentially Regulated Under Phase III

Design Intake Flow (MGD)	Estimated Number of Facilities	Percent of Number of Facilities	Cumulative Percent	Percent of Total Design Intake Flow
0 - 2	0	0	0	0
2 - 5	83	12.2	12.2	0.6
5 - 10	84	12.3	24.5	1.5
10 - 15	74	10.8	35.3	2.3
15 - 25	104	15.2	50.5	5.1
25 - 50	183	26.8	77.3	16
50 - 100	82	12	89.3	14.2
> 100	73	10.7	100	60.3
Total	683	100		100

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include those facilities identified as baseline closures.

Exhibit 2-4 below illustrates the range of design intake flows by industry type.

Exhibit 2-4. Design Intake Flow by Industry Type

Industry Type	Estimated Number of Facilities	Total Design Intake Flow (MGD)	Percent of Total Design Intake Flow	Average Design Intake Flow (MGD)*
Utilities	85	1,927	5	23
Nonutilities	36	482	1	16
Chemical and Allied Products	181	12,340	31	247
Primary Metals	89	8,870	22	240
Paper and Allied Products	225	11,904	30	127
Petroleum and Coal Products	39	3,259	8	112
Food Products	13	670	1	52
Textiles	<5	6	1	6
Other Manufacturing	14	983	2	98
Total	683	40,441	100	921

* Average based on surveyed facilities. May not be reflective of actual industry-wide average design intake flows.
Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include facilities identified as baseline closures.

Exhibit 2-5 combines data from Exhibit 2-3 and 2-4 and provides summary-level data for all industry types.

Exhibit 2-5. Industry Overview

Design Intake Flow (MGD)	Estimated Number of Facilities	Total Design Intake Flow (MGD)	Percent of Total Design Intake Flow
2 - 20	290	2,612	6.5
20 - 50	238	7,693	19
> 50	155	30,136	74.5
Total	683	40,441	100

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include facilities identified as baseline closures.

1.4 Cooling Water System Configurations

Facilities potentially regulated under Phase III employ a variety of cooling water system (CWS) types. Exhibit 2-6 shows the distribution of cooling water system configurations.

Exhibit 2-6. Distribution of Cooling Water System Configurations

CWS Configuration	Estimated Number of CWS*	Percent of Total CWS	Estimated Number of CWS for Electric Generators	Percent of Total Electric Generator CWS	Estimated Number of CWS for Manufacturers	Percent of Total Manufacturer CWS
Once-through	436	49	32	25	404	53
Recirculating	285	32	93	72	192	25
Combination	92	10	3	2	89	12
Other	76	9	1	1	75	10
Total	889	100	129	100	760	100

* Some facilities have more than one cooling water system.
Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include facilities identified as baseline closures.

Exhibit 2-7 illustrates the intake structure arrangements for facilities potentially regulated under Phase III.

Exhibit 2-7. Distribution of Cooling Water Intake Structure Arrangements

Intake Arrangement	Estimated Number of Arrangements	Percent of Arrangements
Canal or Channel Intake	123	16
Bay or Cove Intake	49	7
Submerged Shoreline Intake	208	28
Surface Shoreline Intake	151	20
Submerged Offshore Intake	216	29

Note: The total number of facilities exceeds 683, since some facilities employ multiple intake arrangements.
Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include facilities identified as baseline closures.

1.5 Design Through-Screen Velocities

Exhibit 2-8 below illustrates the wide range of design intake velocities at facilities potentially regulated under Phase III.

Exhibit 2-8. Distribution of Cooling Water Intake Structure (CWIS) Design Through-Screen Velocities

Velocity (feet per second)	Estimated Number of CWIS	Percent of CWIS	Cumulative Percent
0 - 0.5	156	31	31
0.5 - 1	112	22	53
1 - 2	112	22	75
2 - 3	71	14	89
3 - 5	26	5	94

Exhibit 2-8. Distribution of Cooling Water Intake Structure (CWIS) Design Through-Screen Velocities (continued)

Velocity (feet per second)	Estimated Number of CWIS	Percent of CWIS	Cumulative Percent
5 - 7	11	2	96
> 7	19	4	100
Total	507	100	

Note: The average design through-screen velocity for all surveyed cooling water intake structures (unweighted) is 1.67 feet per second. The median design through-screen velocity for all surveyed facilities is 0.92 feet per second.
Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include those facilities identified as baseline closures.

1.6 Existing Intake Technologies

Many facilities potentially regulated under Phase III have intake technologies already in place. Exhibit 2-9 illustrates the number of existing intake technologies. EPA notes that not all intake technologies may be sufficient to meet the performance standards or the requirements of the rule. While not using an intake technology per se, facilities with cooling towers have also been included in this table to demonstrate the usage of flow reduction as a method to reduce impingement mortality and entrainment.

Exhibit 2-9. Distribution of Intake Technologies

Intake Technology Type	Estimated Number of Technologies	Percent of Technologies
Bar Rack/Trash Rack	427	28
Screening Technologies	500	33
Passive Intake Technologies	233	15
Fish Diversion or Avoidance System	35	2
Fish Handling or Return System	33	2
No Intake Technologies	13	1
Cooling Tower	286	19

Note: The total number of technologies exceeds 683, since some facilities employ multiple intake technologies.
Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include those facilities identified as baseline closures.

1.7 Operating Days per Year

As a corollary to the capacity utilization rate (CUR) for electric generators, EPA attempted to analyze the number of operating days for manufacturing facilities. EPA notes, however, that it has not determined an appropriate minimum threshold, nor has it decided to propose such a threshold. Exhibit 2-10 is for informational purposes only. For more information, see the preamble to the proposed rule.

Exhibit 2-10. Distribution of Manufacturing Facilities by Number of Operating Days

Number of Operating Days	Percent of Facilities
< 60 days	4.26
60 - 180 days	3.55
> 180 days	92.18
Total	100

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: An electric generator operating at 15% CUR is roughly equivalent to 55 operating days per year. These data reflect the average number of facility operating hours over a three year period (1996-1998).
Note: All values are weighted and include those facilities identified as baseline closures.

1.8 Land-based Liquefied Natural Gas Facilities

EPA's research also indicates that there are five existing land-based liquefied natural gas facilities in the United States, all on the East coast. Most of these facilities do not withdraw surface water for cooling purposes and would therefore be out of scope of the regulations.

2.0 PRELIMINARY ASSESSMENT OF COMPLIANCE

EPA considered all of the above data in determining the scope, applicability, and flow thresholds in today's proposed rule. Exhibit 2-11 below illustrates a synthesis of some of the pertinent data.

Exhibit 2-11. Technologies Already In Place at Facilities Potentially Regulated Under Phase III.

Design Intake Flow (MGD) Threshold	Electric Generators		Manufacturers	
	% of Facilities With Technology Satisfying Phase II Requirements	% of Facilities With Closed-Cycle, Recirculating Cooling Systems	% of Facilities With Technology Satisfying Phase II Requirements	% of Facilities With Closed-Cycle, Recirculating Cooling Systems
> 50	n/a	n/a	29	4
20 - 50	69	60	54	22
2 - 20	93	82	58	29
Total	82	72	48	20

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI)
Note: All values are weighted and include those facilities identified as baseline closures.

OFFSHORE INDUSTRIES

EPA considered establishing national requirements for three additional industry groups that have been identified as potential large users of cooling water: offshore oil and gas exploration facilities , seafood processing vessels, and offshore liquefied natural gas (LNG) terminals. An industry survey was developed in 2003 to collect data on offshore oil and gas extraction facilities and seafood processing vessels and EPA independently collected information on offshore liquefied natural gas facilities in 2004.

Under the proposed rule, only new offshore oil and gas extraction facilities would be subject to national requirements.

1.0 DESCRIPTION OF THE INDUSTRIES

After EPA proposed the Phase I rule for new facilities (65 FR 49060), the Agency received adverse comment from operators of mobile offshore and coastal drilling units concerning the limited information about their cooling water intakes, associated impingement and entrainment, costs of technologies, or achievability of the controls proposed by EPA. In the Phase I final rule, EPA committed to "propose and take final action on regulations for new offshore oil and gas extraction facilities, as defined at 40 CFR 435.10 and 40 CFR 435.40, in the Phase III section 316(b) rule." EPA subsequently identified seafood processing vessels and offshore liquefied natural gas facilities as other potential large users of cooling water that may be subject to regulation under 316(b). Each of these industries are shown below, as described by the Standard Industrial Classification (SIC) system.

Offshore Oil and Gas Extraction
This industry sector is classified under SIC Major Group 13. This major group includes establishments primarily engaged in: (1) producing crude petroleum and natural gas; (2) extracting oil from oil sands and oil shale; (3) producing natural gasoline and cycle condensate; and (4) producing gas and hydrocarbon liquids from coal at the mine site.

Seafood Processing
This industry sector is classified under SIC Major Group 09. This major group includes establishments primarily engaged in commercial fishing (including crabbing, lobstering, clamming, oystering, and the gathering of sponges and seaweed), and the operation of fish hatcheries and fish and game preserves, in commercial hunting and trapping, and in game propagation.

Offshore Liquefied Natural Gas
This industry sector is classified under SIC Major Group 49. This major group includes establishments engaged in the generation, transmission, and/or distribution of electricity or gas or steam.

1.1 Estimated Numbers of Offshore Facilities Potentially Subject to Regulation

1.1.1 Existing Offshore Facilities

EPA estimated the number of existing facilities potentially regulated under Phase III in each of the three offshore industries.

Offshore Oil and Gas Extraction

Using information from industry sources and other Federal agencies, EPA determined that there were approximately 2929 offshore oil and gas extraction facilities potentially within the scope of the regulations. Of these, 2478 facilities are fixed facilities (i.e., fixed platforms) and were primarily located in the Gulf of Mexico, with some facilities also located in Alaska and along the Pacific coast. The remaining 451 facilities are mobile facilities (i.e., mobile offshore drilling units (MODU)), which can operate in or out of United States waters. Like the fixed platforms, the majority of MODUs operate in the Gulf of Mexico. All fixed platforms and MODUs were considered to be in scope of the regulation, as nearly all operate in Federal waters and are likely to meet the applicability requirements for 316(b).

Seafood Processing

Through existing databases and mailing lists, EPA determined that there were approximately 123 seafood processing vessels potentially within the scope of the regulations. Each of these vessels has been issued an NPDES permit and it was initially assumed that all vessels would meet the minimum flow threshold (greater than 2 MGD) and that at least 25% of the water withdrawn was for cooling purposes. EPA's research indicated that vessels shorter than 100 feet in length were unlikely to withdraw more than 2 MGD and these vessels were removed from the universe of facilities under consideration.

Offshore Liquefied Natural Gas

EPA's research indicates that there are currently no offshore liquefied natural gas facilities in the United States.

1.1.2 New Offshore Facilities

Offshore Oil and Gas Extraction

EPA projects approximately 20 new offshore oil and gas extraction facilities in the next 3 years.

Seafood Processing

Because seafood processing vessels were determined to be outside the scope of the proposed rule, EPA did not estimate the number of projected new seafood processing vessels.

Offshore Liquefied Natural Gas

EPA determined that there are approximately eight offshore liquefied natural gas facilities that are currently under proposal. More are likely to be proposed in the future, as this energy sector is growing rapidly.

1.2 Offshore Facility Characteristics

EPA collected somewhat less information on the offshore industries and therefore will not present detailed tables as in the section above for land-based facilities. This section will, however, provide a summary of the offshore facility characteristics.

Offshore Oil and Gas Exploration Facilities

New offshore oil and gas extraction facilities include both fixed facilities (such as platforms) and mobile facilities (such as MODUs and barges). See chapter 3 for additional details on these facilities.

Seafood Processing Vessel

In developing technology cost modules, EPA assumed that a typical seafood processing vessel was 280 feet in length and primarily used sea chests as the cooling water intake structure. Data available to EPA did not identify intake technologies designed to reduce impingement mortality or entrainment, as most vessels have a simple screen or grate to screen trash and other debris.

Data from respondents to the EPA Technical Survey for Seafood Processing Vessels indicate that the combined design intake flow from all the cooling water intakes in a vessel range from 3 MGD to 45 MGD. The total number of intakes per vessel withdrawing water for cooling purposes ranged from two to ten. These vessels had either a seachest or simple pipe intake for withdrawing cooling water.

Offshore Liquefied Natural Gas Facility

As stated above, most offshore liquefied natural gas facilities do not use surface water for cooling purposes. Some future facilities have indicated that they may use surface water, but are presently planning to use submerged cylindrical wedgewire screens as an intake technology.

2.0 PRELIMINARY ASSESSMENT OF COMPLIANCE

Based upon the information summarized above, the proposed rule would not establish natural requirements for existing offshore oil and gas extraction facilities, new or existing seafood processing vessels, and new or existing offshore liquefied natural gas facilities. For additional detail, see the preamble to today's proposed rule.

Chapter 3: Technology Cost Modules

I. TECHNOLOGY COST MODULES FOR MANUFACTURERS

INTRODUCTION

This chapter presents the technology cost modules used by the Agency to develop compliance costs at model facilities for the proposed rule. Chapter 5 of this document describes the Agency's methodology for assigning particular cost modules to model facilities.

The technology cost modules used in Phase III are the same as those used to determine the compliance costs for Phase II facilities. EPA considers the types of intakes and the technologies available to address impingement and entrainment at Phase II facilities to be consistent with the intakes and technologies at Phase III facilities. Similarly, EPA considers the intakes and technologies found at electric generators and manufacturers to be consistent with one another, again permitting EPA to apply the technology cost modules from Phase II to Phase III facilities.

Note that the cost modules presented in this chapter reference costs developed for year 2002 dollars, which were used to develop Phase II facility costs. However, all costs for Phase III facilities presented in the preamble of today's proposed rule reflect costs that were adjusted to year 2003 dollars.

1.0 SUBMERGED PASSIVE INTAKES

The modules described in this section involve submerged passive intakes, and address both adding technologies to the inlet of existing submerged intakes and converting shoreline based intakes (e.g., shoreline intakes with traveling screens) to submerged offshore intakes with added passive inlet technologies. The passive inlet technologies that are considered include passive screens and velocity caps. All intakes relocated from shore-based to submerged offshore are assumed to employ either a velocity cap or passive screens. Costs for velocity caps are presented separately in section 3.0.

1.1 Relocated Shore-based Intake to Submerged Near-Shore and Offshore with Fine Mesh Passive Screens at Inlet

This section contains three subsections. The first two sections respectively present documentation for passive screen technology selection and estimation parameters; and for development of capital costs for submerged passive intakes. This discussion includes: passive screen technology selection, selection of flow values, intake configurations, connecting walls, and connecting pipes. The second section discusses cost development for: screen construction materials, connecting walls, pipe manifolds, airburst systems, indirect costs, nuclear facilities, O&M costs, construction-related downtime. The third section presents a discussion of the applicability of this cost module.

1.1.1 Selection/Derivation of Cost Input Values

Passive Screen Technology Selection

Passive screens come in one of three general configurations: flat panel, cylindrical, and cylindrical T-type. Only passive screens constructed of welded wedgewire were considered due to the improved performance of wedgewire with respect to debris and fish protection. After discussion with vendors concerning the attributes and prevalence of the various passive screen technology configurations, EPA selected the T-screen configuration as the most versatile with respect to a variety of local intake and waterbody attributes. The most important screen attribute was the requirement for screen placement. Both cylindrical and T-screens allow for placement of the screens extending into the waterbody, which allows for debris to migrate away from the screens once dislodged. T-screens produce greater flow per screen unit and thus were chosen because they are more practical in multi-screen installations.

Due to the potential for build-up and plugging by debris, passive screens are usually installed with an airburst backwash system. This system includes a compressor, an accumulator (also known as, receiver), controls, a distributor and air piping that directs a burst of air into each screen. The air burst produces a rapid backflow through the screen; this air-induced turbulence dislodges accumulated debris, which then drifts away from the screen unit. Vendors claimed (although with minimal data) that only very stagnant water with a high debris load or very shallow water (<2 ft deep) would prevent use of this screen technology. Areas with low water velocities would simply require more frequent airburst backwashes, and few facilities are constrained by water depths as shallow as 2 feet.

While there are waterbodies with levels of debris low enough to preclude installation of an airburst system, EPA has chosen to include an airburst backwash system with each T-screen installation as a prudent precaution. The capital cost of the airburst backwash system is a substantial component, particularly in offshore applications, because of the need to install a separate air supply pipe from the shoreline air supply to each screen or group of smaller screens. Thus, the assumption that airburst backwash systems are needed in all applications is considered as part of an overall cost approach that increases projected capital costs to the industry to develop a high-side cost estimate.

T-screens ranging in diameter from 2 feet (T24) to 8 feet (T96), in one-foot intervals, are used in the analysis. Costs provided are for two types of screens one with a slot size of approximately 1.75 mm referred to as "fine mesh" and one with a slot size of 0.76 mm referred to as "very fine mesh." The design flow values used for each size screen correspond to wedgewire T-screens with a through screen velocity of 0.5 feet per second. Exhibits 3-1 and 3-2 presents design specifications for the fine mesh and very fine mesh wedgewire T-screens costed.

Exhibit 3-1. Fine Mesh Passive T-Screen Design Specifications

Fine Mesh Passive T-Screen Design Specifications

Screen Size	Capacity	Slot Size	Screen Length	Airburst Pipie Diameter	Screen Outlet Diameter	Screen Weight
	gpm	mm	Ft	Inches	Inches	Lbs
T24	2,500	1.75	6.3	2	18	375
T36	5,700	1.75	9.3	3	30	1,050
T48	10,000	1.75	13.3	4	36	1,600
T60	15,800	1.75	16.6	6	42	2,500
T72	22,700	1.75	19.8	8	48	4,300
T84	31,000	1.75	22.9	10	60	6,000
T96	40,750	1.75	26.4	12	72	NA

*Source: Johnson Screen - Brochure 2002 - High Capacity Screen at 50% Open Area

Exhibit 3-2. Very Fine Mesh Passive T-Screen Design Specifications

Very Fine Mesh Passive T-Screen Design Specifications

Screen Size	Capacity	Slot Size	Screen Length	Airburst Pipie Diameter	Screen Outlet Diameter	Screen Weight
	gpm	mm	Ft	Inches	Inches	Lbs
T24	1,680	0.76	6.3	2	18	375
T36	3,850	0.76	9.3	3	30	1,050
T48	6,750	0.76	13.3	4	36	1,600
T60	10,700	0.76	16.6	6	42	2,500
T72	15,300	0.76	19.8	8	48	4,300
T84	20,900	0.76	22.9	10	60	6,000
T96	27,500	0.76	26.4	12	72	NA

*Source: Johnson Screen - Brochure 2002 - High Capacity Screen at 33% Open Are

Selection of Flow Values

The flow values used in the development of cost equations range from a design flow of 2,500 gpm (which is the design flow for the smallest screen (T24) for which costs were obtained) to a flow of 163,000 gpm (which is equivalent to the design flow of four T96 screens) for fine mesh screens and 1,680 gpm to 165,000 (which is equivalent to the design flow of six T96 screens) for very fine mesh screens. The higher flow values were chosen because they were nearly equal to the flow in a 10-foot diameter pipe at a pipe velocity of just 4.6 feet per second. A 10-foot diameter pipe was chosen as the largest size for individual pipes because this size was within the range of sizes that are capable of being installed using the technology assumed in the cost model. Additionally, the need to spread out the multiple screens across the bottom is facilitated by multiple pipes. One result of this decision is that for facilities with design flows significantly greater than 165,000 gpm, the total costs are based on dividing the intake into multiple units and summing the costs of each.

Intake Configuration

The scenarios evaluated in this analysis are based on retrofit construction in which the new passive screens are connected to the existing intake by newly installed pipes, while the existing intake pumps and pump wells remain intact and functional. The cost scenario also retains the existing screen wells and bays, since in most cases they are connected directly to the pump wells. Facilities may retain the existing traveling screens as a backup, but the retention of functioning traveling screens is not necessary. No operating costs are considered for the existing screens since they are not needed. Even if they are retained, there should be almost no debris to collect on their surfaces. Thus, they would only need to be operated on an infrequent basis to ensure they remain functional.

The new passive screens are placed along the bottom of the waterway in front of the existing intake and connected to the existing intake with pipes that are laid either directly on or buried below the stream bed. The key components of the retrofit are: the transition connection to the existing intake, the connecting pipe or pipes (a.k.a. manifold or header), the passive screens or velocity cap located at the pipe inlet, and if passive screens are used, the backwash system.

At most of the T-screen retrofit installations, particularly those requiring more than one screen, the installation of passive T-screens will likely require relocating the intake to a near-shore location or to a submerged location farther offshore, depending on the screen spacing, water depth, and other requirements. An exception would be smaller flow intakes where the screen could be connected directly to the front of the intake with a minimal pipe length (e.g., half screen diameter). Other considerations that may make locating farther offshore necessary or desirable include: the availability of cooler water, lower levels of debris, and fewer aquatic organisms for placements outside the littoral zone. As such, costs have been developed for a series of distances from the shoreline.

In retrofits where flow requirements do not increase, EPA has found existing pumps and pump wells can be, and have been, retained as part of the new system. The cost scenarios assume flow volumes do not increase. Thus, using existing pumps and pump wells is both feasible and economically prudent. There are, however, two concerns regarding the use of existing pumps and pump wells. One is the degree of additional head loss associated with the new pipes and screens. The second is the intake downtime needed to complete the installation and connection of the new passive screen system or velocity cap. The downtime considerations are discussed later in a separate section.

The additional head losses associated with the passive screen retrofit scenario described here include the frictional losses in the connecting pipes and the losses through the screen surface. If the new connecting pipe velocities are kept low (e.g., 5 feet per second is used in this analysis), then the head loss in the extension pipe should remain low enough to allow the existing pumps to function properly in most instances. For example, a 48-inch diameter pipe at a flow of 28,000 gpm (average velocity of 4.96 feet per second) will have a head loss of 2.31 feet of water per 1,000-foot pipe length (Shaw and Loomis 1970). The new passive screens will contribute an additional 0.5 to 0.75 feet of water to this head loss, which will further increase when the screen is clogged by debris (Screen Services 2002). In fact, the rate at which this screen head loss increases due to debris build-up will dictate the frequency of use of the air backwash. Pump wells are generally equipped with alarms that warn of low water levels due to increased head loss through the intake. If the screen becomes plugged to the point where backwash fails to maintain the necessary water level in the pump well, the pump flow rate must be reduced. This reduction may result in a derating or shut down of the associated generating unit. Lower than normal surface water levels may exacerbate this problem.

In terms of required dimensions for installation, Exhibits 3-1 and 3-2 show screen length is just over three times the diameter and each screen requires a minimum clearance of one-half diameter on all sides except the ends. Thus, an 8-foot diameter screen will require a minimum water depth of 16 feet at the screen location (four feet above, four feet below, and eight feet for the screen itself). It is recommended that T-screens be oriented such that the long axis is parallel to the waterbody flow direction. T-screens can be arranged in an end-to-end configuration if necessary. However, using a greater separation above the minimum will facilitate dispersion of the released accumulated debris during screen backwashes.

In the retrofit scenario described here, screen size and number are based on using a single screen with the screen size increasing with increasing design flows. When flow exceeds the capacity of a single T96 screen, multiple T96 screens are used. This retrofit scenario also assumes the selected screen location has a minimum water depth equal to or greater than the values shown in Exhibit 3-3.

Exhibit 3-3. Minimum Depth at Screen Location For Single Screen Scenario

Fine Mesh Flow	Very Fine Mesh Flow	Screen Size	Minimum Depth
2,500 gpm	1,680 gpm	T24	4 ft
5,700 gpm	3,850 gpm	T36	6 ft
10,000 gpm	6,750 gpm	T48	8 ft
15,800 gpm	10,700 gpm	T60	10 ft
22,700 gpm	15,300 gpm	T72	12 ft
31,000 gpm	20,900 gpm	T84	14 ft
40,750 gpm	27,500 gpm	T96	16 ft
>40,750 gpm	>27,500 gpm	Multiple T96	16 ft

In certain instances water depth or other considerations will require using a greater number of smaller diameter screens. For these cases the same size header pipe can be used, but the intake will require either more branched piping or multiple connections along the header pipe.

Connecting Wall

The retrofit of passive T-screen technology where the existing pump well and pumps are retained will require a means of connecting the new screen pipes to the pump well. Pump wells that are an integral part of shoreline intakes (often the case) will require installing a wall in front of the existing intake pump well or screen bays. This wall serves to block the existing intake opening and to connect the T-screen pipe(s) to the existing intake pump wells. In the proposed cost scenario, the T-screen pipe(s) can be attached directly to holes passing through the wall at the bottom.

Two different types of construction have been used in past retrofits or have been proposed in feasibility studies. In one, a wall constructed of steel plates is attached to and covers the front of each intake bay or pump well, such that one or more connecting pipes feed water into each screen bay or pump well individually. In this scenario, a single steel plate or several interlocking plates are affixed to the front of the screen bays by divers, and the T-screen pipe manifolds are then attached to flanged fittings welded at the bottom of the plate(s). For smaller flow intakes that require a single screen, this may be the best configuration since the screen can be attached directly to the front of the intake minimizing the intrusion of the retrofit operation into the waterway.

In the second scenario, an interlocking sheet pile wall is installed in the waterbody directly in front of, and running the length of, the existing intake. Individual screen manifold pipe(s) are attached to holes cut in the bottom along the length of the sheet pile wall. In this case, a common plenum between the sheet pile wall and the existing intake runs the length of the intake. This configuration provides the best performance from an operational standpoint because it allows for flow balancing between the screen/pump bays and the individual manifold pipes. If there are no concerns with obstructing the waterway, the sheet pile wall can be placed far enough out so that the portion of the wall parallel to the intake can be installed first along with the pipes and screens that extend further offshore. In this case, the plenum ends are left open so that the intake can remain functional until the offshore construction is completed. At that point, the intake must shut down to install the final end portions of the wall, the air piping connection to the air supply, and make final connections of the manifold pipes. EPA is not aware of any existing retrofits where this construction technique has been used. However, it has been proposed in a feasibility study where a new, larger intake was to be constructed offshore (see discussion in Construction Downtime section).

Costs were developed for this module based on the second scenario described above. These costs are assumed equal or greater than costs for steel plate(s) affixed to the existing intake opening, and therefore inclusive of either approach. This assumption is based on the use of a greater amount of steel material for sheet piles (which is offset somewhat by the fabrication cost for the steel plates), the

use of similarly-sized heavy equipment (pile driver versus crane), and similar diver costs for constructing pipe connections and reinforcements in the sheet pile wall versus installing plates. Costs were developed for both freshwater environments and, with the inclusion a cost factor for coating the steel with a corrosion-resistant material, for saltwater environments.

Connecting Pipes

The design (length and configuration) of the connecting pipes (also referred to as pipe manifold or header) is partly dictated by intake flow and water depth. A review of the pipe diameter and design flow data submitted to EPA by facilities with submerged offshore intakes indicates intake pipe velocities at design flow were typically around 5 feet per second. Note that a minimum of 2.5 to 3 feet per second is recommended to prevent deposition of sediment and sand in the pipe (Metcalf & Eddy 1972). Also, calculations based on vendor data concerning screen attachment flange size and design flow data resulted in pipe velocities ranging from 3.2 to 4.5 feet per second for the nominal size pipe connection. EPA has elected to size the connecting pipes based on a typical design pipe velocity of 5 feet per second.

Even at 5 feet per second, the piping requirements are substantial. For example, if the existing intake has traveling screens with a high velocity (e.g., 2.5 feet per second through-screen velocity), then the cross-sectional area of the intake pipe needed to provide the same flow would be approximately one-third of the existing screen area (assuming existing screen open area is 68%). Given the above assumptions, an existing intake with a 10-foot wide traveling screen and a 20-foot water depth would require a 9.4-foot diameter pipe and be connected to at least four 8-foot diameter fine mesh T-screens (T96). The flow rate for this hypothetical intake screen would be 155,000 gpm.

For small volume flows (40,750 gpm or less for fine mesh–see Exhibit 3-3), T-screens (particularly those with a single screen unit) can be installed very close to the existing intake structure, as the upstream or downstream extensions of the screen should not be an issue. In the 10-foot wide by 20-foot deep traveling screen example above, each of the T96 screens required is 26 feet long. For this example, it is possible to place the four T96 screens directly in front of the existing intake connected to a single manifold extending 56 feet (2*8+2*8+2*8+8) to the centerline of the last T-screen. This is based on a configuration where the manifold has multiple ports (four in this case) spaced along the top. However, this configuration will experience some flow imbalance between the screens. A better configuration would be a single pipe branching twice in a double "H" arrangement. In this case, the total pipe length would be 62 feet (20+26+2*8). Therefore, a minimum pipe length of 66 feet (20 meters) was selected to cover the pipe installation costs for screens installed close to the intake.

Based on the above discussion, facilities with design flow values requiring multiple manifold pipes (i.e., >163,000 gpm) will require the screens to extend even further out. In these cases, costs for a longer pipe size are appropriate. Using a longer pipe allows for individual screens to be spread out laterally and/or longitudinally. Longer pipes would also tend to provide access to deeper water where larger screens can be used. While using smaller screens allows for operations in shallower water, many more screens would be needed. This configuration covers a greater bottom area and requires more branching and longer, but smaller, pipes. Therefore, with the exception of the lower intake flow facilities, a length of connecting pipe longer than66 feet (20 meters) is assumed to be required.

The next assumed pipe length is 410 feet (125 meters), based on the Phase I proposed rule cost estimates. A length of 125 meters was selected in Phase I costing as a reasonable estimate for extending intakes beyond the littoral zone. Additional lengths of 820 feet (250 meters) and 1640 feet (500 meters) were selected to cover the possible range of intake distances. The longest distance (1640 feet) is similar in magnitude to the intake distances reported for many of the facilities with offshore intakes located on large bodies of water, such as oceans and Great Lakes.

As described in the document Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule, Appendix A, submerged intake pipes can be constructed in two ways. One construction uses steel that is concrete-lined and coated on the outside with epoxy and a concrete overcoat. The second construction uses prestressed concrete cylinder pipe (PCCP). Steel is generally used for lake applications; both steel and PCCP are used for riverine applications; PCCP is typically used in ocean applications. A review of the submerged pipe laying costs developed for the Phase I proposed rule showed that the costs of installing steel and PCCP pipe using the conventional method were similar, with steel being somewhat higher in cost. EPA has thus elected to use the Phase I cost methodology for conventional steel pipe as representative of the cost for both steel and concrete pipes installed in all waterbodies. The conventional pipe laying method was selected because it could be performed in front of an existing intake and was least affected by the limitations associated with local topography.

While other methods such as the bottom-pull or micro-tunneling methods could potentially be used, the bottom-pull method requires sufficient space for laying pipe onshore while the micro-tunneling method requires that a shaft be drilled near the shoreline, which may be difficult to perform in conjunction with an existing intake. The conventional steel pipe laying cost methodology and assumptions

are described in detail in the document Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule, Appendix A.

1.1.2 Capital Cost Development

Screen Material Construction and Costs

Costs were obtained for T-screens constructed of three different types of materials: 304 stainless steel, 316 stainless steel, and copper-nickel (CuNi) alloy. In general, screens installed in freshwater are constructed of 304 stainless steel. However, where Zebra Mussels are a problem, CuNi alloys are often used because the leached copper tends to discourage screen biofouling with Zebra mussels. In corrosive environments such as brackish and saltwater, 316 stainless steel is often used. If the corrosive environment is harsh, particularly where oxygen levels are low, CuNi alloys are recommended. Since the T-screens are to be placed extending out into the waterway, such low oxygen environments are not expected to be encountered.

Based on this information, EPA has chosen to base the cost estimates on utilizing screens made of 304 stainless steel for freshwater environments without Zebra Mussels, CuNi alloy for freshwater environments with the potential for Zebra Mussels and 316 stainless steel for brackish and saltwater environments. Exhibit 3-4 provides a list of states that contain or are adjacent to waterbodies where Zebra Mussels are currently found. The cost for CuNi screens are applied to all freshwater environments located within these states. EPA notes that the screens comprise only a small portion of the total costs, particularly where the design of other components are the same, such as the proposed design scenarios for freshwater environments with Zebra Mussels versus those without.

Exhibit 3-4. List of States with Freshwater Zebra Mussels as of 2001

List of States with Freshwater Zebra Mussels as of 2001	
State Name	**Abbreviation**
Alabama	AL
Connecticut	CT
Illinois	IL
Indiana	IN
Iowa	IA
Kentucky	KY
Louisiana	LA
Michigan	MI
Minnesota	MN
Mississippi	MS
Missouri	MO
New York	NY
Ohio	OH
Oklahoma	OK
Pennsylvania	PA
Tennessee	TN
Vermont	VT
West Virginia	WV
Wisconsin	WI

Exhibit 3-5 presents the component and total installed costs for the three types of screens. A vendor indicated that the per screen costs will not change significantly between those with fine mesh and very fine mesh so the same screen costs are used for each. Installation and mobilization costs are based on vendor-provided cost estimates for velocity caps, which are comparable to those for T-screens. The individual installation cost per screen of $35,000 was reduced by 30% for multiple screen installations. Costs for steel fittings are also included. These costs are based on steel fitting costs developed for the new facility Phase I effort and are adjusted for a pipe

velocity of 5 feet per second and converted to 2002 dollars. An additional 5% was added to the total installed screen costs to account for installation of intake protection and warning devices such as pilings, dolphins, buoys, and warning signs.

Exhibit 3-5. T-Screen Equipment and Installation Costs

T-Screen Equipment and Installation Costs

Size	Number of Screens	Capacity	Total Screen Cost by Material			Air Burst Equipment	Screen Installation	Mobilization	Steel Fitting
		gpm	304SS	316SS	CuNi				
T24	1	2,500	$5,800	$6,100	$8,000	$10,450	$25,000	$15,000	$2,624
T36	1	5,700	$10,000	$11,200	$18,000	$15,050	$25,000	$15,000	$3,666
T48	1	10,000	$17,000	$18,800	$31,700	$22,362	$30,000	$15,000	$5,067
T60	1	15,800	$23,000	$26,200	$44,500	$28,112	$35,000	$15,000	$6,964
T72	1	22,700	$34,000	$39,500	$69,700	$35,708	$35,000	$20,000	$9,227
T84	1	31,000	$45,000	$51,900	$93,400	$43,588	$35,000	$20,000	$11,961
T96	1	40,750	$61,000	$70,200	$124,000	$49,338	$35,000	$25,000	$15,189
T96	2	81,500	$122,000	$140,400	$248,000	$49,338	$49,000	$25,000	$28,865
T96	3	122,250	$183,000	$210,600	$372,000	$49,338	$73,500	$30,000	$42,840
T96	4	163,000	$244,000	$280,800	$496,000	$49,338	$98,000	$30,000	$57,113

The same costs are used for both fine mesh and very fine mesh with major difference being the design flow for each screen size.

Connecting Wall Cost Development

The cost for the connecting wall that blocks off the existing intake and provides the connection to the screen pipes is based on the cost of an interlocking sheet pile wall constructed directly in front of the existing intake. In general, the costs are mostly a function of the total area of the wall and will vary with depth. Cost estimates were developed for a range of wall dimensions. The first step was to estimate the nominal length of the existing intake for each of the design flow values shown in Exhibits 3-1 and 3-2. The nominal length was estimated using an assumed water depth and intake velocity. The use of actual depths and intake velocities imparted too many variables for the selected costing methodology. A depth of 20 feet was selected because it was close to both the mean and median intake water depth values reported by Phase III facilities in their Detailed Technical Questionnaires.

The length of the wall was also based on an assumed existing intake, through-screen velocity of 1 feet per second and an existing screen open area of 50%. Most existing coarse screens have an open area of 68%. However, a 50% area was chosen to produce a larger (i.e., more costly) wall size. Selecting a screen velocity of 1 feet per second also will overestimate wall length (and therefore, costs) for existing screen velocities greater than 1 feet per second. This is the case for most of the facilities (approximately 50% of Phase III facilities reported screen velocities of 1 feet per second or greater for at least one cooling water intake structure and just under 70% of the Phase II Facilities reported screen velocities of 1 feet per second or greater). An additional length of 30 to 60 feet (scaled between 30 feet for 2,500 to 60 feet for 163,000 gpm with a minimum of 30 ft for lower flows) was added to cover the end portions of the wall and to cover fixed costs for smaller intakes. The costs are based on the following:

- Sheet pile unit cost of $24.50/sq ft RS Means 2001)
- An additional 50% of sheet pile cost to cover costs not included in sheet pile unit cost[1]
- Total pile length of 45 feet for 20-foot depth including 15-foot penetration and 10-foot extension above water level
- Mobilization of $18,300 for 20-foot depth RS Means 2001), added twice (assuming sheet pile would be installed in two stages to minimize generating unit downtime (see Downtime discussion). The same mobilization costs are used for both saltwater and freshwater environments.
- An additional cost of 33% for corrosion-resistant coating for saltwater environments.

Exhibits 3-6 and 3-7 present the estimated wall lengths, mobilization costs, and total costs for 20-foot depth for both freshwater and saltwater environments for fine mesh and very fine mesh screens, respectively.

Exhibit 3-6. Sheet Pile Wall Capital Costs for Fine Mesh Screens

Sheet Pile Wall Capital Costs for Fine Mesh Screens

Design Flow	Total Estimated Wall Length	Mobilization	Sheet Pile Wall Total Costs 20 Ft Water Depth*	
gpm	Ft		Freshwater	Saltwater
2,500	31	$36,600	$87,157	$103,840
5,700	32	$36,600	$89,351	$106,758
10,000	34	$36,600	$92,359	$110,759
15,800	36	$36,600	$96,416	$116,155
22,700	39	$36,600	$101,243	$122,575
31,000	43	$36,600	$107,049	$130,297
40,750	47	$36,600	$113,870	$139,369
81,500	64	$36,600	$142,376	$177,283
122,250	81	$36,600	$170,883	$215,196
163,000	96	$36,600	$195,960	$248,549

* Total costs include mobilization

[1]Note that this 50% value was derived by comparing the estimated costs of a sheet pile wall presented in a feasibility study for the Salem Nuclear Plant to the cost estimated for a similarly sized sheet pile wall using the EPA method described here. This factor was intended to cover the cost of items such as walers, bracing and installation costs not included in the R S Means unit cost. The Salem facility costs included bypass gates, which are assumed to be similar in cost to the pipe connections.

Exhibit 3-7. Sheet Pile Wall Capital Costs for Very Fine Mesh Screens

Sheet Pile Wall Capital Costs for Very Fine Mesh Screens

Design Flow	Total Estimated Wall Length	Mobilization	Sheet Pile Wall Costs 20 Ft Water Depth*	
gpm	Ft		Freshwater	Saltwater
1,680	30	$36,600	$86,854	$103,438
3,850	31	$36,600	$88,056	$105,037
6,750	32	$36,600	$90,085	$107,735
10,700	34	$36,600	$92,848	$111,410
15,300	36	$36,600	$96,066	$115,690
20,900	38	$36,600	$99,984	$120,900
27,500	41	$36,600	$104,601	$127,041
55,000	53	$36,600	$123,838	$152,627
82,500	64	$36,600	$143,076	$178,213
110,000	76	$36,600	$162,314	$203,799
165,000	99	$36,600	$200,789	$254,971

* Total costs include mobilization

Pipe Manifold Cost Development

For facilities with design intake flows that are 10% or more greater than the 163,000 gpm to 165,000 gpm maximum costed (i.e., above 180,000 gpm), multiple intakes are costed and the costs are summed. This approach leads to probable costing over-estimates for both the added length of end sections wall costs.

Pipe costs are developed using the same general methodology as described in Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule, Appendix A, but modified based on a design pipe velocity of 5 feet per second. The pipe laying cost methodology was revised to include: costs for several different pipe lengths were developed. These pipe lengths include: 66 feet (20 meters), 410 feet (125 meters), 820 feet (250 meters), and 1640 feet (500 meters). The cost for pipe installation includes an equipment rental component for the pipe laying vessel, support barge, crew, and pipe laying equipment. The Phase I proposed rule Economic and Engineering Analyses document estimates that 500 feet of pipe can be laid in a day under favorable conditions. Equipment rental costs for the longer piping distances were adjusted upward, in single-day increments, to limit daily production rates not to exceed 550 feet/day. For the shorter distance of 66 feet (20 meters), the single-day pipe laying vessel/equipment costs were reduced by a factor of 40%. This reduction is based on the assumption that, in most cases, a pipe laying vessel is not needed because installation can be performed via crane located on the shoreline.

Figure 3-1 presents the capital cost curves for the pipe portion only for each of the offshore distance scenarios. The pipe cost development methodology adopted from the Phase I effort used a different set of flow values than are shown in Exhibit 3-1. Therefore, second-order, best-fit equations were derived from pipe cost data. These equations were applied to the flow values in Exhibit 3-1 to obtain the relevant installed pipe cost component.

An additional equipment component representing the cost of pipe fittings such as tees or elbows are included in the screen equipment costs. The costs are based on the cost estimates developed for the Phase I proposed rule, adjusted to a pipe velocity of 5 feet per second and 2002 dollars.

Airburst System Costs

Capital costs for airburst equipment sized to backwash each of the T-screens were obtained from vendor estimates. These costs included air supply equipment (compressor, accumulator, distributor) minus the piping to the screens, air supply housing, and utility

connections and wiring. Capital costs of the airburst air supply system are shown in Exhibit 3-8. Costs for a housing structure, electrical, and controls were added based on the following:

- electrical costs = 10% of air supply equipment (BPJ)
- Controls = 5% of air supply equipment (BPJ)
- Housing = $142/sq ft for area shown in Exhibit 3-8. This cost was based on the $130/sq ft cost used in the Phase I cost for pump housing, adjusted to 2002 dollars.

Exhibit 3-8. Capital Costs of Airburst Air Supply Equipment

Screen Size	Vendor Supplied Equipment Costs	Estimated Housing Area	Housing Area	Housing Costs	Electrical	Controls	Total Airburst Minus Air Piping to Screens
			sq ft		10%	5%	
T24	$6,000	5x5	25	$3,550	$600	$300	$10,450
T36	$10,000	5x5	25	$3,550	$1,000	$500	$15,050
T48	$15,000	6x6	36	$5,112	$1,500	$750	$22,362
T60	$20,000	6x6	36	$5,112	$2,000	$1,000	$28,112
T72	$25,000	7x7	49	$6,958	$2,500	$1,250	$35,708
T84	$30,000	8x8	64	$9,088	$3,000	$1,500	$43,588
T96	$35,000	8x8	64	$9,088	$3,500	$1,750	$49,338

The costs of the air supply pipes, or "blow pipes," are calculated for each installation depending on the length of the intake pipe, plus an assumed average distance of 70 feet from the airburst system housing to the intake pipe at the front of the sheet pile wall. Pipe costs are based on this total distance multiplied by a derived unit cost of installed pipe Vendors indicated that the pipes are typically made of schedule 10 stainless steel or high density polyethylene and that material costs are only a portion of the total installed costs. Consistent with the selection of screen materials, EPA chose to assume that the blow pipes are constructed of 304 stainless steel for freshwater and 316 stainless steel for saltwater applications.

The unit costs for the installed blow pipes are based on the installed cost of similar pipe in a structure on land multiplied by an underwater installation factor. This underwater installation factor was derived by reviewing the materials-versus-total costs for underwater steel pipe installation, which ranged from about 3.2 to 4.5 with values decreasing with increasing pipe size. A review of the materials-versus-installed-on-land costs for the smaller diameter stainless steel pipe (RS Means 2001) found that if the installed-on-land unit costs are multiplied by 2.0, the resulting materials-to-total- estimated (underwater)-installed-cost ratios fell within a similar range. These costs are considered as over-estimating costs somewhat because they include 304 and 316 stainless steel where less costly materials may be used. Also, they do not consider potential savings associated with concurrent installation alongside the much larger water intake pipe.

Blow pipe sizes were provided by vendors for T60 and smaller screens. For larger screens, the blow pipe diameter was derived by calculating pipe diameters (and rounding up to even pipe sizes) using the same ratio of screen area to blow pipe area calculated for T60 screens. This is based on the assumption that blow pipe air velocities are proportional to the needed air/water backwash velocities at the screen surface. A separate blow pipe was included for each T-screen where multiple screens are included, but only one set of the air supply equipment (compressor, accumulator, distributor, controls etc.) is included in each installation. The calculated costs for the air supply pipes are shown in Exhibit 3-9.

Exhibit 3-9. Capital Costs of Installed Air Supply Pipes for Fine Mesh Screens

Design Flow Fine Mesh	Design Flow Very Fine Mesh	Air Pipe Unit Cost - Schedule 10 304 SS	Air Pipe Unit Cost - Schedule 10 316 SS	Freshwater Airburst Distribution Installed Pipe Costs				Saltwater Airburst Distribution Installed Pipe Costs			
gpm	gpm	$/Ft	$/Ft	20 Meters	125 Meters	250 Meters	500 Meters	20 Meters	125 Meters	250 Meters	500 Meters
2,500	1,680	$57.3	$119.5	$7,764	$27,485	$50,961	$97,915	$16,210	$57,379	$106,391	$204,413
5,700	3,850	$85.4	$102.0	$11,575	$40,973	$75,970	$145,966	$13,834	$48,970	$90,798	$174,454
10,000	6,750	$102.0	$118.7	$13,834	$48,970	$90,798	$174,454	$16,093	$56,966	$105,625	$202,943
15,800	10,700	$160.3	$188.4	$21,739	$76,954	$142,685	$274,147	$25,550	$90,442	$167,694	$322,198
22,700	15,300	$222.8	$279.0	$30,209	$106,934	$198,274	$380,954	$37,830	$133,910	$248,292	$477,056
31,000	20,900	$304.0	$368.5	$41,220	$145,910	$270,542	$519,806	$49,971	$176,890	$327,983	$630,169
40,750	27,500	$376.8	$456.0	$51,100	$180,883	$335,388	$644,396	$61,828	$218,861	$405,804	$779,692
81,500	55,000	$376.8	$456.0	$102,199	$361,766	$670,775	$1,288,793	$123,656	$437,722	$811,609	$1,559,383
122,250	82,500	$376.8	$456.0	$153,299	$542,650	$1,006,163	$1,933,189	$185,485	$656,582	$1,217,413	$2,339,075
163,000	110,000	$376.8	$456.0	$204,398	$723,533	$1,341,550	$2,577,586	$247,313	$875,443	$1,623,218	$3,118,766
-	165,000	$376.8	$456.0	$306,597	$1,085,299	$2,012,326	$3,866,378	$370,969	$1,313,165	$2,434,826	$4,678,150

Indirect Costs

The total calculated capital costs were adjusted to include the following added costs:

- Engineering at 10% of direct capital costs
- Contractor overhead and profit at 15% of direct capital costs (based on O&P component of installing lift station in RS Means 2001); some direct cost components, e.g., the intake pipe cost and blow pipe cost, already include costs for contractor overhead and profit
- Contingency at 10% of direct capital costs
- Sitework at 10% of direct capital costs; based on sitework component of Fairfax Water Intake costs data, including costs for erosion & sediment control, trash removal, security, dust control, access road improvements, and restoration (trees, shrubs, seeding & sodding).

Total Capital Costs

Fine Mesh

Exhibit 3-10 presents the total capital costs of the complete system for fine mesh screens including indirect costs. Figures 3-2, 3-3, and 3-4 present the plotted capital costs in Exhibit 3-10 for freshwater, saltwater, and freshwater with Zebra mussels, respectively. Figures 3-2, 3-3, and 3-4 also present the best-fit, second order equations used in estimating compliance costs.

Very Fine Mesh

Exhibit 3-11 presents the total capital costs of the complete system for very fine mesh screens including indirect costs. Figures 3-5, 3-6, and 3-7 present the plotted capital costs in Exhibit 3-11 for freshwater, saltwater, and freshwater with Zebra mussels, respectively.

Exhibit 3-10. Total Capital Costs of Installed Fine Mesh T-screen System at Existing Shoreline Based Intakes

Design Flow	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
gpm	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
2,500	$330,608	$356,632	$333,958	$458,425	$487,945	$461,775	$694,677	$728,359	$698,027	$1,007,472	$1,049,477	$1,010,822
5,700	$359,106	$389,320	$371,286	$524,990	$563,194	$537,170	$807,170	$854,887	$819,350	$1,210,950	$1,277,690	$1,223,130
10,000	$405,008	$437,575	$427,389	$612,009	$652,566	$634,390	$944,036	$994,105	$966,417	$1,446,429	$1,515,522	$1,468,810
15,800	$460,179	$498,982	$492,913	$739,998	$792,284	$772,732	$1,160,061	$1,228,398	$1,192,795	$1,837,241	$1,937,682	$1,869,975
22,700	$530,563	$580,486	$584,916	$893,959	$970,848	$948,312	$1,415,327	$1,524,319	$1,469,680	$2,293,842	$2,467,040	$2,348,195
31,000	$602,745	$659,150	$676,434	$1,069,950	$1,157,317	$1,143,639	$1,717,372	$1,841,598	$1,791,061	$2,846,829	$3,044,774	$2,920,518
40,750	$691,543	$757,467	$787,461	$1,270,404	$1,374,281	$1,366,322	$2,054,067	$2,203,125	$2,149,984	$3,455,143	$3,694,566	$3,551,061
81,500	$1,034,259	$1,142,774	$1,226,094	$2,120,425	$2,304,845	$2,312,260	$3,526,716	$3,801,500	$3,718,551	$6,175,421	$6,630,933	$6,367,256
122,250	$1,420,292	$1,571,396	$1,708,044	$3,023,393	$3,288,357	$3,311,146	$5,071,576	$5,472,086	$5,359,329	$9,016,065	$9,687,666	$9,303,817
163,000	$1,813,456	$2,005,510	$2,197,126	$3,943,125	$4,286,990	$4,326,795	$6,652,462	$7,177,056	$7,036,132	$11,940,891	$12,826,940	$12,324,561

Exhibit 3-11. Total Capital Costs of Installed Very Fine Mesh T-screen System at Existing Shoreline Based Intakes

Design Flow	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
gpm	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
1,680	$329,296	$355,254	$332,813	$451,952	$481,545	$455,469	$681,911	$715,832	$685,428	$982,352	$1,024,929	$985,869
3,850	$354,622	$384,438	$367,411	$507,964	$546,100	$520,753	$774,855	$822,895	$787,644	$1,148,553	$1,216,401	$1,161,342
6,750	$396,579	$428,325	$420,079	$580,540	$620,605	$604,039	$884,451	$934,421	$907,951	$1,331,420	$1,401,198	$1,354,919
10,700	$446,379	$483,934	$480,749	$689,904	$741,492	$724,274	$1,065,566	$1,133,860	$1,099,937	$1,655,065	$1,756,769	$1,689,435
15,300	$510,005	$558,302	$567,076	$820,297	$896,659	$877,368	$1,276,515	$1,386,288	$1,333,586	$2,026,108	$2,202,703	$2,083,179
20,900	$573,744	$627,794	$651,118	$968,061	$1,054,341	$1,045,435	$1,525,747	$1,650,395	$1,603,120	$2,477,203	$2,678,590	$2,554,577
27,500	$652,189	$714,992	$752,903	$1,134,364	$1,236,677	$1,235,077	$1,798,524	$1,947,874	$1,899,238	$2,961,902	$3,205,326	$3,062,615
55,000	$944,813	$1,047,085	$1,146,240	$1,832,361	$2,013,654	$2,033,788	$2,989,159	$3,264,526	$3,190,586	$5,136,240	$5,599,755	$5,337,667
82,500	$1,270,016	$1,411,756	$1,572,156	$2,567,323	$2,827,597	$2,869,463	$4,225,531	$4,626,915	$4,527,671	$7,378,247	$8,061,852	$7,680,387
110,000	$1,596,585	$1,777,795	$1,999,439	$3,308,039	$3,647,292	$3,710,892	$5,476,429	$6,003,830	$5,879,283	$9,656,711	$10,560,407	$10,059,565
165,000	$2,276,664	$2,536,812	$2,880,944	$4,829,568	$5,326,782	$5,433,848	$8,044,641	$8,824,075	$8,648,921	$14,345,849	$15,689,726	$14,950,129

Nuclear Facilities

Construction and material costs tend to be substantially greater for nuclear facilities due to burden of increased security and to the requirements for more robust system design. Rather than performing a detailed evaluation of the differences in capital costs for nuclear facilities, EPA has chosen to apply a simple cost factor based on total costs.

In the Phase I costing effort, EPA used data from an Argonne National Lab study on retrofitting costs of fossil fuel power plants and nuclear power plants. This study reported average, comparative costs of $171 for nuclear facilities and $108 for fossil fuel facilities, resulting in a 1.58 costing factor. In comparison, recent consultation with a traveling screen vendor, the vendor indicated costing factors in the range of 1.5-2.0 were reasonable for estimating the increase in costs associated with nuclear power plants based on their experience. Because today there are likely to be additional security burdens above that experienced when the Argonne Report was generated, EPA has selected 1.8 as a capital costing factor for nuclear facilities. Capital costs for nuclear facilities are not presented here but can be estimated by multiplying the applicable non-nuclear facility costs by the 1.8 costing factor.

O&M Costs

O&M cost are based on the sum of costs for annual inspection and cleaning of the intake screens by a dive team and for estimated operating costs for the airburst air supply system. Dive team costs were estimated for a total job duration of one to four days, and are shown in Exhibit 3-12. Dive team cleaning and inspections were estimated at once per year for low debris locations and twice per year for high debris locations. The O&M costs for the airburst system are based on power requirements of the air compressor and labor requirements for routine O&M. Vendors cited a backwash frequency per screen from as low as once per week to as high as once per hour for fine mesh screens. The time needed to recharge the accumulator is about 0.5 hours, but can be as high as 1 hour for those with smaller compressors or accumulators that backwash more than one screen simultaneously.

The Hp rating of the typical size airburst compressor for each screen size was obtained from a vendor and is presented in the table in Attachment 3A. A vendor stated that several hours per week would be more than enough labor for routine maintenance, so labor is assumed to be two to four hours per week based on roughly half-hour daily inspection of the airburst system. However, during seasonal periods of high debris such as leaves in the fall, it may be necessary for someone to man the backwash system 24 hours/day for several weeks (Frey 2002). Thus, an additional one to 4.5 weeks of 24-hour labor are included for these periods (one week low debris fine mesh; 1.5 weeks low debris very fine mesh; three weeks high debris fine mesh; and 4.5 weeks high debris very fine mesh). Since very fine mesh screens will tend to collect debris at a more rapid rate, backwash frequencies and labor requirements were increased by 50% for very fine mesh screens.

The O&M cost of the airburst system are based on the following:

- Average backwash frequency in low debris areas is 2 times per day (3 times per day for very fine mesh)
- Average backwash frequency in high debris areas is 12 times per day (18 times per day for very fine mesh)
- Time to recharge accumulator is 0.5 hours
- Compressor motor efficiency is 90%
- Cost of electric power consumed is $0.04/Kwh
- Routine inspection and maintenance labor is 3 hours per week (4.5 hours per week for very fine mesh) for systems up to 182,400 gpm
- O&M labor rate per hour is $41.10/hr. The rate is based on Bureau of Labor Statistics Data using the median labor rates for electrical equipment maintenance technical labor (SOC 49-2095) and managerial labor (SOC 11-1021); benefits and other compensation are added using factors based on SIC 29 data for blue collar and white collar labor. The two values were combined into a single rate assuming 90% technical labor and 10% managerial. See Doley 2002 for details.

Exhibit 3-13 presents the total O&M cost for relocating intakes offshore with fine mesh and very fine mesh passive screens. These data are plotted in Figures 3-8 and 3-9 which also shows the second-order equations that were fitted to these data and used to estimate the O&M costs for individual Phase III facilities. Attachment 3A presents the worksheet data used to develop the annual O&M costs. As with the capital costs, at facilities where the design flow exceeds the maximum cost model design flow of 165,000 gpm plus 10% (180,000 gpm), the design flow are divided and the corresponding costs are summed.

Exhibit 3-12. Estimated Costs for Dive Team to Inspect and Clean T-screens

Installation and Maintenance Diver Team Costs

Item	Daily Cost*	One Time Cost*	Total	Adjusted Total			
Duration			One Day	One Day	Two Day	Three Day	Four Day
Cost Year			1999	2002	2002	2002	2002
Supervisor	$575		$575	$627	$1,254	$1,880	$2,507
Tender	$200		$200	$218	$436	$654	$872
Diver	$375		$750	$818	$1,635	$2,453	$3,270
Air Packs	$100		$100	$109	$218	$327	$436
Boat	$200		$200	$218	$436	$654	$872
Mob/Demob		$3,000	$3,000	$3,270	$3,270	$3,270	$3,270
Total			$4,825	$5,260	$7,250	$9,240	$11,230

***Source: Paroby 1999 (cost adjusted to 2002 dollars).**

Exhibit 3-13. Total O&M Costs for Passive Screens Relocated Offshore

Relocate Ofshore With New Fine Mesh Screens			Relocate Ofshore With New Very Fine Mesh Screens		
Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris	Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris
gpm			gpm		
2,500	$16,463	$35,654	1,680	$22,065	$48,221
5,700	$16,500	$35,872	3,850	$22,120	$48,548
10,000	$16,560	$36,235	6,750	$22,210	$49,092
15,800	$20,712	$42,497	10,700	$27,442	$56,496
22,700	$20,748	$42,715	15,300	$27,497	$56,823
31,000	$20,808	$43,078	20,900	$27,588	$57,367
40,750	$20,869	$43,441	27,500	$27,678	$57,912
81,500	$25,299	$51,374	55,000	$33,328	$67,821
122,250	$25,601	$53,189	82,500	$33,782	$70,544
163,000	$27,894	$58,984	110,000	$36,226	$77,246
-	-	-	165000	$37,133	$82,692

Construction Related Downtime

Downtime may be a substantial cost item for retrofits using the existing pump wells and pumps. The EPA retrofit scenario includes a sheet pile wall in front of the existing intake. This scenario is modeled after a proposed scenario presented in a feasibility study for the Salem Nuclear Plant. In this scenario, a sheet pile plenum with bypass gates is constructed 40 feet in front of the existing intake with about twelve 10-foot diameter header pipes connecting the plenum to about 240 T-screens. Construction is estimated to take two

years, with installation of the sheet pile plenum in the first year. The facility projects the installation of 10-foot header pipes and screens to take nine months and the air backwash piping to take two months. The feasibility study states that Units 1 & 2 would each have to be shutdown for about six months, to install the plenum, and for an additional two months to install the 10-foot header pipe connection to the plenum and to install the air piping. Thus, an estimated total of eight months downtime is estimated for this very large (near worst case) intake scenario. This scenario was discarded by the facility due to uncertainty about biofouling and debris removal at slack tides. No cost estimates were developed and, therefore no incentive to focus on a system design and a construction sequence that would minimize downtime existed.

In the same feasibility study, a scenario is proposed where a new intake with dual flow traveling screens is installed at a distance of 65 feet offshore inside a cofferdam. In this scenario, a sheet pile plenum wall connects the new intake to the existing shore intake. In this scenario the intake is constructed first; Units 1 & 2 are estimated to be shut down for about one month each to construct and connect the plenum walls to the existing intake.

It would seem that the T-screen plenum construction scenario could follow the same approach, i.e., performed while the units are operating. This approach would result in a much lower downtime, similar to that for the offshore intake, but including consideration for added time for near-shore air pipe installation. There are two relevant differences between these scenarios. One is the distance offshore to the T-screen piping connection versus the new intake structure (40 feet versus 65 feet). The second is that T-screens, pipes, and plenum would be installed underwater while the new intake would be constructed behind a coffer dam. Conceivably the offshore portion of the T-screen plenum (excluding the ends) and all pipe and screen installation on the offshore side could be performed without shutting down the intake.

The WH Zimmer plant is a facility that EPA has identified as actually having converted an existing shoreline intake with traveling screens to submerged offshore T-screens. This facility was originally constructed as a nuclear facility but was never completed. In the late 80's it was converted to a coal fired plant. The original intake was to supply service water and make-up water for recirculating wet towers, and had been completed. However, the area in front of the intake was plagued with sediment deposition. A decision was made to abandon the traveling screens and install T-screens approximately 50 feet offshore. However, because the facility was not operating at the time of this conversion, there was no monetary incentive to minimize construction time. Actual construction took six to eight months for this intake, with a design flow of about 61,000 gpm (Frey 2002). The construction method in this case used a steel wall installed in front of the existing intake pump wells.

The Agency consulted the WH Zimmer plant engineer and asked him to estimate how long it would take to perform this retrofit particularly with a goal of minimizing generating unit downtime. The estimated downtime was a minimum of seven to nine weeks, assuming mobilization goes smoothly and a tight construction schedule is maintained. A more generous estimate of a total of 12 to 15 weeks was estimated for their facility assuming some predictable disruption to construction schedules. This estimate includes five to six weeks for installing piping (some support pilings can be laid ahead of time), an additional five to six weeks to tie in piping and install the wall, and an additional two to three weeks to clean and dredge the intake area. This last two- to three-week period was a construction step somewhat unique to the Zimmer plant, especially because the presence of sediment was the driving factor in the decision to convert the system.

Based on the above information, EPA has concluded that a reasonable unit downtime should be in the range of 13 to 15 weeks for total downtime. It is reasonable to assume that this downtime can be scheduled to coincide with routine generating unit downtime of approximately four weeks, resulting in a total potential lost generation period of nine to 11 weeks. Rather than select a single downtime for all facilities installing passive screens, EPA chose to apply a 13 to 15 week total downtime duration based on variations in project size using design flow as a measure of size. As such, EPA assumed a downtime of 13 weeks for facilities with intake flow volumes of less than 400,000 gpm, 14 weeks for facilities with intake flow volumes greater than 400,000 gpm but less than 800,000 gpm, and 15 weeks for facilities with intake flow volumes greater than 800,000 gpm.

Application

General Applicability

The following site-related conditions may preclude the use of passive T-screens or create operational problems:

- Water depths of <2 feet at screen location; for existing facilities this should not be an issue
- Stagnant waterbodies with high debris load
- Waterbodies with frazil ice in winter.

Frazil ice consists of fine, small, needle-like structures or thin, flat, circular plates of ice suspended in water. In rivers and lakes it is formed in supercooled, turbulent water. Remedies for this problem include finding another location such as deeper water that is outside of the turbulent water or creating a provision for periodically applying heated water to the screens. The application of heated water may not be feasible or economically justifiable in many instances.

Some facilities have reported limited success in alleviating frazil ice problems by blowing a small constant stream of air through the screen backwash system (Whitaker 2002b).

Application of Different Pipe Lengths

As noted previously, the shortest pipe length cost scenario (20 meters) are assumed to be applicable only to facilities with flows less than 163,000 gpm. Conversely, facilities located on large waterbodies that are subject to wave action and shifting sediment are assumed to install the longest pipe length scenario of 500 meters. Large waterbodies in this instance will include Great Lakes, oceans, and some estuarine/tidal rivers. The matrix in Exhibit 3-14 will provide some initial guidance. Generally, if the waterbody width is known, the pipe length should not exceed half the width.

Exhibit 3-14. Selection of Applicable Relocation Offshore Pipe Lengths By Waterbody

	Freshwater Rivers/Streams	Lakes/Reservoirs	Estuaries/Tidal Rivers	Great Lakes	Oceans
20 Meters	Flow <163,000	Flow <163,000	NA	NA	NA
125 Meters	TBD	TBD	TBD	NA	NA
250 Meters	TBD	TBD	TBD	TBD	NA
500 Meters	NA	NA	TBD	TBD	ALL

TBD: Criteria or selection to be determined; criteria may include design flow, waterbody size (if readily available).

1.2 Add Submerged Fine Mesh Passive Screens to Existing Offshore Intakes

Please note that much of the supporting documentation has been previously described in section 1.1.

Capital Costs

Adding passive screens to an existing submerged offshore intake requires many of the same construction steps and components described in section 1.1 above, excluding those related to the main trunk of the manifold pipe and connecting wall. Similar construction components include: modifying the submerged inlet to connect the new screens, installing T-screens, and installing the airburst backwash air supply equipment and the blowpipes. Nearly all of these components will require similar equipment, construction steps and costs as described in section 1.1 for the specific components. One possible difference is that the existing submerged piping distance may not match one of the four lengths for which costs were estimated. This difference only affects this component of cost. The cost scenario distance chosen is the one that closely matches or exceeds the existing offshore distance. Exhibits 3-15 and 3-16 present the combined costs of the installed T-screens, airburst air supply system, and air supply pipes for fine mesh and very fine mesh screens, respectively. The costs in Exhibit 3-15 and 3-16 include direct and indirect costs, as described in section 1.1. Figures 3-10, 3-11, 3-12, 3-13, 3-14, and 3-15 present plots of the data in Exhibits 3-15 and 3-16. The figures include the second-order, best-fit equations are used to estimate technology costs for specific facilities.

Exhibit 3-15. Capital Cost of Installing Fine Mesh Passive T-screens at an Existing Submerged Offshore Intake

Design Flow	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
gpm	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
2,500	$100,137	$112,839	$103,487	$128,732	$172,535	$132,081	$162,773	$243,602	$166,122	$230,855	$385,735	$234,204
5,700	$120,312	$125,414	$132,492	$162,939	$176,361	$175,119	$213,685	$237,012	$225,865	$315,178	$358,314	$327,358
10,000	$154,594	$160,610	$176,975	$205,541	$219,877	$227,922	$266,192	$290,432	$288,573	$387,494	$431,543	$409,674
15,800	$194,029	$204,426	$226,763	$274,090	$298,519	$306,823	$369,400	$410,535	$402,134	$560,020	$634,566	$592,754
22,700	$245,131	$264,554	$299,484	$356,382	$403,871	$410,736	$488,825	$569,725	$543,178	$753,711	$901,432	$808,064
31,000	$293,433	$316,628	$367,122	$445,234	$500,659	$518,923	$625,950	$719,744	$699,639	$987,382	$1,157,915	$1,061,071
40,750	$352,983	$382,546	$448,900	$541,169	$610,243	$637,086	$765,200	$881,312	$861,118	$1,213,263	$1,423,448	$1,309,181
81,500	$562,086	$621,213	$753,921	$938,458	$1,076,608	$1,130,293	$1,386,521	$1,618,744	$1,578,356	$2,282,647	$2,703,017	$2,474,482
122,250	$795,243	$883,934	$1,082,995	$1,359,802	$1,567,025	$1,647,554	$2,031,896	$2,380,230	$2,319,649	$3,376,084	$4,006,639	$3,663,837
163,000	$1,021,242	$1,139,497	$1,404,912	$1,773,988	$2,050,286	$2,157,658	$2,670,113	$3,134,559	$3,053,783	$4,462,364	$5,303,105	$4,846,034

Exhibit 3-16. Capital Cost of Installing Very Fine Mesh Passive T-screens at an Existing Submerged Offshore Intake

Design Flow	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
gpm	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
1,680	$100,173	$102,084	$103,690	$128,768	$134,314	$132,284	$162,809	$172,683	$166,326	$230,891	$249,421	$234,408
3,850	$120,156	$125,350	$132,945	$162,783	$176,297	$175,572	$213,530	$236,948	$226,319	$315,023	$358,250	$327,812
6,750	$154,275	$160,428	$177,774	$205,221	$219,694	$228,721	$265,872	$290,250	$289,372	$387,174	$431,360	$410,674
10,700	$193,241	$203,882	$227,611	$273,302	$297,975	$307,672	$368,612	$409,990	$402,982	$559,232	$634,022	$593,603
15,300	$244,023	$263,866	$301,094	$355,275	$403,183	$412,346	$487,718	$569,036	$544,789	$752,603	$900,743	$809,674
20,900	$291,795	$315,515	$369,168	$443,596	$499,547	$520,970	$624,313	$718,632	$701,686	$985,745	$1,156,802	$1,063,118
27,500	$350,954	$381,218	$451,667	$539,140	$608,915	$639,854	$763,172	$879,984	$863,885	$1,211,235	$1,422,120	$1,311,948
55,000	$557,781	$618,309	$759,208	$934,154	$1,073,703	$1,135,580	$1,382,216	$1,615,840	$1,583,643	$2,278,342	$2,700,113	$2,479,769
82,500	$788,414	$879,206	$1,090,554	$1,352,973	$1,562,298	$1,655,113	$2,025,067	$2,375,502	$2,327,207	$3,369,255	$4,001,912	$3,671,395
110,000	$1,011,641	$1,132,697	$1,414,495	$1,764,387	$2,043,486	$2,167,240	$2,660,512	$3,127,759	$3,063,366	$4,452,763	$5,296,305	$4,855,617
165,000	$1,458,718	$1,640,302	$2,062,999	$2,587,837	$3,006,486	$3,192,117	$3,932,025	$4,632,895	$4,536,305	$6,620,401	$7,885,714	$7,224,682

O&M Costs

O&M costs are assumed to be nearly the same as for relocating the intake offshore with passive screens. EPA assumes there are some offsetting costs associated with the fact that the existing intake should already have periodic inspection/cleaning by divers. The portion of the costs representing a single annual inspection has therefore been deducted. Exhibits 3-17 and 3-18 presents the annual O&M costs for fine mesh and very fine mesh screens, respectively. Separate costs are provided for low debris and high debris locations. Figures 3-16 and 3-17 present the plotted O&M data along with the second-order, best fit equations.

Exhibit 3-17. Net Intake O&M Costs for Fine Mesh Passive T-screens Installed at Existing Submerged Offshore Intakes

Existing Offshore With New Fine Mesh Screens			Existing Offshore With New Very Fine Mesh Screens		
Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris	Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris
gpm			gpm		
2,500	$11,203	$30,394	1,680	$16,805	$42,961
5,700	$11,240	$30,612	3,850	$16,860	$43,288
10,000	$11,300	$30,975	6,750	$16,950	$43,832
15,800	$13,462	$35,247	10,700	$20,192	$49,246
22,700	$13,498	$35,465	15,300	$20,247	$49,573
31,000	$13,558	$35,828	20,900	$20,338	$50,117
40,750	$13,619	$36,191	27,500	$20,428	$50,662
81,500	$16,059	$42,134	55,000	$24,088	$58,581
122,250	$16,361	$43,949	82,500	$24,542	$61,304
163,000	$16,664	$47,754	110,000	$24,996	$66,016
-	-	-	165000	$25,903	$71,462

Construction Downtime

Unlike the cost for relocating the intake from shore-based to submerged offshore, the only construction activities that would require shutting down the intake is to modify the inlet and install the T-screens. Installing the air supply system and the major portion of the air blowpipes can be performed while the intake is operating. Downtimes are assumed to be similar to those for adding velocity caps, which were reported to range from two to seven days. An additional one to two days may be needed to connect the blowpipes to the T-screens. The total estimated intake downtime of three to nine days can easily be scheduled to coincide with the routine maintenance period for power plants (which the Agency assumed to be four weeks for typical plants).

Application

Separate capital costs have been developed for freshwater, freshwater with Zebra mussels, and saltwater environments. In selecting the materials of construction, the same methodology described in section 1.1 is used. Because the retrofit is an addition to an existing intake, selecting the distance offshore involves matching the existing distance to the nearest or next highest distance costed.

Similarly, the O&M costs are applied using the same method as described in section 1.1.

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ATTACHMENT A3
O&M DEVELOPMENT DATA

Exhibit 3A-1. O&M Development Data - Relocate Offshore with Fine Mesh Screens

Design Flow	Compressor Power	Low Debris Backwash Frequency	High Debris Backwash Frequency	Annual Power Required - Low Debris	Annual Power Required - High Debris	Annual Power Costs - Low Debris*	Annual Power Costs - High Debris*	Annual Labor Required - Low Debris	Annual Labor Cost - Low Debris	Annual Labor Required - High Debris	Annual Labor Cost - High Debris	Dive Team Days Low Debris	Dive Team Costs Low Debris	Dive Team Costs High Debris
		Events/day	Events/day	Kwh	Kwh	$0.04	$0.04	Hours		Hours				
2,500	2	2	12	605	3,631	$24	$145	272	$11,179	608	$24,989	1	$5,260	$10,520
5,700	5	2	12	1,513	9,076	$61	$363	272	$11,179	608	$24,989	1	$5,260	$10,520
10,000	10	2	12	3,025	18,153	$121	$726	272	$11,179	608	$24,989	1	$5,260	$10,520
15,800	12	2	12	3,631	21,783	$145	$871	324	$13,316	660	$27,126	2	$7,250	$14,500
22,700	15	2	12	4,538	27,229	$182	$1,089	324	$13,316	660	$27,126	2	$7,250	$14,500
31,000	20	2	12	6,051	36,305	$242	$1,452	324	$13,316	660	$27,126	2	$7,250	$14,500
40,750	25	2	12	7,564	45,382	$303	$1,815	324	$13,316	660	$27,126	2	$7,250	$14,500
81,500	25	4	24	15,127	90,763	$605	$3,631	376	$15,454	712	$29,263	3	$9,240	$18,480
122,250	25	6	36	22,691	136,145	$908	$5,446	376	$15,454	712	$29,263	3	$9,240	$18,480
163,000	25	8	48	30,254	181,527	$1,210	$7,261	376	$15,454	712	$29,263	4	$11,230	$22,460

Exhibit 3A-2. O&M Development Data - Relocate Offshore with Very Fine Mesh Screens

Design Flow	Compressor Power	Low Debris Backwash Frequency	High Debris Backwash Frequency	Annual Power Required - Low Debris	Annual Power Required - High Debris	Annual Power Costs - Low Debris*	Annual Power Costs - High Debris*	Annual Labor Required - Low Debris	Annual Labor Cost - Low Debris	Annual Labor Required - High Debris	Annual Labor Cost - High Debris	Dive Team Days Low Debris	Dive Team Costs Low Debris	Dive Team Costs High Debris
gpm	Hp					at $/kw =	at $/kw =							
		Events/day	Events/day	Kwh	Kwh	$0.04	$0.04	Hours		Hours				
1,680	2	3	18	908	5,446	$36	$218	408	$16,769	912	$37,483	1	$5,260	$10,520
3,850	5	3	18	2,269	13,615	$91	$545	408	$16,769	912	$37,483	1	$5,260	$10,520
6,750	10	3	18	4,538	27,229	$182	$1,089	408	$16,769	912	$37,483	1	$5,260	$10,520
10,700	12	3	18	5,446	32,675	$218	$1,307	486	$19,975	990	$40,689	2	$7,250	$14,500
15,300	15	3	18	6,807	40,844	$272	$1,634	486	$19,975	990	$40,689	2	$7,250	$14,500
20,900	20	3	18	9,076	54,458	$363	$2,178	486	$19,975	990	$40,689	2	$7,250	$14,500
27,500	25	3	18	11,345	68,073	$454	$2,723	486	$19,975	990	$40,689	2	$7,250	$14,500
55,000	25	6	36	22,691	136,145	$908	$5,446	564	$23,180	1068	$43,895	3	$9,240	$18,480
82,500	25	9	54	34,036	204,218	$1,361	$8,169	564	$23,180	1068	$43,895	3	$9,240	$18,480
110,000	25	12	72	45,382	272,290	$1,815	$10,892	564	$23,180	1068	$43,895	4	$11,230	$22,460
165000	25	18	108	68,073	408,435	$2,723	$16,337	564	$23,180	1068	$43,895	4	$11,230	$22,460

Figure 3-1. Capital Costs Conventional Steel Pipe Laying Method at Various Offshore Distances

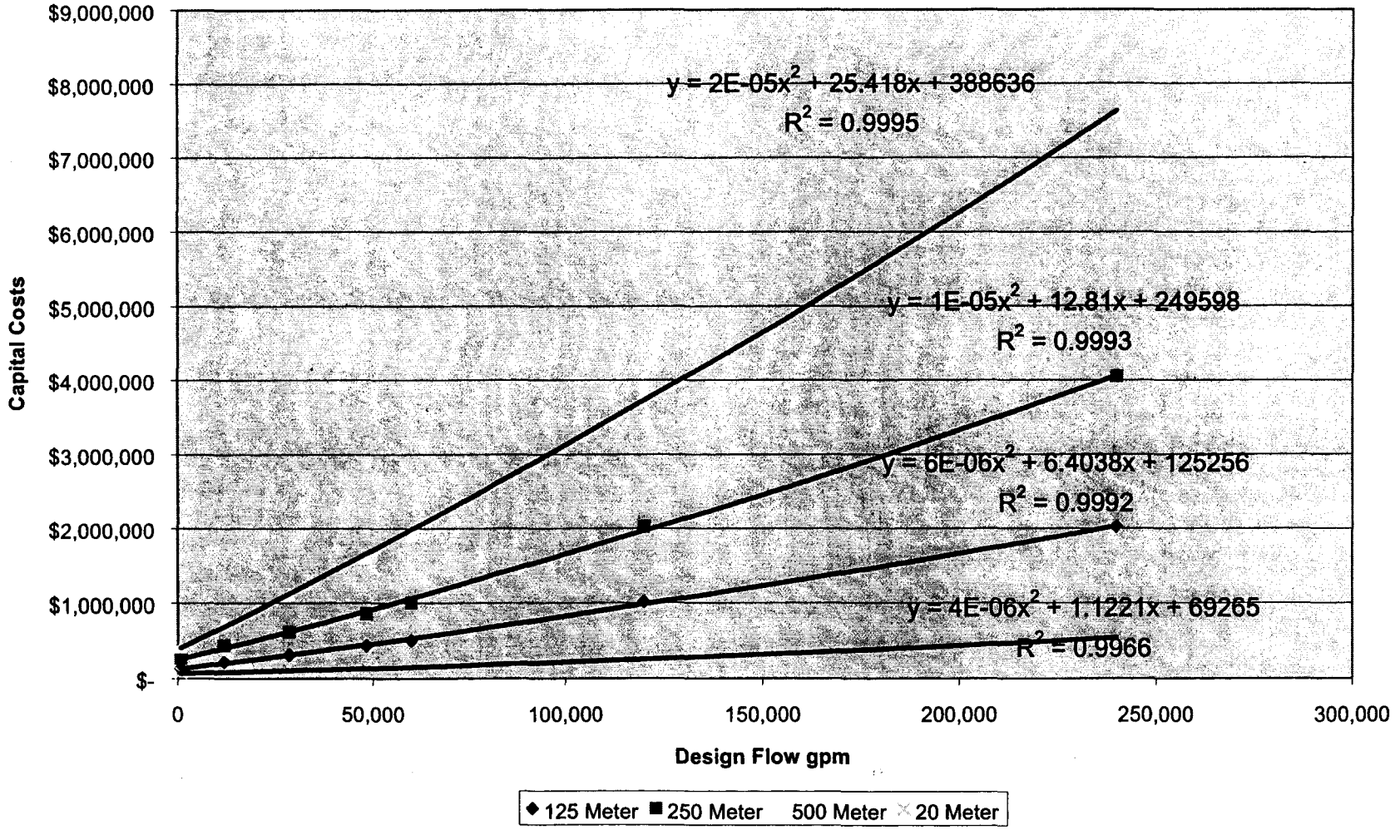


Figure 3-2. Capital Costs for Fine Mesh Passive Screen Relocation Offshore in Freshwater at Selected Offshore Distances

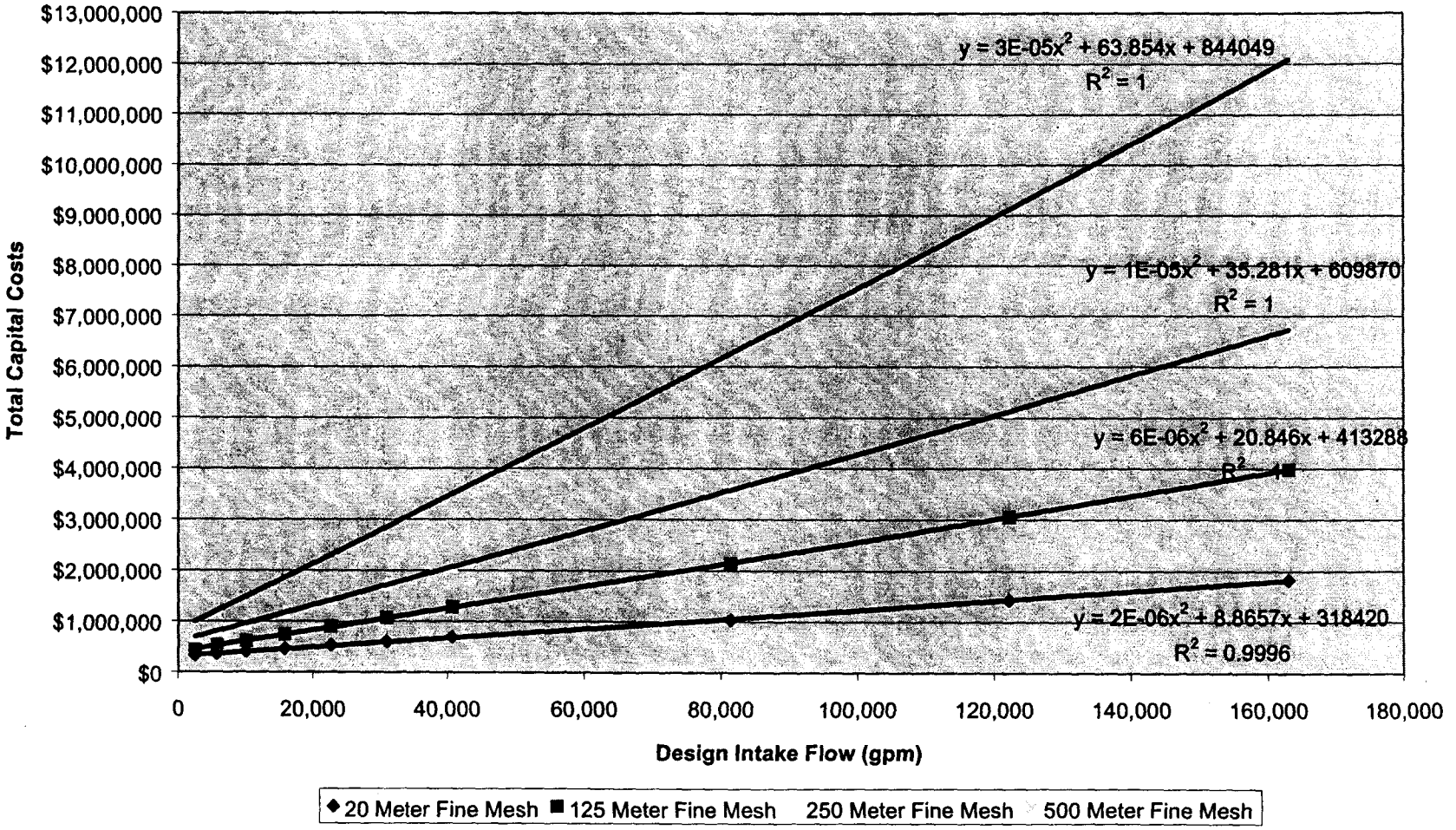


Figure 3-3. Capital Costs for Mesh Passive Screen Relocation Offshore in Saltwater at Selected Offshore Distances

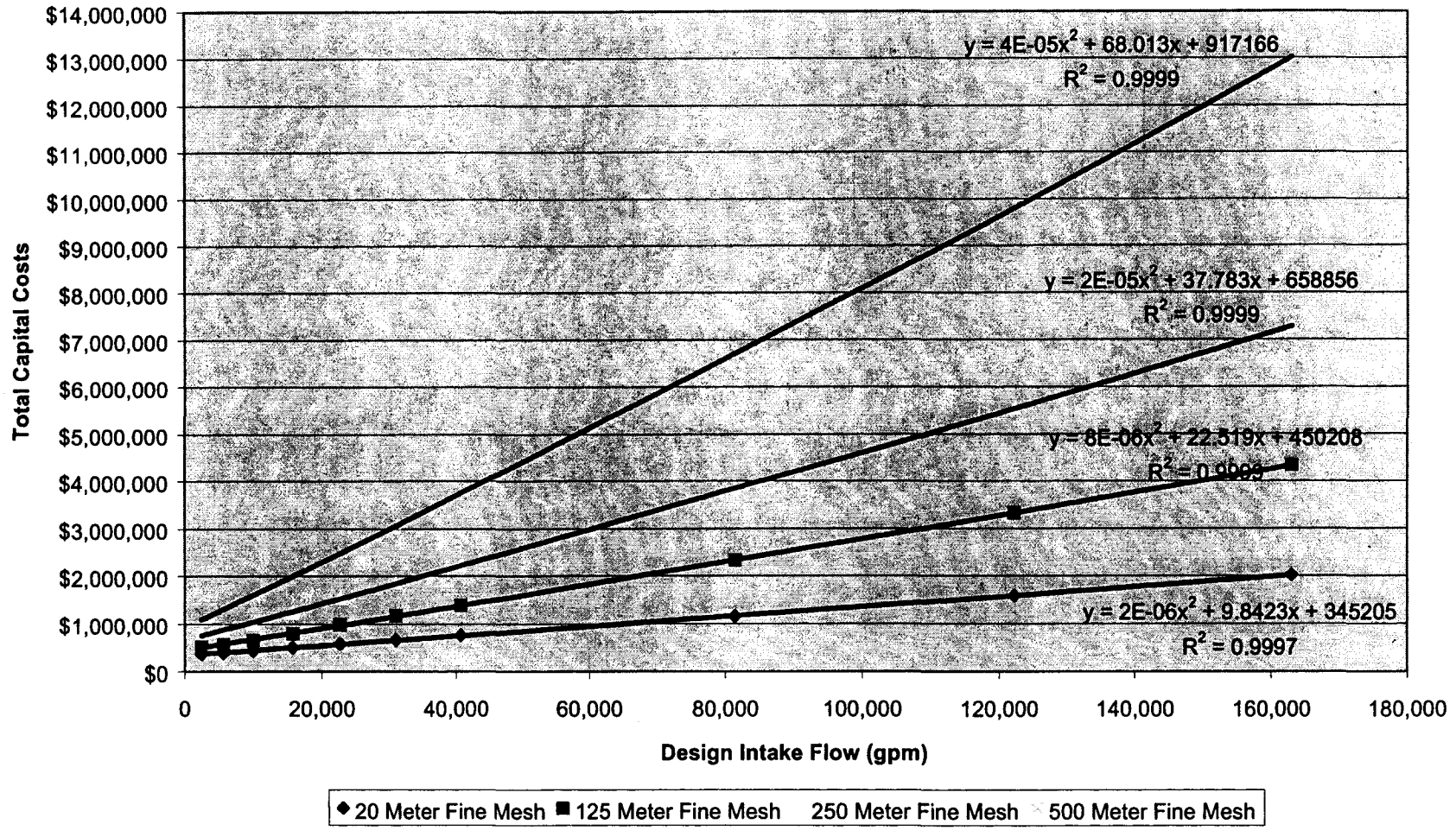


Figure 3-4. Capital Costs for Fine Mesh Passive Screen Relocation Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

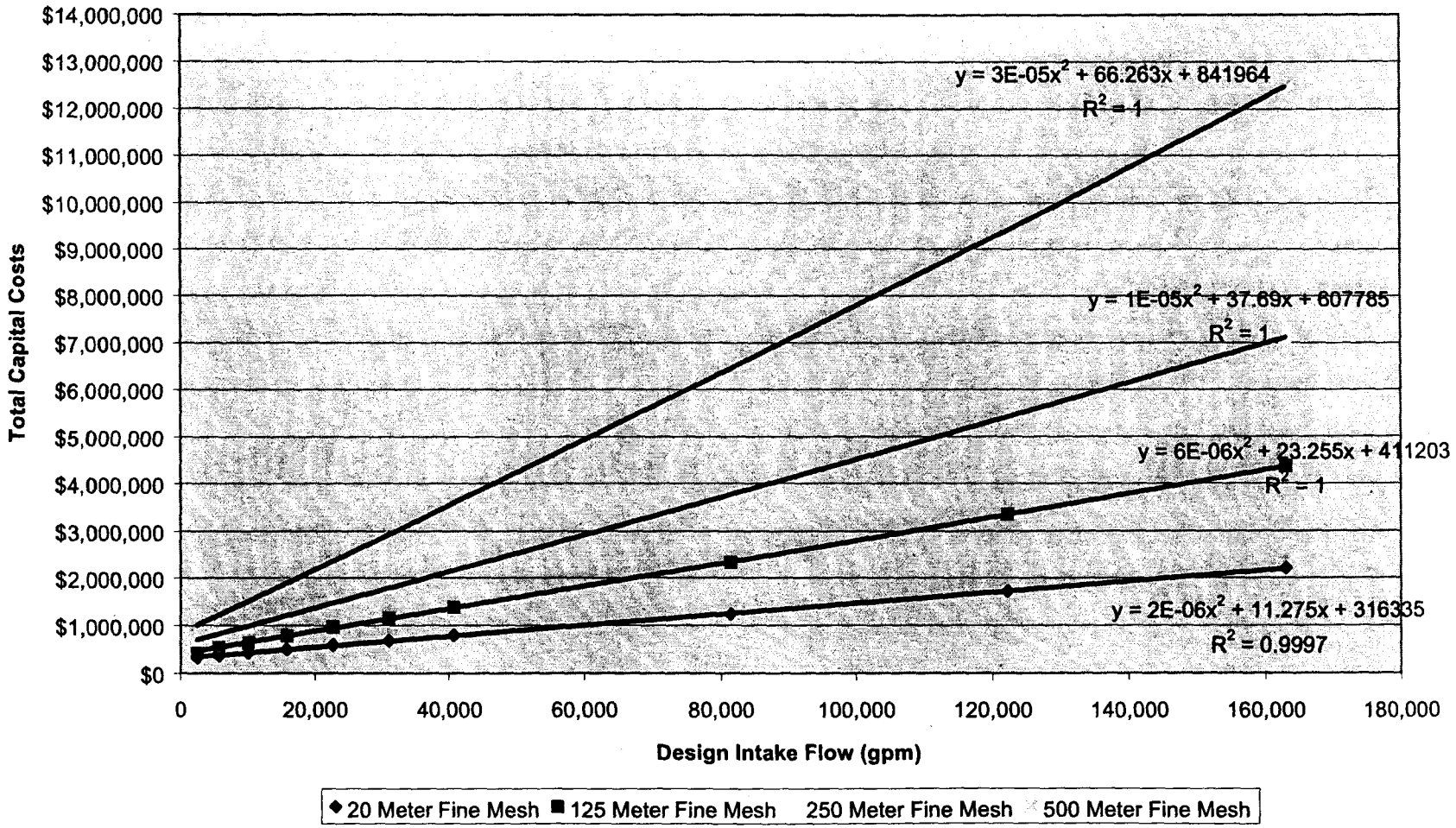


Figure 3-5. Capital Costs for Very Fine Mesh Passive Screen Relocation Offshore in Freshwater at Selected Offshore Distances

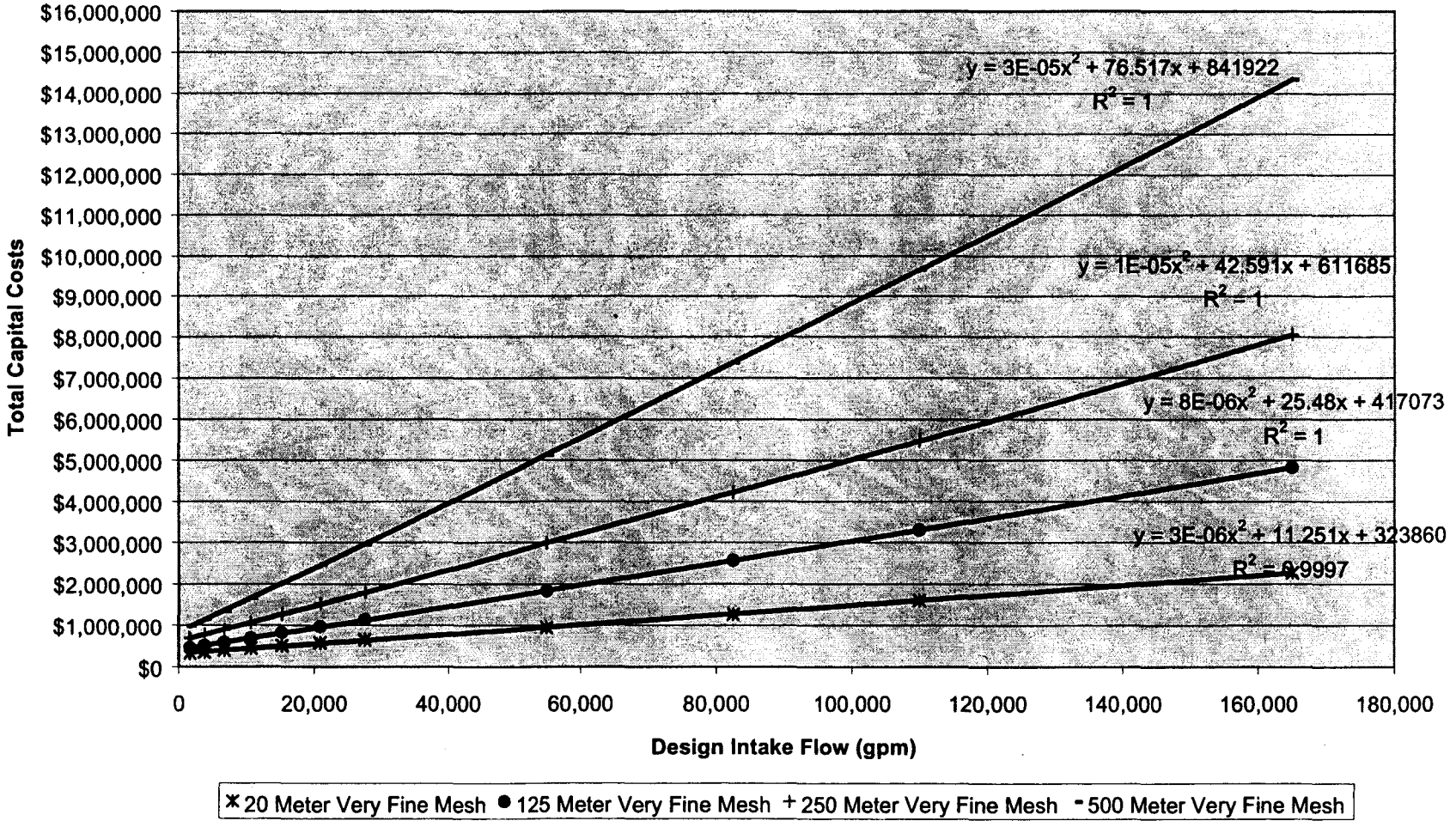


Figure 3-6. Capital Costs for Very Fine Mesh Passive Screen Relocation Offshore in Selected Offshore Distances

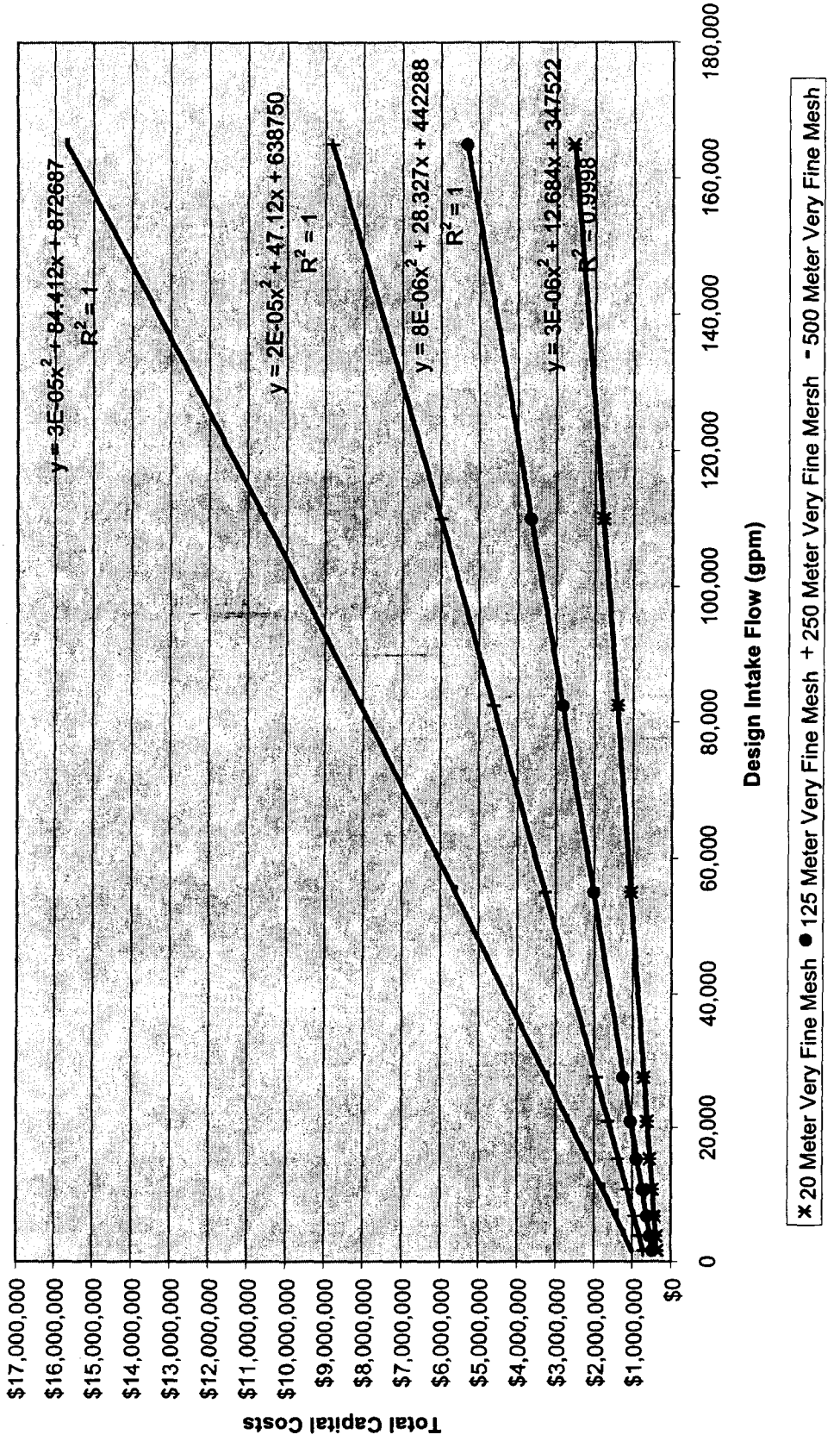


Figure 3-7. Capital Costs for Very Fine Mesh Passive Screen Relocation Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

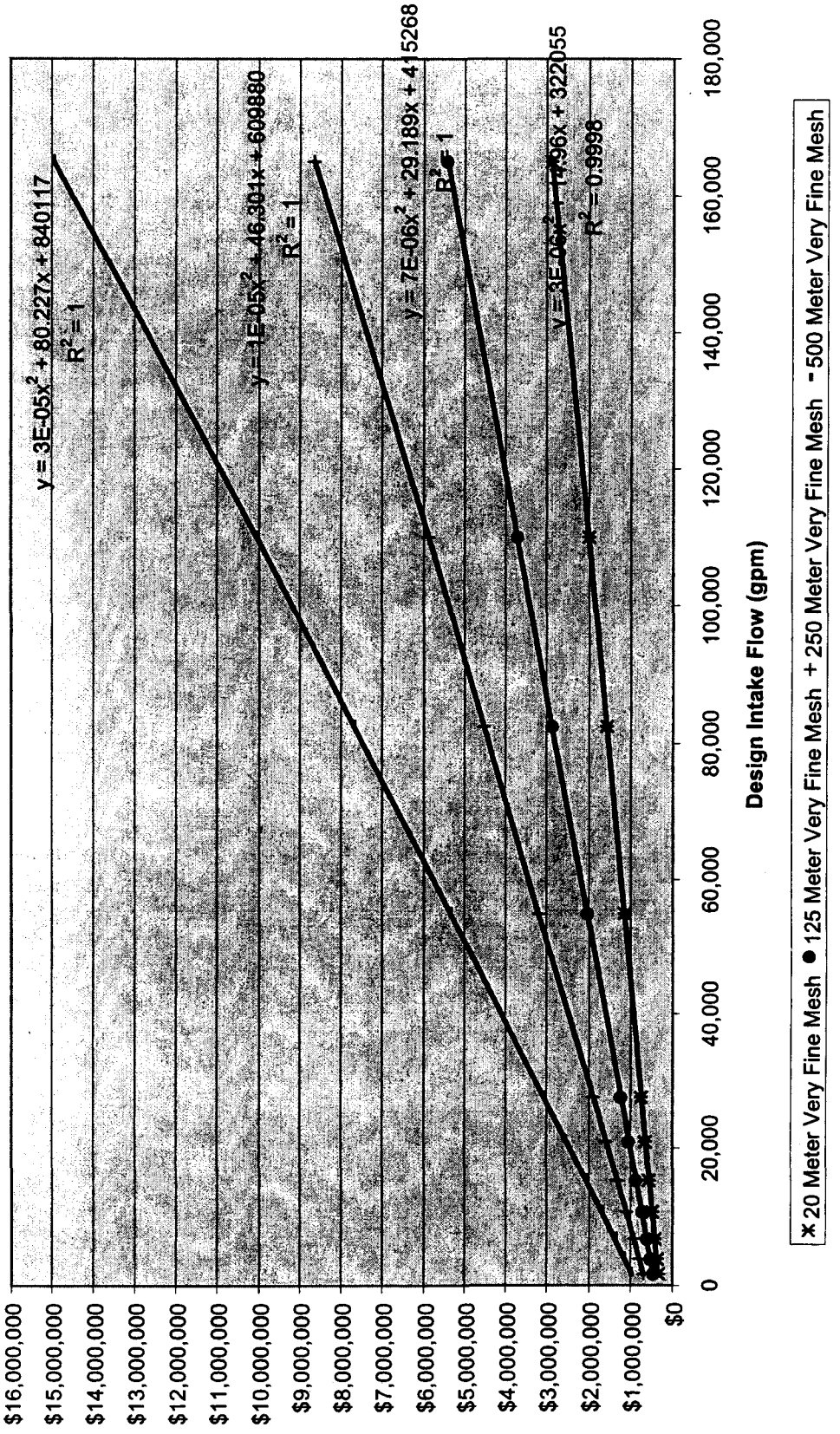
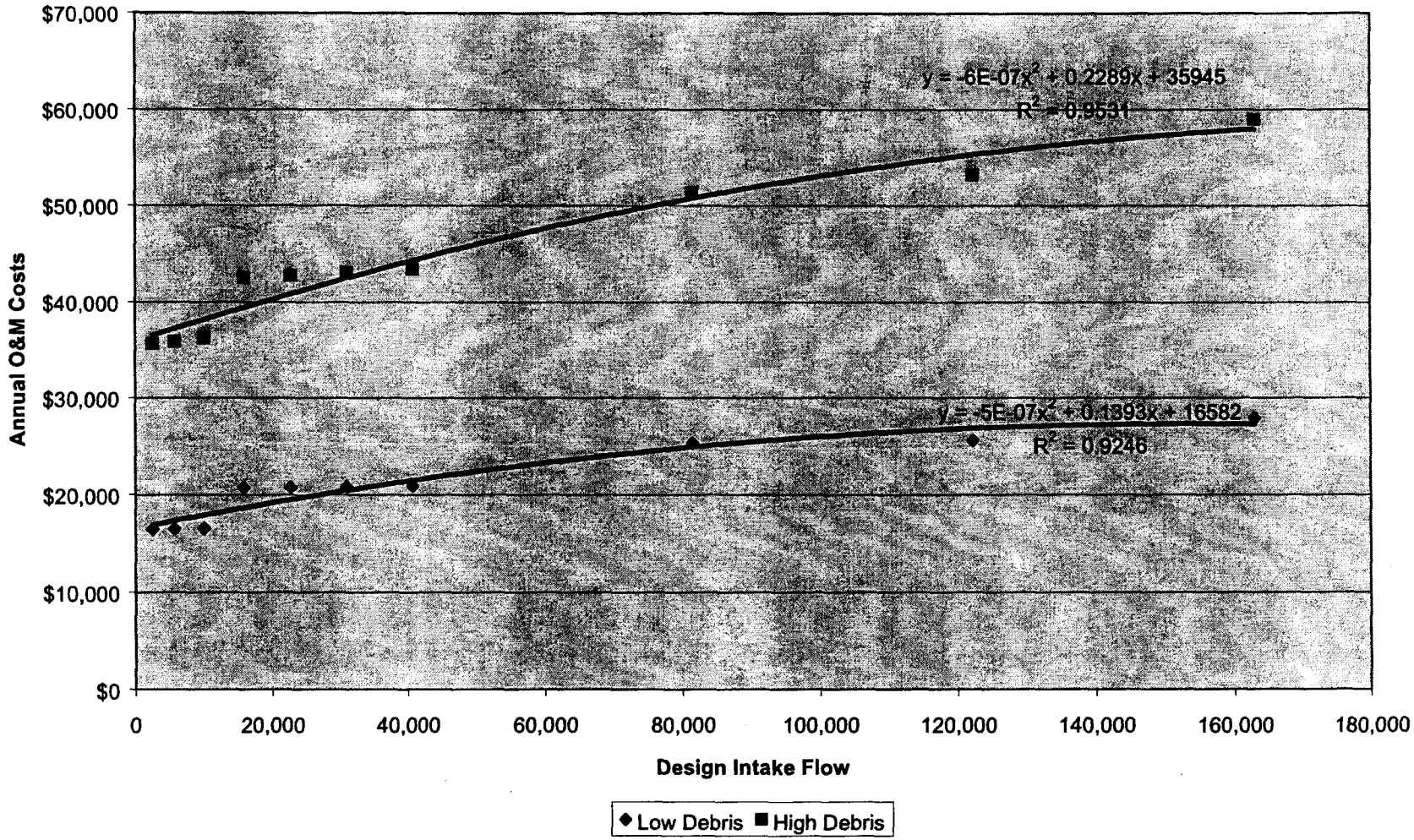


Figure 3-8. Total O&M Cost for Fine Mesh Passive Screen Relocated Offshore with Airburst Backwash



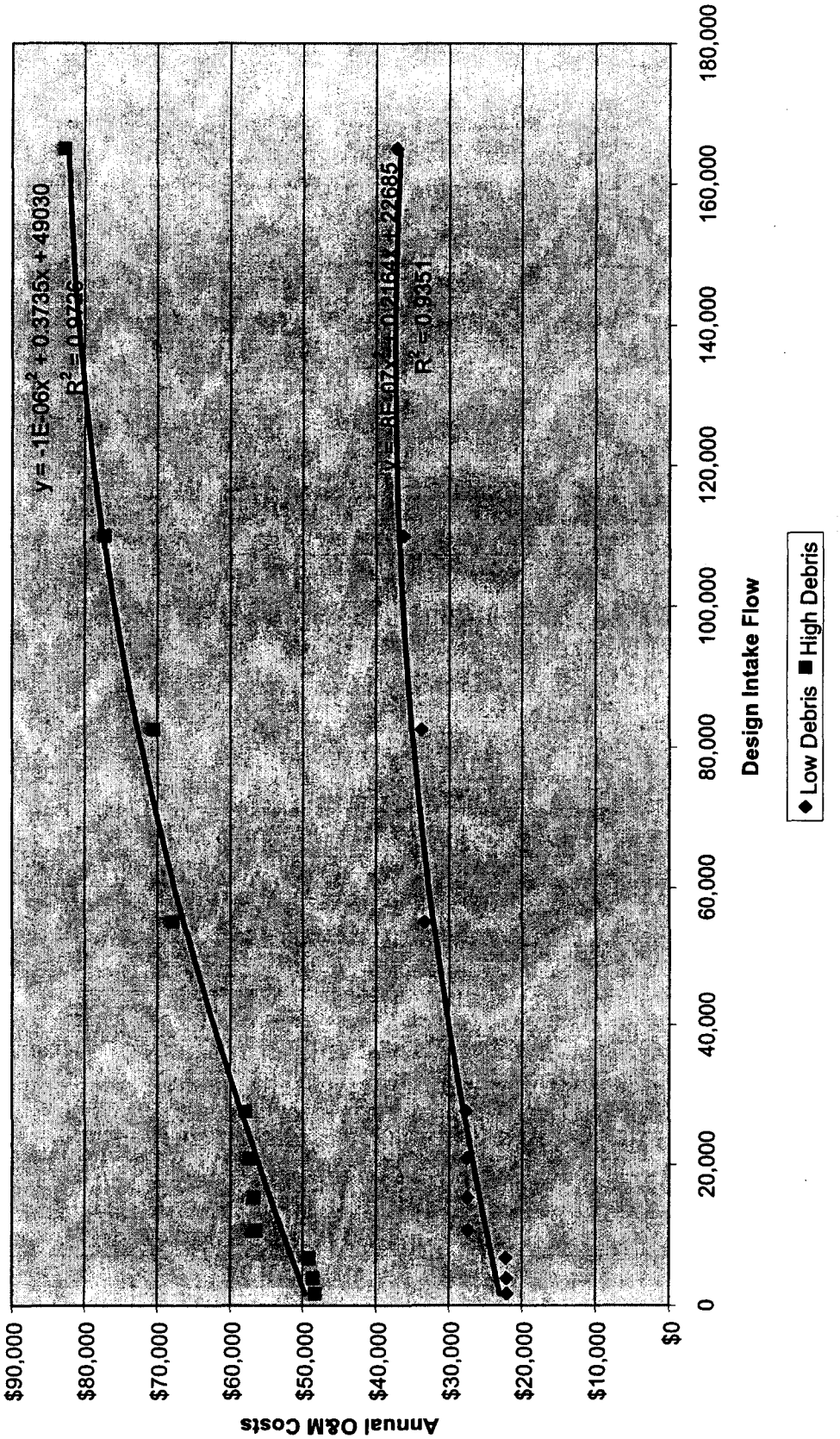


Figure 3-9. Total O&M Cost for Very Fine Mesh Passive Screen Relocated Offshore with Airburst Backwash

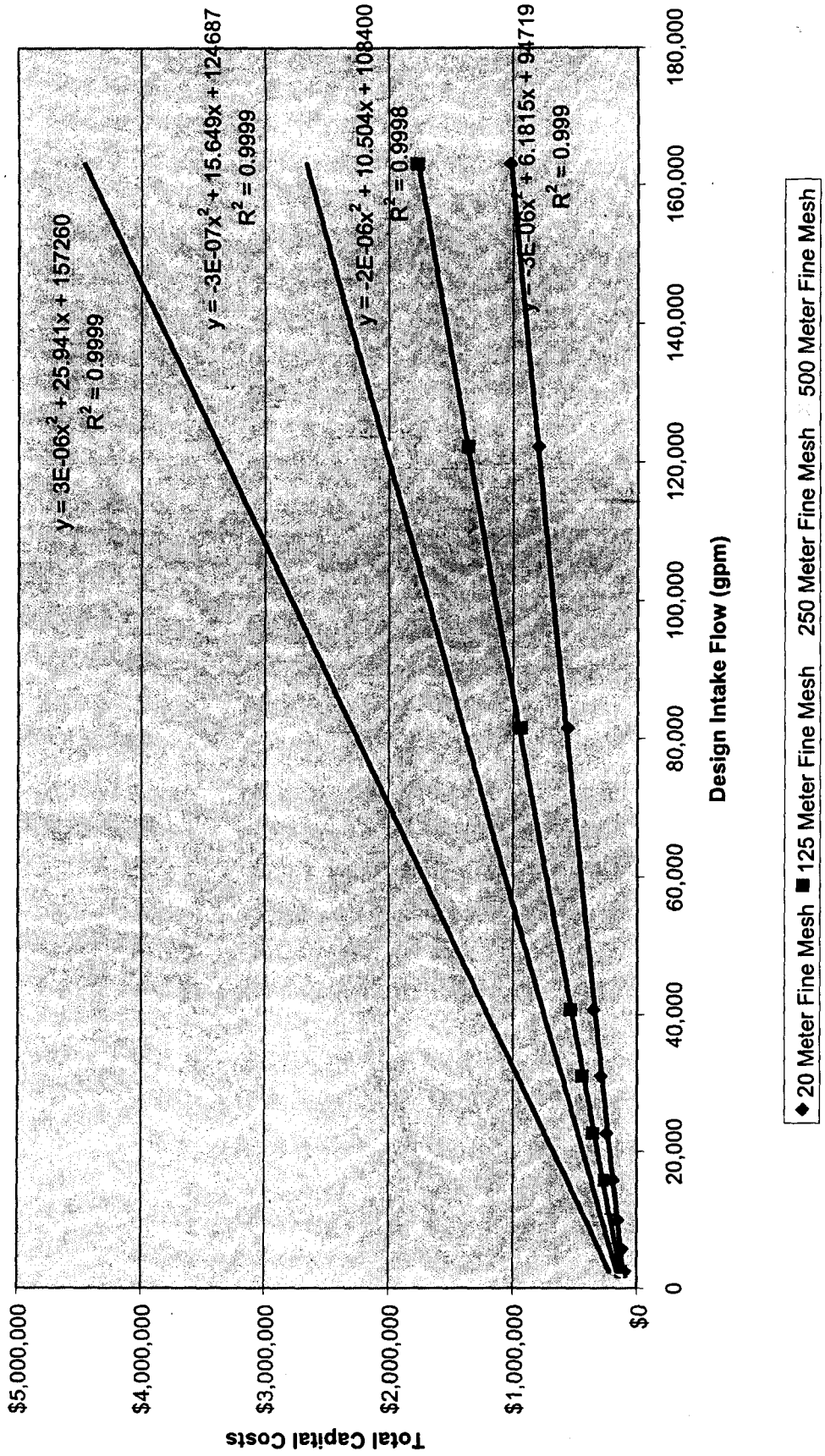


Figure 3-10. Capital Costs for Fine Mesh Passive Screen Existing Offshore in Freshwater at Selected Offshore Distances

Figure 3-11. Capital Costs for Fine Mesh Passive Screen Existing Offshore in Saltwater at Selected Offshore Distances

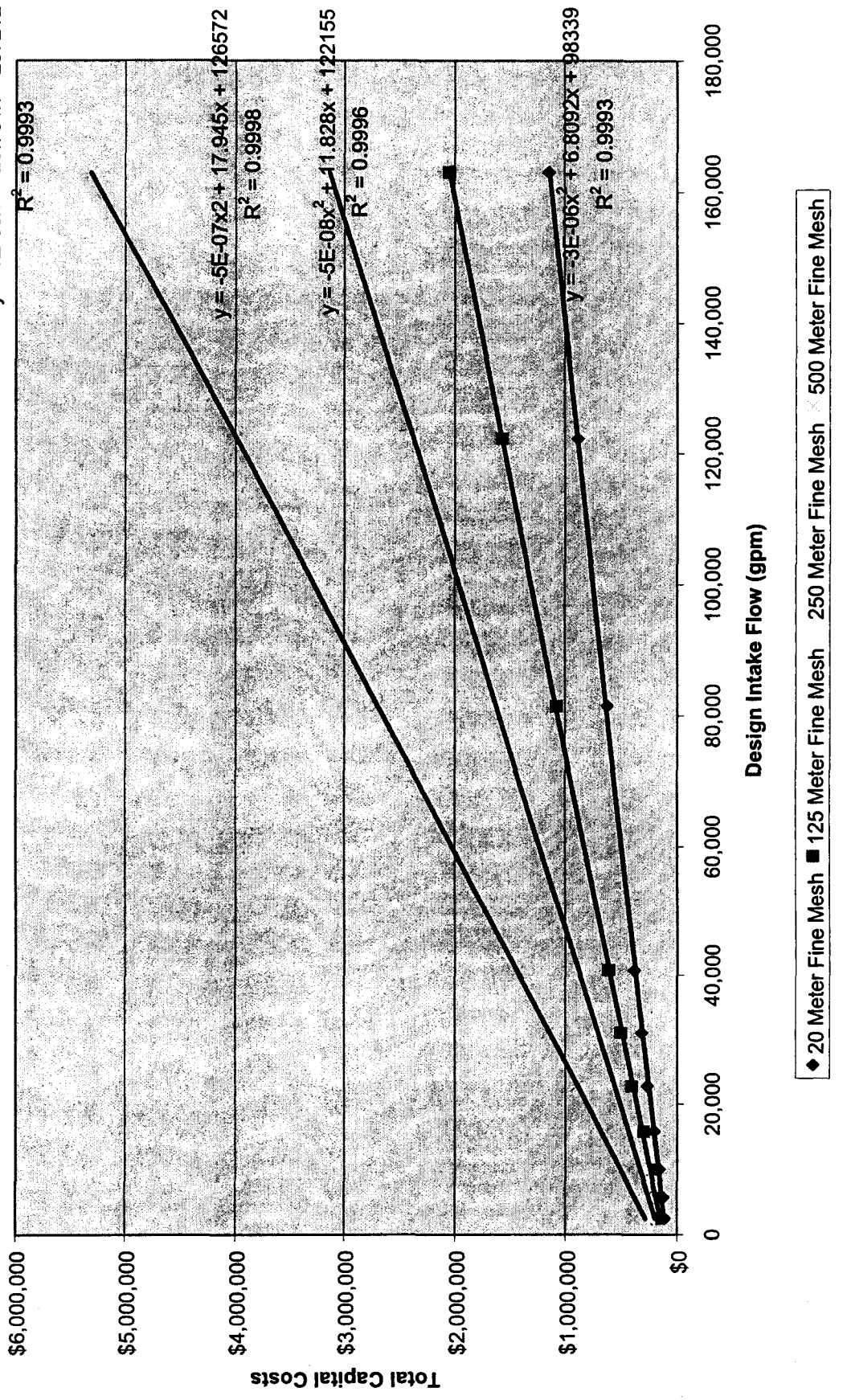


Figure 3-12. Capital Costs for Fine Mesh Passive Screen Existing Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

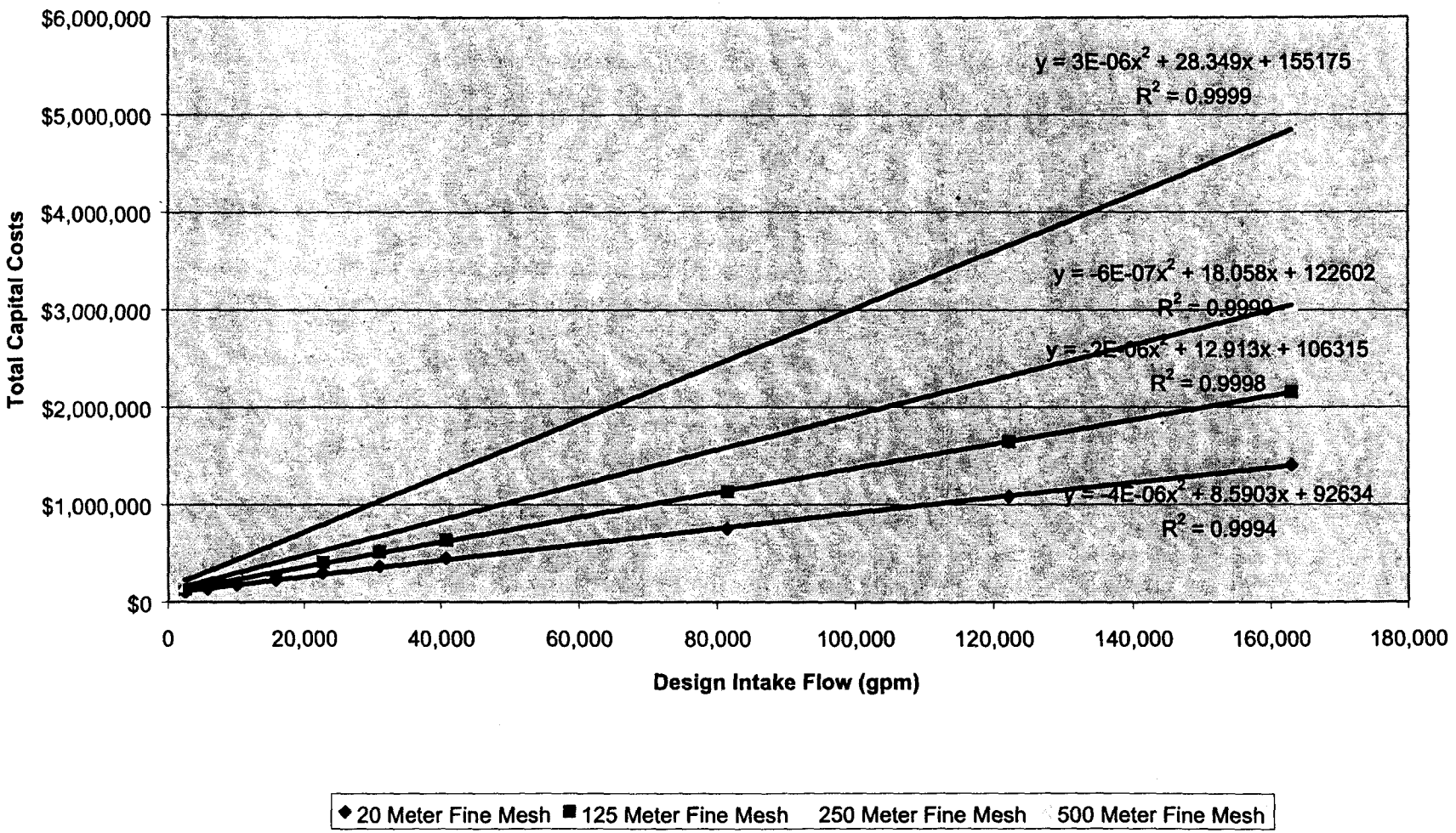


Figure 3-13. Capital Costs for Very Fine Mesh Passive Screen Existing Offshore in Freshwater at Selected Offshore Distances

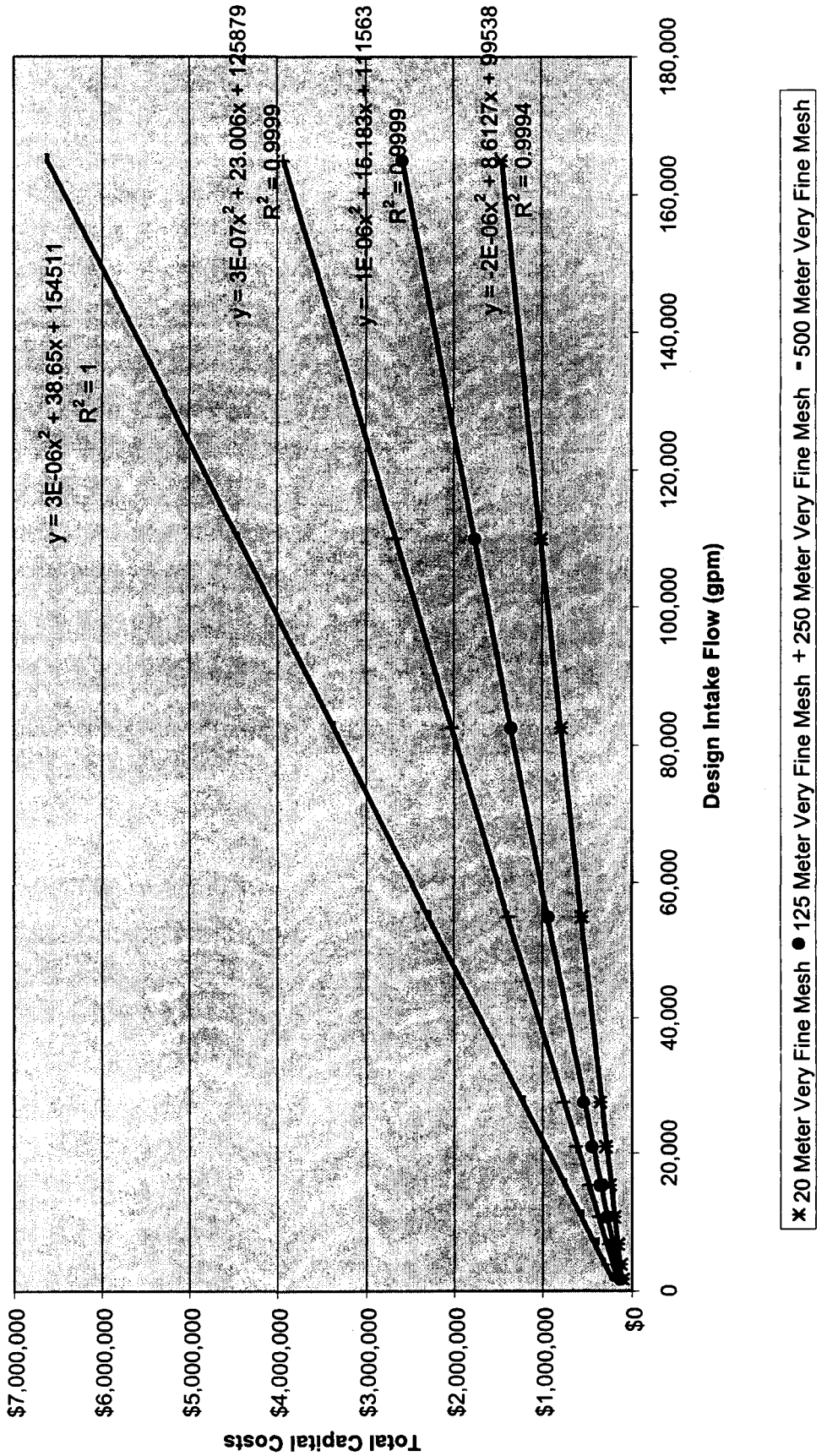


Figure 3-14. Capital Costs for Very Fine Mesh Passive Screen Existing Offshore in Saltwater at Selected Offshore Distances

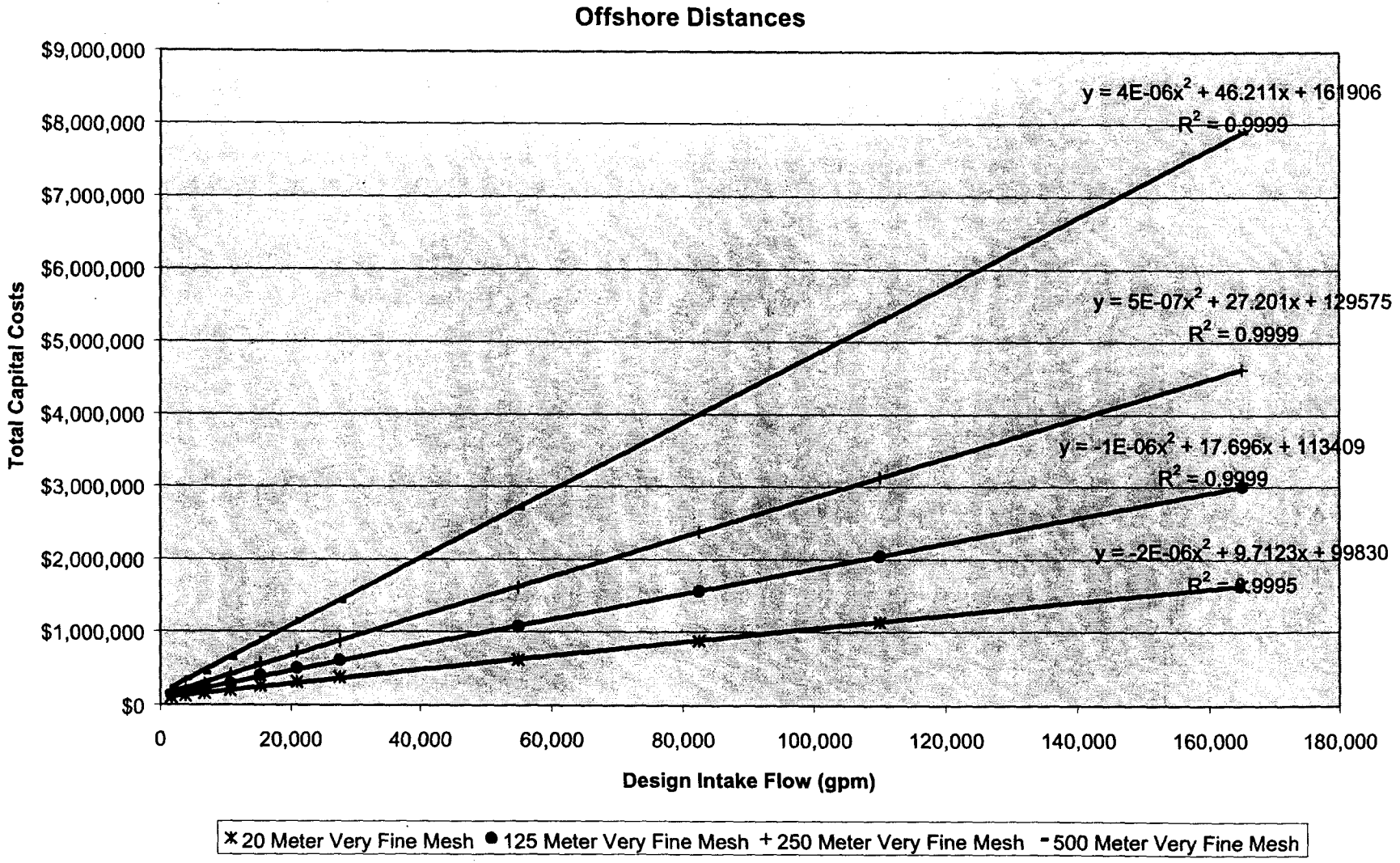
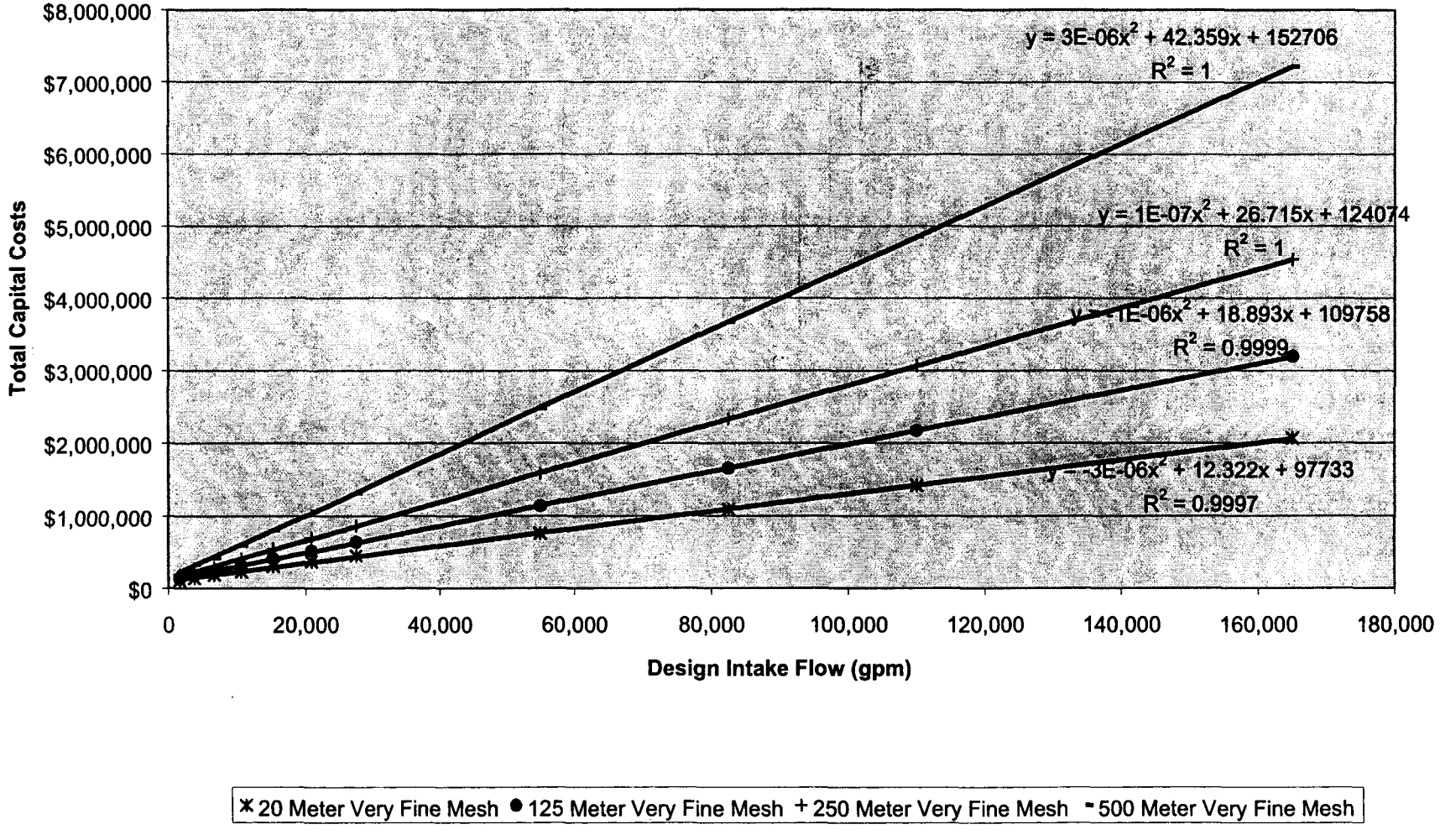


Figure 3-15. Capital Costs for Very Fine Mesh Passive Screen Existing Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances



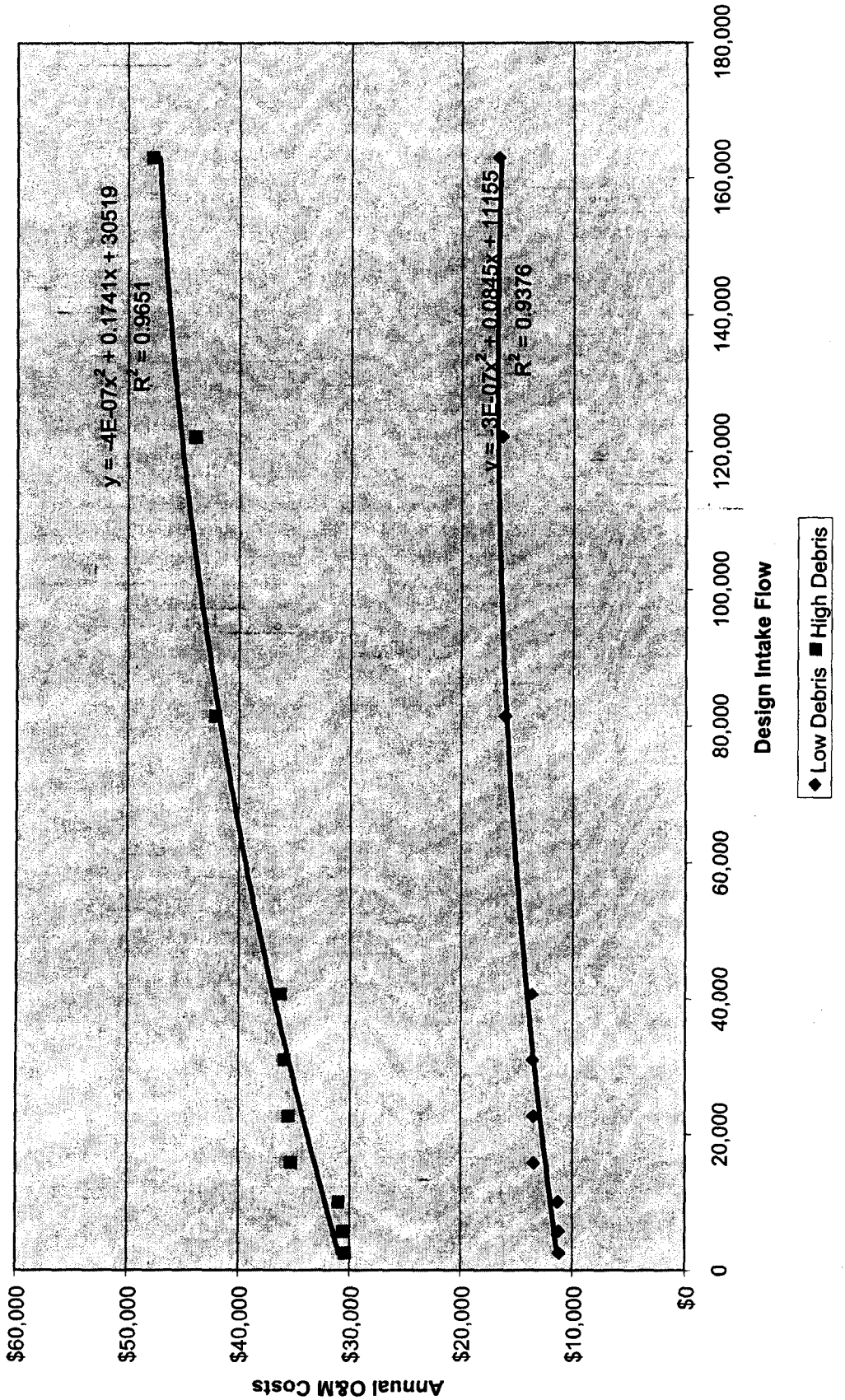


Figure 3-16. Total O&M Costs for Fine Mesh Passive Screen Existing Offshore with Airburst Backwash

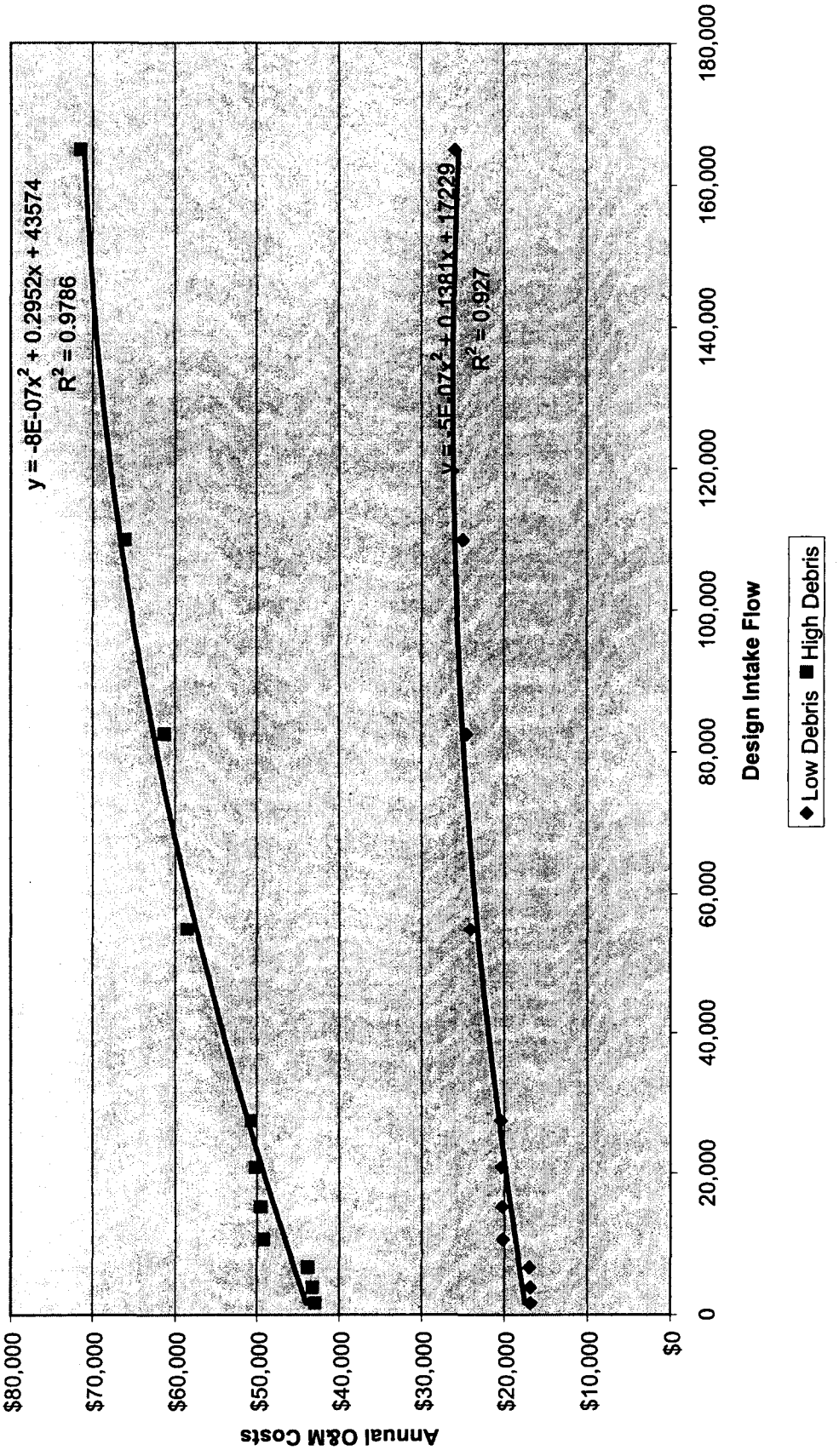


Figure 3-17. Total O&M Costs for Very Fine Mesh Passive Screen Existing Offshore with Airburst Backwash

2.0 IMPROVEMENTS TO EXISTING SHORELINE INTAKES WITH TRAVELING SCREENS

2.1 Replace Existing Traveling Screens with New Traveling Screen Equipment

The methodology described below is based on data, where available, from the Detailed Technical Questionnaires. Where certain facility data are unavailable (e.g., Short Technical Questionnaire facilities), the methodology generally uses statistical values (e.g., median values). The costs for traveling screen improvements described below are for installation in an existing or newly built intake structure. Where the existing intake is of insufficient design or size, construction costs for increasing the intake size are developed in a separate cost module and the cost for screen modification/installation at both the existing and/or new intake structure(s) are applied according to the estimated size of each.

Estimating Existing Intake Size

The capital cost of traveling screen equipment is highly dependent on the size and surface area of the screens employed. In developing compliance costs for existing facilities in Phase I, a single target, through-screen velocity was used. This decision ensured the overall screen area of the units being costed was a direct function of design flow. Thus, EPA could rely on a cost estimating methodology for traveling screens that focused primarily on design flow. In the Phase I approach, a single screen width was chosen for a given flow range. Variations in cost were generally based on differences in screen well depth. Where the flow exceeded the maximum flow for the largest screen costed, multiples of the largest (14 feet wide) screens were costed. Because, in this instance, EPA was applying it's cost methodology to hypothetical facilities, screen well depth could be left as a dependent variable. However, for existing facilities this approach is not tenable because existing screen velocities vary considerably between facilities. Because the size of the screens is very much dependent on design flow and screen velocity, a different approach -- one that first estimates the size of the existing screens -- is warranted.

Estimating Total Screen Width

Available data from the Detailed Questionnaires concerning the physical size of existing intake structures and screens are limited to vertical dimensions (e.g., water depth, distance of water surface to intake deck, and intake bottom to water surface). Screen width dimensions (parallel to shore) are not provided. For each model facility EPA has developed data concerning actual and estimated design flow. Through-screen velocity is available for most facilities--even those that completed only the Short Technical Questionnaire. Given the water depth, intake flow, and through screen velocity, the aggregate width of the intake screens can be estimated using the following equation:

Screen Width (Ft) = Design Flow (cfs) / (Screen Velocity (feet per second) x Water Depth (Ft) x Open Area (decimal %))

The variables "design Flow," "screen velocity," and "water depth" can be obtained from the database for most facilities that completed the Detailed Technical Questionnaire. These database values may not always correspond to the same waterbody conditions. For example, the screen velocity may correspond to low flow conditions while the water depth may represent average conditions. Thus, calculated screen widths may differ from actual values, but likely represents a reasonable estimate, especially given the limited available data. EPA considers the above equation to be a reasonable method for estimating the general size of the existing intake for cost estimation purposes. Determining the value for water depth at the intake, where no data is available, is described below.

The last variable in the screen width equation is the percent open area, which is not available in the database. However, the majority of the existing traveling screens are coarse mesh screens (particularly those requiring equipment upgrades). In most cases (at least for power plants), the typical mesh size is 3/8 inch (Petrovs 2002, Gathright 2002). This mesh size corresponds to an industry standard that states the mesh size should be half the diameter of the downstream heat exchanger tubes. These tubes are typically around 7/8 inch in diameter for power plant steam condensers. For a mesh size of 3/8 inch, the corresponding percent open area for a square mesh screen using 14 gauge wire is 68%. This combination was reported as "typical" for coarse mesh screens (Gathright 2002). Thus, EPA will use an assumed percent open area value of 68% in the above equation.

At facilities where the existing through-screen velocity has been determined to be too high for fine mesh traveling screens to perform properly, a target velocity of 1.0 feet per second was used in the above equation to estimate the screen width that would correspond to the larger size intake that would be needed.

Screen Well Depth

The costs for traveling screens are also a function of screen well depth, which is not the same as the water depth. The EPA cost estimates for selected screen widths have been derived for a range of screen well depths ranging from 10 feet to 100 feet. The screen well depth is the distance from the intake deck to the bottom of the screen well, and includes both water depth and distance from the water surface to the deck. For those facilities that reported "distance from intake bottom to water surface" and "distance from water surface to intake top," the sum of these two values can be used to determine actual screen well depth. For those Phase III facilities that did not report this data, statistical values such as the median were used. The median value of the ratio of the water depth to the screen well depth for all facilities that reported such data was 0.66. Thus, based on median reported values, the screen well depth can be estimated by assuming it is 1.5 times the water depth where only water depth is reported. For those Phase III facilities that reported water depth data, the median water depth at the intake was 18.0 feet.

Based on this discussion, screen well depth and intake water depth are estimated using the following hierarchy:

- If "distance from intake bottom to water surface" plus "distance from water surface to intake top" are reported, then the sum of these values are used for screen well depth
- If only the "distance from intake bottom to water surface" and/or the "depth of water at intake" are reported, one of these values (if both are known, the former selected is over the latter) is multiplied by a factor of 1.5
- If no depth data are reported, this factor is applied to the median water depth value of 18 feet (i.e., 27 feet) and this value is used.

This approach leaves open the question of which costing scenario well depth should be used where the calculated or estimated well depth does not correspond to the depths selected for cost estimates. EPA has selected a factor of 1.2 as the cutoff for using a shallower costing well depth. Exhibit 3-18 shows the range of estimated well depths that correspond to the specific well depths used for costing.

Exhibit 3-18. Guidance for Selecting Screen Well Depth for Cost Estimation

Calculated or Estimated Screen Well Depth (Ft)	Well Depth to be Costed
0-12 ft	10 ft
>12-30 ft	25 ft
>30-60 ft	50 ft
>60-90 ft	75 ft

Traveling Screen Replacement Options

Compliance action requirements developed for each facility may result in one of the following traveling screen improvement options:

- No Action.
- Add Fine Mesh Only (improves entrainment performance).
- Add Fish Handling Only (improves impingement performance).
- Add Fine Mesh and Fish Handling (improves entrainment and impingement performance).

Exhibit 3-19 shows potential combinations of existing screen technology and replacement technologies that are applied to these traveling screen improvement options. In each case, there are separate costs for freshwater and saltwater environments.

Areas highlighted in grey in Exhibit 3-19 indicate that the compliance scenario is not compatible with the existing technology combination. The table shows there are three possible technology combination scenarios that for a retrofit involving modifying the existing intake structure only,. Each scenario is described briefly below:

Scenario A - Add fine mesh only

This scenario involves simply purchasing a separate set of fine mesh screen overlay panels and installing them in front of the existing coarse mesh screens. This placement may be performed on a seasonal basis. This option is not considered applicable to existing screens without fish handling and return systems, since the addition of fine mesh will retain additional aquatic organisms that would require some means for returning them to the waterbody. Corresponding compliance O&M costs include seasonal placement and removal of fine mesh screen overlay panels.

Exhibit 3-19. Compliance Action Scenarios and Corresponding Cost Components

Compliance Action	Cost Component Included in EPA Cost Estimates	Existing Technology	
		Traveling Screens Without Fish Return	Traveling Screens With Fish Return
Add Fine Mesh Only (Scenario A)	New Screen Unit	NA	No
	Add Fine Mesh Screen Overlay	NA	Yes
	Fish Buckets	NA	No
	Add Spray Water Pumps	NA	No
	Add Fish Flume	NA	No
Add Fish Handling Only (Scenario B)	New Screen Unit[1]	Yes	NA
	Add Fine Mesh Screen Overlay[2]	No	NA
	Fish Buckets	Yes	NA
	Add Spray Water Pumps	Yes	NA
	Add Fish Flume	Yes	NA
Add Fine Mesh With Fish Handling (Scenario C and Dual-Flow Traveling Screens)	New Screen Unit	Yes	NA
	Add Fine Mesh Screen Overlay	Yes[3]	NA
	Fish Buckets	Yes	NA
	Add Spray Water Pumps	Yes	NA
	Add Fish Flume	Yes	NA

[1] Replace entire screen unit, includes one set of smooth top or fine mesh screen.
[2] Add fine mesh includes costs for a separate set of overlay fine mesh screen panels that can be placed in front of coarser mesh screens on a seasonal basis.
[3] Does not include initial installation labor for fine mesh overlays. Seasonal deployment and removal of fine mesh overlays is included in O&M costs.

Scenario B - Add fish handling and return

This scenario requires the replacement of all of the traveling screen units with new ones that include fish handling features, but no specific mesh requirements are included. Mesh size is assumed to be 1/8-inch by ½-inch smooth top. A less costly option would be to retain and retrofit portions of the existing screen units. However, vendors noted that approximately 75% of the existing screen components would require replacement and it would be more prudent to replace the entire screen unit (Gathright 2002, Petrovs 2002). Costs for additional spray water pumps and a fish return flume are included. Capital and O&M costs do not include any component for seasonal placement of fine mesh overlays.

Scenario C - Add fine mesh with fish handling and return

This scenario requires replacement of all screen units with units that include fish handling and return features plus additional spray water pumps and a fish return flume. Costs for a separate set of fine mesh screen overlay panels with seasonal placement are included.

Double Entry-Single Exit (Dual-Flow) Traveling Screens

The conditions for scenario C also apply to dual-flow traveling screens described separately below.

Fine Mesh Screen Overlay

Several facilities that have installed fine mesh screens found that during certain periods of the year the debris loading created operating problems. These problems prompted operators to remove fine mesh screens and replace them with coarser screens for the duration of the period of high and/or troublesome debris. As a high-side approach, when fine mesh screens replace coarse mesh screens (Scenarios A and C), EPA has decided to include costs for using two sets of screens (one coarser mesh screen such as 1/8-inch by 1/4-inch smooth top and one fine mesh overlay) with annual placement and removal of the fine mesh overlay. This placement of fine mesh overlay can occur for short periods when sensitive aquatic organisms are present or for longer periods being removed only during a the period when troublesome debris is present. Fine mesh screen overlays are also included in the costs for dual-flow traveling screens described separately below.

Mesh Type

In general three different types of mesh are considered here. One is the coarse mesh which is typical in older installations. Coarse mesh is considered to be the baseline mesh type and the typical mesh size is 3/8 inch square mesh. When screens are replaced, two types of mesh are considered. One is fine mesh, which is assumed to have openings in the 1 to 2 mm range. The other mesh type is the smooth top mesh. Smooth top mesh has smaller openings (at least in one dimension) than coarse mesh (e.g., 1/8-inch by ½-inch is a common size) and is manufactured in a way that reduces the roughness that is associated with coarse mesh. Smooth top mesh is used in conjunction with screens that have fish handling and return systems. The roughness of standard coarse mesh has been blamed for injuring (descaling) fish as they are washed over the screen surface when they pass from the fish bucket to the return trough during the fish wash step. Due to the tighter weave of fine mesh screens, roughness is not an issue when using fine mesh.

2.1.1 Traveling Screen Capital Costs

The capital cost of traveling screen equipment is generally based on the size of the screen well (width and depth), construction materials, type of screen baskets, and ancillary equipment requirements. While EPA has chosen to use the same mix of standard screen widths and screen well depths as were developed for the new facility Phase I effort, as described above, the corresponding water depth, design flow, and through-screen velocities in most cases differ. As presented in Exhibit 3-19, cost estimates do not need to include a compliance scenario where replacement screen units without fish handling and return equipment are installed. Unlike the cost methodology developed for Phase I, separate costs are developed in Phase III costing for equipment suitable for freshwater and saltwater environments. Costs for added spray water pumps and fish return flumes are described below, but unlike the screening equipment are generally a function of screen width only.

Screen Equipment Costs

EPA contacted traveling screen vendors to obtain updated costs for traveling screens with fine mesh screens and fish handling equipment for comparison to the 1999 costs developed for Phase I. Specifically, costs for single entry-single exit (through-flow) screens with the following attributes were requested:

-Spray systems
-Fish trough
-Housings and transitions
-Continuous operating features
-Drive unit
-Frame seals
-Engineering
-Freshwater versus saltwater environments.

Only one vendor provided comparable costs (Gathright 2002). The costs for freshwater environments were based on equipment constructed primarily of epoxy-coated carbon steel with stainless steel mesh and fasteners. Costs for saltwater and brackish water environments were based on equipment constructed primarily of 316 stainless steel with stainless steel mesh and fasteners.

EPA compared these newly obtained equipment costs to the costs for similar freshwater equipment developed for Phase I, adjusted for inflation to July 2002 dollars. EPA found that the newly obtained equipment costs were lower by 10% to 30%. In addition, a comparison of the newly obtained costs for brackish water and freshwater screens showed that the costs for saltwater equipment were roughly 2.0 times the costs for freshwater equipment. This factor of approximately 2.0 was also suggested by a separate vendor (Petrovs 2002). Rather than adjust the Phase I equipment costs downward, EPA chose to conclude that the Phase I freshwater equipment costs adjusted to 2002 were valid (if not somewhat overestimated), and that a factor of 2.0 would be reasonable for estimating the cost of comparable saltwater/brackish water equipment. Exhibits 3-20 and 3-21 present the Phase I equipment costs, adjusted for inflation to July 2002 dollars, for freshwater and saltwater environments respectively.

Exhibit 3-20. Equipment Costs for Traveling Screens with Fish Handling for Freshwater Environments, 2002 Dollars

Well Depth	Basket Screening Panel Width (Ft)			
(Ft)	2	5	10	14
10	$69,200	$80,100	$102,500	$147,700
25	$88,600	$106,300	$145,000	$233,800
50	$133,500	$166,200	$237,600	$348,300
75	$178,500	$228,900	$308,500	$451,800
100	$245,300	$291,600	$379,300	$549,900

Exhibit 3-21. Equipment Costs for Traveling Screens with Fish Handling for Saltwater Environments, 2002 Dollars

Well Depth	Basket Screening Panel Width (Ft)			
(Ft)	2	5	10	14
10	$138,400	$160,200	$205,000	$295,400
25	$177,200	$212,600	$290,000	$467,600
50	$267,000	$332,400	$475,200	$696,600
75	$357,000	$457,800	$617,000	$903,600
100	$490,600	$583,200	$758,600	$1,099,800

Costs for fine mesh screen overlay panels were cited as approximately 8% to 10% of the total screen unit costs (Gathright 2002). The EPA cost estimates for fine mesh overlay screen panels are based on a 10% factor applied to the screen equipment costs shown in Exhibit 3-20 and 3-21. Note that if the entire screen basket required replacement, then the costs would increase to about 25% to 30% of the screen unit costs (Gathright 2002, Petrovs 2002). However, in the scenarios considered here, basket replacement would occur only when fish handling is being added. In those scenarios, EPA has chosen to assume that the entire screen unit will require replacement. The cost of new traveling screen units with smooth top mesh is only about 2% above that for fine mesh (Gathright 2002). EPA has concluded that the cost for traveling screen units with smooth top mesh is nearly indistinguishable from that for fine mesh. Therefore, EPA has not developed separate costs for each.

Screen Unit Installation Costs

Vendors indicated that the majority of intakes have stop gates or stop log channels that enable the isolation and dewatering of the screen wells. Thus, EPA assumes, in most cases, screens can be replaced and installed in dewatered screen wells without the use of divers. When asked whether most screens were accessible by crane, a vendor did note that about 70% to 75% may have problems accessing the intake screens by crane from overhead. In such cases, the screens are dismantled (screen panels are removed, chains are removed and screen structure is removed in sections that key into each other). Such overhead access problems may be due to structural cover or buildings, and access is often through the side wall. According to one vendor, this screen dismantling requirement may add 30% to the installation costs. For those installations that do not need to dismantle screens, these costs typically are $15,000 to $30,000 per unit (Petrovs 2002). Another vendor cited screen installation costs as +/- $45,000 per screen giving an example of $20,000 for a 15-foot screen plus the costs of a crane and forklift ($15,000 - $20,000 divided between screens) (Gathright 2002). Note that these installation costs are for the typical range of screen sizes; vendors noted that screens in the range of the 100-foot well depth are rarely encountered.

Exhibit 3-22 presents the installation costs developed from vendor supplied data. These costs include crane and forklift costs and are presented on a per screen basis. Phase I installation costs included an intake construction component not included in Phase III costs. The costs shown here assume the intake structure and screen wells are already in-place. Therefore, installation involves removing existing screens and installing new screens in their place. Any costs for increasing the intake size are developed as a separate module. Vendors indicated costs for disposing of the existing screens were minimal. The cost of removal and disposal of old screens, therefore, are assumed to be included in the Exhibit 3-22 estimates.

Exhibit 3-22. Traveling Screen Installation Costs

Well Depth	Basket Screening Panel Width (Ft)			
(Ft)	2	5	10	14
10	$15,000	$18,000	$21,000	$25,000
25	$22,500	$27,000	$31,500	$37,000
50	$30,000	$36,000	$42,000	$50,000
75	$37,500	$45,000	$52,500	$62,500
100	$45,000	$54,000	$63,000	$75,000

Installation of Fine Mesh Screen Panel Overlays

Screen panel overlay installation and removal costs are based on an estimate of the amount of labor required to replace each screen panel. Vendors provided the following estimates for labor to replace screen baskets and panels (Petrovs 2002, Gathright 2002):

- 1.0 hours per screen panel overlay (1.5 hours to replace baskets and panel)
- Requires two-man team for small screen widths (assumed to be 2- and 5-foot wide screens)
- Requires three-man team for large screen widths (assumed to be 10- and 14-foot wide screens)
- Number of screen panels is based on 2-foot tall screen panels on front and back extending 6 feet above the deck. Thus, a screen for a 25-foot screen well is estimated to have 28 panels.

Labor costs are based on a composite labor rate of $41.10/hr (See O&M cost section).

These assumptions apply to installation costs for Scenario A. These same assumptions also apply to O&M costs for fine mesh screen overlay in Scenarios A and C, where it is applied twice for seasonal placement and removal.

Indirect Costs Associated with Replacement of Traveling Screens

EPA noted that equipment costs (Exhibits 3-20 and 3-21) included the engineering component and that installation costs (Exhibit 3-22) included costs for contractor overhead and profit. Because the new screens are designed to fit the existing screen well channels and the existing structure is of a known design, contingency and allowance costs should be minimal. Also, no costs for sitework were included because existing intakes, in most cases, should already have provisions for equipment access. Because inflation-adjusted equipment costs exceeded the recently obtained equipment vendor quotation by 10% to 30%, EPA has concluded any indirect costs are already included in the equipment cost component.

Combining Per Screen Costs with Total Screen Width

As noted above, total screen costs are estimated using a calculated screen width as the independent variable. In many cases, this calculated width will involve using more than one screen, particularly if the width is greater than 10 to 14 feet. Vendors have indicated there is a general preference for using 10-foot wide screens over 14-foot screens, but that 14-foot screens are more economical (reducing civil structure costs) for larger installations. The screen widths and corresponding number and screens used to plot screen cost data and develop cost equations are as follows:

2 ft	=	a single	2-ft screen
5 ft	=	a single	5-ft screen
10 ft	=	a single	10-ft screen

20 ft	=	two	10-ft screens
30 ft	=	three	10-ft screens
40 ft	=	four	10-ft screens
50 ft	=	five	10-ft screens
60 ft	=	six	10-ft screens
70 ft	=	five	14-ft screens
84 ft	=	six	14-ft screens
98 ft	=	seven	14-ft screens
112 ft	=	eight	14-ft screens
126 ft	=	nine	14-ft screens
140 ft	=	ten	14-ft screens.

Any widths greater than 140 feet are divided and the costs for the divisions are summed.

Ancillary Equipment Costs for Fish Handling and Return System

When adding a screen with a fish handling and return system where no fish handling system existed before, there are additional requirements for spray water and a fish return flume. The equipment and installation costs for the fish troughs directly adjacent to the screen and spray system are included in the screen unit and installation costs. However, the costs for pumping additional water for the new fish spray nozzles and the costs for the fish return flume from the end of the intake structure to the discharge point are not included. Fish spray and flume volume requirements are based solely on screen width and are independent of depth.

Pumps for Spray Water

Wash water requirements for the debris wash and fish spray were obtained from several sources. Where possible, the water volume was divided by the total effective screen width to obtain the unit flow requirements (gpm/ft). Total unit flow requirements for both debris wash and fish spray combined ranged from 26.7 gpm/ft to 74.5 gpm/ft. The only data with a breakdown between the two uses reported a flow of 17.4 gpm/ft for debris removal and 20.2 gpm/ft for fish spray, with a total of 37.5 gpm/ft (Petrovs 2002). Based on these data, EPA assumed a total of 60 gpm/ft with each component being equal at 30 gpm/ft. These values are near the high end of the ranges reported and were selected to account for additional water needed at the upstream end of the fish trough to maintain a minimum depth.

Because the existing screens already have pumps to provide the necessary debris spray flow, only the costs for pumps sized to deliver the added fish spray are included in the capital cost totals. Costs for the added fish spray pumps are based on the installed equipment cost estimates developed for Phase I, adjusted to July 2002 dollars. These costs already include an engineering component. An additional 10% was added for contingency and allowance. Also, 20% was added to theses costs to account for any necessary modifications to the existing intake (based on BPJ). Exhibit 3-23 presents the costs for adding pumps for the added fish spray volume.

The costs in Exhibit 3-23 were plotted and a best-fit, second-order equation derived from the data. Pump costs were then projected from this equation for the total screen widths described earlier.

Exhibit 3-23. Fish Spray Pump Equipment and Installation Costs

Centrifugal Pump Flow (gpm)	Costs for Centrifugal Pumps - Installed (1999 Dollars)	Pump Costs Adjusted to July 2002	Retrofit Cost & Indirect Costs	Total Installed Cost
10	$800	$872	$262	$1,134
50	$2,250	$2,453	$736	$3,189
75	$2,500	$2,725	$818	$3,543
100	$2,800	$3,052	$916	$3,968
500	$3,700	$4,033	$1,210	$5,243
1,000	$4,400	$4,796	$1,439	$6,235
2,000	$9,000	$9,810	$2,943	$12,753
4,000	$18,000	$19,620	$5,886	$25,506

Fish Return Flume

In the case of the fish return flume, the total volume of water to be carried was assumed to include both the fish spray water and the debris wash water. A total unit flow of 60 gpm/ft screen width was assumed as a conservative value for estimating the volume to be conveyed. Return flumes may take the form of open troughs or closed pipe and are often constructed of reinforced fiberglass (Gathright 2002, Petrovs 2002). The pipe diameter is based on an assumed velocity of 1.5 feet per second, which is at the low end of the range of pipe flow velocities. Higher velocities will result in smaller pipes. Actual velocities may be much higher in order to ensure fish are transported out of the pipe. With lower velocities fish can continually swim upstream. Vendors have noted that the pipes do not tend to flow full, so basing the cost on a larger pipe sized on the basis of a low velocity is a reasonable approach.

Observed flume return lengths varied considerably. In some cases, where the intake is on a tidal waterbody, two return flumes may be used alternately to maintain the discharge in the downstream direction of the receiving water flow. A traveling screen vendor suggested lengths of 75 to 150 feet (Gathright 2002). EPA reviewed facility description data and found example flume lengths ranging from 30 ft to 300 ft for intakes without canals, and up to several thousand feet for those with canals. For the compliance scenario typical flume length, EPA chose the upper end of the range of examples for facilities without intake canals (300 ft). For those intakes located at the end of a canal, the cost for the added flume length to get to the waterway (assumed equal to canal length) is estimated by multiplying an additional unit cost-per-ft times the canal length. This added length cost is added to the non-canal facility total cost.

To simplify the cost estimation approach, a unit pipe/support structure cost ($/inch-diameter/ft-length) was developed based on the unit cost of a 12-inch reinforced fiberglass pipe at $70/ft installed (RS Means 2001) and the use of wood pilings at 10-foot intervals as the support structure. Piling costs assume that the average piling length is 15 feet and unit cost for installed pilings is $15.80/ft (RS Means 2001). The unit costs already include the indirect costs for contractor overhead and profit. Additional costs include 10% for engineering, 10% for contingency and allowance, and 10% for sitework. Sitework costs are intended to cover preparation and restoration of the work area adjacent to the flume. Based on these cost applied to an assumed 300-foot flume, a unit cost of $10.15/in diameter/ft was derived. Flume costs for the specific total screen widths were then derived based on a calculated flume diameter (using the assumed flow volume of 60 gpm/ft, the 1.5-feet per second velocity when full) times the unit cost and the length.

EPA was initially concerned whether there would be enough vertical head available to provide the needed gradient, particularly for the longer applications. In a typical application, the upstream end of the flume is located above the intake deck and the water flows down the flume to the water surface below. A vendor cited a minimum gradient requirement in the range of 0.001 to 0.005 ft drop/ft length. For a 300-foot pipe, the needed vertical head based on these gradients is only 0.3 feet to 1.5 feet. The longest example fish return length identified by EPA was 4,600 feet at the Brunswick, SC plant. The head needed for that return, based on the above minimum gradient range, is 4.6 feet to 23 feet. Based on median values from the industry questionnaire data base, intake decks are often about half the intake water depth above the water surface, EPA has concluded in most cases there was more than enough gradient available. Indeed, the data suggest if the return length is too short, there may be a potential problem from too great a gradient producing velocities that could injure fish.

Exhibit 3-24 presents the added spray water pumps costs, 300-foot flume costs and the unit cost for additional flume length above 300 feet. Note that a feasibility study for the Drayton Point power plant cited an estimated flume unit cost of $100/ft which does not include indirect costs but is still well below comparable costs shown in Exhibit 3-24.

Exhibit 3-24. Spray Pump and Flume Costs

Total Screen Width (ft)	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Fish Spray Flow at 30 gpm/ft (gpm)	60	150	300	600	900	1200	1500	1800	2100	2520	2940	3360	3780	4200
Pump Costs	$3,400	$3,900	$4,400	$5,500	$6,700	$8,100	$9,500	$11,100	$12,800	$15,300	$18,000	$21,000	$24,100	$27,500
Total Wash Flow at 60 gpm/ft (gpm)	120	300	600	1200	1800	2400	3000	3600	4200	5040	5880	6720	7560	8400
Pipe Dia at 1.5 fps (In)	6.0	8.0	12.0	16.0	20.0	23.0	25.0	28.0	30.0	33.0	35.0	38.0	40.0	42.0
Flume Costs at $10.15	$18,272	$24,362	$36,543	$48,724	$60,905	$70,041	$76,131	$85,267	$91,358	$100,493	$106,584	$115,720	$121,810	$127,901
Flume Cost per Ft Added	$61	$81	$122	$162	$203	$233	$254	$284	$305	$335	$355	$386	$406	$426

Total Capital Costs

Indirect costs such as engineering, contractor overhead and profit, and contingency and allowance have been included in the individual component costs as they apply. Exhibit 3-25 through 3-30 (at the end of this section) present the total capital costs for compliance scenarios A, B, and C for both freshwater and saltwater environments. These costs are then plotted in Figures 3-18 through 3-23, which also include the best-fit, second-order equations of the data. These equations are used in the estimation of capital costs for the various technology applications.

2.1.2 Downtime Requirements

Placement of the fine screen overlay panels (Scenario A & C) can be done while the screen is operating. The screens are stopped during the placement and, between the placement of each panel, the screen rotated once. Installation of the ancillary equipment for the fish return system can be performed prior to screen replacement. Only the step of replacing the screen units would require shutdown of that portion of the intake. Vendors have reported that it would take from one to three days to replace traveling screen units where fish troughs and new spray piping are needed. The total should be no more than two weeks for multiple screens (Gathright 2002). If necessary, facilities with multiple screens and pumps could operate at the reduced capacity associated with taking a single pump out of service. However, it would be more prudent to schedule the screen replacement during a scheduled maintenance shutdown which typically occurs on an annual basis. Even at the largest installations with numerous screens, there should be sufficient time during the scheduled maintenance period to replace the screens and install controls and piping. Therefore, EPA is not including any monetary consideration for unit downtime associated with screen replacement or installation. Downtime for modification or addition to the intake structure to increase its size are discussed in a separate cost module.

Nuclear Facilities

Costs for nuclear facilities are not presented here. However, these costs were estimated applying a 1.8 cost factor to the applicable non-nuclear facility costs (see passive screen module for discussion).

2.1.3 O&M Cost Development

In general, O&M costs for intake system retrofit involve calculating the net difference between the existing system O&M costs and the new system O&M costs. The Phase I O&M cost estimates for traveling screens were generally derived as a percentage of the capital costs. This approach, however, does not lend itself well to estimating differences in operating costs for retrofits that involve similar equipment but have different operating and maintenance requirements such as changes in the duration of the screen operation. Therefore, a more detailed approach was developed.

The O&M costs developed here include only those components associated with traveling screens. Because cooling water flow rates are assumed not to change as a result of the retrofit, the O&M costs associated with the intake pumps are not considered. For traveling screens, the O&M costs are broken down into three components: labor, power requirements, and parts replacement. The basis and assumptions for each are described below.

Labor Requirements

The basis for estimating the total annual labor cost is based on labor hours as described below. In each baseline and compliance scenario the estimated number of hours is multiplied times a single hourly rate of $41.10/hour. This rate was derived by first estimating the hourly rate for a manager and a technician. The estimated management and technician rates were based on Bureau of Labor Statistics hourly rates for management and electrical equipment technicians. These rates were multiplied by factors that estimate the additional costs of other compensation (e.g., benefits) to yield estimates of the total labor costs to the employer. These rates were adjusted for inflation to represent June 2002 dollars (see Doley 2002 for details). The two labor category rates were combined into one compound rate using the assumption that 90% of the hours applied to the technicians and 10% to management. A 10% management component was considered as reasonable because the majority of the work involves physical labor, with managers providing oversight and coordination with the operation of the generating units.

A vendor provided general guidelines for estimating basic labor requirements for traveling screens as averaging 200 hours and ranging from 100 to 300 hours per year per screen for coarse mesh screens without fish handling and double that for fine mesh screens with fish handling (Gathright 2002). The lower end of the range corresponds to shallow narrow screens and the high end of the range corresponds to the widest deepest screens. Exhibits 3-31 and 3-32 present the estimated annual number of labor hours required to operate and maintain a "typical" traveling screen.

Exhibit 3-31. Basic Annual O&M Labor Hours for Coarse Mesh Traveling Screens Without Fish Handling

Well Depth	Basket Screening Panel Width			
feet	2	5	10	14
10	100	150	175	200
25	120	175	200	225
50	130	200	225	250
75	140	225	250	275
100	150	250	275	300

Exhibit 3-32. Basic Annual O&M Labor Hours for Traveling Screens With Fish Handling

Well Depth	Basket Screening Panel Width (Ft)			
feet	2	5	10	14
10	78	78	117	117
25	168	168	252	252
50	318	318	477	477
75	468	468	702	702
100	618	618	927	927

When fine mesh screens are added as part of a compliance option, they are included as a screen overlay. EPA has assumed when sensitive aquatic organisms are present these fine mesh screens will be in place. EPA also assumes during times when levels of troublesome debris are present the facility will remove the fine mesh screen panels leaving the coarse mesh screen panels in place. The labor assumptions for replacing the screen panels are described earlier, but in this application the placement and removal steps occur once each per year. Exhibit 3-33 presents the estimated annual labor hours for placement and removal of the fine mesh overlay screens.

Exhibit 3-33. Total Annual O&M Hours for Fine Mesh Overlay Screen Placement and Removal

Well Depth	Basket Screening Panel Width			
feet	2	5	10	14
10	78	78	117	117
25	168	168	252	252
50	318	318	477	477
75	468	468	702	702
100	618	618	927	927

Operating Power Requirement

Power is needed to operate the mechanical equipment, specifically the motor drives for the traveling screens and the pumps that deliver the spray water for both the debris wash and the fish spray.

Screen Drive Motor Power Requirement

Coarse mesh traveling screens without fish handling are typically operated on an intermittent basis. When debris loading is low the screens may be operated several times per day for relatively short durations. Traveling screens with fish handling and return systems, however, must operate continuously if the fish return system is to function properly.

A vendor provided typical values for the horsepower rating for the drive motors for traveling screens which are shown in Exhibit 3-34. These values were assumed to be similar for all of the traveling screen combinations considered here. Different operating hours are assumed for screens with and without fish handling. This is due to the fact that screens with fish handling must be operated continuously. A vendor estimated that coarse mesh screens without fish handling are typically operated for a total of 4 to 6 hrs/day (Gathright 2002). The following assumptions apply:

- The system will be shut down for four weeks out of the year for routine maintenance
- For fine mesh, operating hours will be continuous (24 hrs/day)
- For coarse mesh, operating hours will be an average of 5 hours/day (range of 4 to 6)
- Electric motor efficiency of 90%
- Power cost of $0.04/kWh for power plants.

Wash Water and Fish Spray Pump Power Requirement

As noted previously, spray water is needed for both washing debris off of the screens (which occurs at all traveling screens) and for a fish spray (which is needed for screens with fish handling and return systems). The nozzle pressure for the debris spray can range from 80 to 120 psi. A value of 120 psi was chosen as a high value which would include any static pressure component. The following assumptions apply:

- Spray water pumps operate for the same duration as the traveling screen drive motors
- Debris wash requires 30 gpm/ft screen length
- Fish spray requires 30 gpm/ft screen length
- Pumping pressure is 120 psi (277 ft of water) for both
- Combined pump and motor efficiency is 70%
- Electricity cost is $0.04/KWh for power plants.

The pressure needed for fish spray is considerably less than that required for debris, but it is assumed that all wash water is pumped to the higher pressure and regulators are used to step down the pressure for the fish wash. Exhibits 3-35 and 3-36 present the power costs for the spray water for traveling screens without and with fish handling, respectively. Spray water requirements depend on the presence of a fish return system but are assumed to otherwise be the same regardless of the screen mesh size.

Exhibit 3-34. Screen Drive Motor Power Costs

				Power Costs - Fine Mesh			Power Costs - Coarse Mesh		
Screen Width	Well Depth	Motor Power	Electric Power	Operating Hours	Annual Power	Annual Power Costs at $/Kwh of	Operating Hours	Annual Power	Annual Power Costs at $/Kwh of
Ft	Ft	Hp	Kw		Kwh	$0.04		Kwh	$0.04
2	10	0.5	0.414	8,064	3,342	$134	1,680	696	$28
2	25	1	0.829	8,064	6,684	$267	1,680	1,393	$56
2	50	2.7	2.210	8,064	17,824	$713	1,680	3,713	$149
2	75	5	4.144	8,064	33,421	$1,337	1,680	6,963	$279
2	100	6.7	5.512	8,064	44,450	$1,778	1,680	9,260	$370
5	10	0.75	0.622	8,064	5,013	$201	1,680	1,044	$42
5	25	1.5	1.243	8,064	10,026	$401	1,680	2,089	$84
5	50	4	3.316	8,064	26,737	$1,069	1,680	5,570	$223
5	75	7.5	6.217	8,064	50,131	$2,005	1,680	10,444	$418
5	100	10.0	8.268	8,064	66,674	$2,667	1,680	13,891	$556
10	10	1	0.829	8,064	6,684	$267	1,680	1,393	$56
10	25	3.5	2.901	8,064	23,395	$936	1,680	4,874	$195
10	50	10	8.289	8,064	66,842	$2,674	1,680	13,925	$557
10	75	15	12.433	8,064	100,262	$4,010	1,680	20,888	$836
10	100	20.0	16.536	8,064	133,349	$5,334	1,680	27,781	$1,111
14	10	2	1.658	8,064	13,368	$535	1,680	2,785	$111
14	25	6.25	5.181	8,064	41,776	$1,671	1,680	8,703	$348
14	50	15	12.433	8,064	100,262	$4,010	1,680	20,888	$836
14	75	20	16.578	8,064	133,683	$5,347	1,680	27,851	$1,114
14	75	26.6	22.048	8,064	177,799	$7,112	1,680	37,041	$1,482

Exhibit 3-35. Wash Water Power Costs Traveling Screens Without Fish Handling

						Fine Mesh			Coarse Mesh		
Screen Width	Flow Rate	Total Head	Hydraulic-Hp	Brake-Hp	Power Requirement	Annual Hours	Annual Power	Total Costs at $/Kwh of	Annual Hours	Annual Power	Total Costs at $/Kwh of
ft	gpm	ft	Hp	Hp	Kw	hr	Kwh	$0.04	hr	Kwh	$0.04
2	60	277	4.20	6.0	4.5	8064	36,072	$1,443	1680	7,515	$301
5	150	277	10.49	15.0	11.2	8064	90,179	$3,607	1680	18787	$751
10	300	277.1	20.98	30.0	22.4	8064	180,359	$7,214	1680	37575	$1,503
14	420	277	29.37	42.0	31.3	8064	252,502	$10,100	1680	52605	$2,104

Exhibit 3-36. Wash Water and Fish Spray Power Costs Traveling Screens With Fish Handling

						Fine Mesh			Coarse Mesh		
Screen Width	Flow Rate	Total Head	Hydraulic-Hp	Brake-Hp	Power Requirement	Annual Hours	Annual Power	Total Costs at $/Kwh of	Annual Hours	Annual Power	Total Costs at $/Kwh of
ft	gpm	ft	Hp	Hp	Kw	hr	Kwh	$0.04	hr	Kwh	$0.04
2	120	277	8.39	12.0	8.9	8064	72,143	$2,886	1680	15,030	$601
5	300	277	20.98	30.0	22.4	8064	180,359	$7,214	1680	37575	$1,503
10	600	277	41.97	60.0	44.7	8064	360,717	$14,429	1680	75149	$3,006
14	840	277	58.76	83.9	62.6	8064	505,004	$20,200	1680	105209	$4,208

Parts Replacement

A vendor estimated that the cost of parts replacement for coarse mesh traveling screens without fish handling would be approximately 15% of the equipment costs every 5 years (Gathright 2002). For traveling screens with fish handling, the same 15% would be replaced every 2.5 years. EPA has assumed for all screens that the annual parts replacement costs would be 6% of the equipment costs for those operating continuously and 3% for those operating intermittently. These factors are applied to the equipment costs in Exhibits 3-20 and 3-21. Traveling screens without fish handling (coarse mesh) operate fewer hours (estimated at 5 hrs/day) and should therefore experience less wear on the equipment. While the time of operation is nearly five times longer for continuous operation, the screen speed used is generally lower for continuous operation. Therefore, the wear and tear, hence O&M costs, are not directly proportional.

Baseline and Compliance O&M Scenarios

Exhibit 3-37 presents the six baseline and compliance O&M scenario cost combinations developed by EPA.

For the few baseline operations with fine mesh, nearly all had fish returns and or low screen velocities, indicating that such facilities will likely not require compliance action. Thus, there is no baseline cost scenario for traveling screens with fine mesh without fish handling and return. Exhibits 3-38 through 3-43 (at the end of this section) present the O&M costs for the cost scenarios shown in Exhibit 3-37. Figures 3-24 through 3-29 present the graphic plots of the O&M costs shown in these tables with best-fit, second-order equations of the plots. These equations are used in the estimation of O&M costs for the various technology applications.

Exhibit 3-37. Mix of O&M Cost Components for Various Scenarios

	Baseline Without Fish Handling	Baseline Without Fish Handling	Baseline with Fish Handling & Scenario B Compliance	Baseline with Fish Handling & Scenario B Compliance	Scenario A & C Compliance	Scenario A & C Compliance
Mesh Type	Coarse	Coarse	Coarse or Smooth Top	Coarse or Smooth Top	Smooth Top & Fine	Smooth Top & Fine
Fish Handling	None	None	Yes	Yes	Yes	Yes
Water Type	Freshwater	Saltwater	Freshwater	Saltwater	Freshwater	Saltwater
Screen Operation	5 hrs/day	5 hrs/day	Continuous	Continuous	Continuous	Continuous
Basic Labor	100-300 hrs	100-300 hrs	200-600 hrs	200-600 hrs	200-600 hrs	200-600 hrs
Screen Overlay Labor	None	None	None	None	Yes	Yes
Screen Motor Power	5 hrs/day	5 hrs/day	Continuous	Continuous	Continuous	Continuous
Debris Spray Pump Power	5 hrs/day	5 hrs/day	Continuous	Continuous	Continuous	Continuous
Fish Spray Pump Power	None	None	Continuous	Continuous	Continuous	Continuous
Parts Replacement - % Equipment Costs	3%	3%	6%	6%	6%	6%

O&M for Nuclear Facilities

Unlike the assumption for capital costs, the O&M costs for nuclear facilities consider the differences in the component costs. The power cost component is assumed to be the same. The equipment replacement cost component uses the same annual percentage of equipment cost factors, but is increased by the same factor as the capital costs (2.0). A Bureau of Labor Statistics document (BLS 2002) reported that the median annual earnings of a nuclear plant operator were $57,220 in 2002 compared to $46,090 for power plant operators in general. Thus, nuclear operators earnings were 24% higher than the industry average. No comparable data were available for maintenance personnel. This factor of 24% is used for estimating the increase in labor costs for nuclear facilities. This factor may

be an overestimation: nuclear plant operators require a proportionally greater amount of training and the consequences of their actions engender greater overall risks than the intake maintenance personnel. EPA recalculated the O&M costs using the revised equipment replacement and labor costs. EPA found that the ratio of non-nuclear to nuclear O&M costs did not vary much for each scenario and water depth. Therefore, EPA chose to use the factor derived from the average ratio (across total width values) of estimated nuclear facility O&M to non-nuclear facility O&M for each scenario and well depth to estimate the nuclear facility O&M costs. Exhibit 3-44 presents the cost factors to be used to estimate nuclear facility O&M costs for each cost scenario and well depth using the non-nuclear O&M values as the basis.

Exhibit 3-44. Nuclear Facility O&M Cost Factors

Well Depth	Baseline O&M Traveling Screens Without Fish Handling	Baseline O&M Traveling Screens Without Fish Handling	Baseline & Scenario B Compliance O&M Traveling Screens With Fish Handling	Baseline & Scenario B Compliance O&M Traveling Screens With Fish Handling	Scenario A & C Compliance O&M Traveling Screens With Fish Handling	Scenario A & C Compliance O&M Traveling Screens With Fish Handling
Ft	Freshwater	Saltwater	Freshwater	Saltwater	Freshwater	Saltwater
10	1.32	1.41	1.29	1.40	1.28	1.39
25	1.35	1.46	1.33	1.46	1.32	1.44
50	1.39	1.51	1.39	1.53	1.36	1.49
75	1.41	1.53	1.43	1.57	1.38	1.51
100	1.42	1.55	1.45	1.60	1.40	1.53

2.1.4 Double Entry-Single Exit (Dual-flow) Traveling Screens

Another option for replacing coarse mesh single entry-single exit (through-flow) traveling screens is to install double entry-single exit (dual-flow) traveling screens. Such screens are designed and installed to filter water continuously, using both upward and downward moving parts of the screen. The interior space between the upward and downward moving screen panels is closed off on one side (oriented in the upstream direction), while screened water exits towards the pump well through the open end on the other side.

One major advantage of dual-flow screens is that the direction of flow through the screen does not reverse as it does on the back side of a through-flow screen. As such, there is no opportunity for debris stuck on the screen to dislodge on the downstream side. In through-flow screens, debris that fails to dislodge as it passes the spray wash can become dislodged on the downstream side (essentially bypassing the screen). Such debris continues downstream where it can plug condenser tubes or require more frequent cleaning of fixed screens set downstream of the intake screen to prevent condenser tube plugging. Such maintenance typically requires the shut down of the generating units. Since dual-flow screens eliminate the opportunity for debris carryover, the spray water pressure requirements are reduced with dual-flow screens requiring a wash water spray pressure of 30 psi compared to 80 to 120 psi for through-flow screens (Gathright 2002). Dual-flow screens are oriented such that the screen face is parallel to the direction of flow. By extending the screen width forward (perpendicular to the flow) to a size greater than one half the screen well width, the total screen surface area of a dual-flow screen can exceed that of a through-flow screen in the same application. Therefore, if high through-screen velocities are affecting the survival of impinged organisms in existing through-flow screens, the retrofit of dual-flow screens may help alleviate this problem. The degree of through-screen velocity reduction will be dependent on the space constraints of the existing intake configuration. In new intake construction, dual-flow screens can be installed with no walls separating the screens.

Retrofitting existing intakes containing through-flow screens with dual-flow screens can be performed with little or minor modifications to the existing intake structure. In this application, the dual-flow screens are constructed such that the open outlet side will align with the previous location of the downstream side of the through-flow screen. The screen is constructed with supports that slide into the existing screen slots and with "gull wing" baffles that close off the area between the screens downstream end and the screen well walls. The baffles are curved to better direct the flow. For many existing screen structures, the opening where the screen passes through the intake deck (including the open space in front of the screen) is limited to a five-foot opening front to back which limits the equivalent total overall per screen width of just under 10 ft for dual-flow retrofit screens. Because dual-flow screens filter on both sides the effective width is twice that of one screen panel. However, a vendor indicated, in many instances the screen well opening can be extended forward by demolishing a portion of the concrete deck at the front end. The feasibility and extent of such a modification (such as maximum width of the retrofit screen) is dependent on specific design of the existing intake, particularly concerning the proximity of obstructions upstream of the existing screen units. Certainly, most through-flow screens of less than 10 ft widths could be retrofitted with dual-flow screens that result in greater effective screen widths. Those 10 ft wide or greater that have large deck openings and/or available space could also install dual-flow screens with greater effective screen widths.

Capital Cost for Dual-Flow Screens

A screen vendor provided general guidance for both capital and O&M costs for dual-flow screens (Gathright 2002). The cost of dual-flow screens with fish handling sized to fit in existing intake screen wells could be estimated using the following factors applied to the costs of a traveling screen with fish handling that fit the existing screen well:

- For a screen well depth of 0 to <20 ft add 15% to the cost of a similarly sized through-flow screen.
- For a screen well depth of 20 ft to <40 ft add 10% to the cost of a similarly sized through-flow screen.
- For a screen well depth of greater than 40 ft add 5% to the cost of a similarly sized through-flow screen.

Installation costs are assumed to be similar to that for through-flow screens. The above factors were applied to the total installed cost of similarly sized through-flow screens, however, an additional 5% was added to the above cost factors to account for modifications that may be necessary to accommodate the new dual-flow screens such as demolition of a portion of the deck area. It is assumed that dual-flow screens can be installed in place of most through-flow screens but the benefit of lower through screen velocities may be limited for larger width (e.g., 14-ft) existing screens. The dual-flow screens are assumed to include fine mesh overlays and fish return systems, so the cost factors are applied to the scenario C through-flow screens only. The costs for dual-flow screens are not presented here but can be derived by applying the factor shown in Exhibit 3-45 below.

The capital costs for adding fine mesh overlays to existing dual-flow screens (scenario A) is assumed to be the same as for through-flow screens. This assumption is based on the fact that installation labor is based on the number of screen panels and should be the nearly the same and that the cost of the screen overlays themselves should be nearly the same. The higher equipment costs for dual-flow screens is mostly due to the equipment and equipment modifications located above the deck.

Exhibit 3-45. Capital Cost Factors for Dual-Flow Screens

Screen Depth	Capital Cost Factor[1]
10 Ft	1.2
25 Ft	1.15
50 Ft	1.1
75 Ft	1.1

[1] Applied to capital costs for similarly sized through-flow screens derived from equations shown in Figures 3-22 and 3-23 (Scenario C freshwater and saltwater)

O&M Costs for Dual-Flow Screens

A vendor indicated that a significant benefit of dual-flow screens is reduced O&M costs compared to similarly sized through-flow screens. O&M labor was reported to be as low as one tenth that for similarly sized through-flow traveling screens (Bracket Green 2002). Also, wash water flow is nearly cut in half and the spray water pressure requirement drops from 80 to 120 psi for through-flow screens to about 30 psi. Examples were cited where dual-flow retrofits paid for themselves in a two to five year period. Using an assumption of 90% reduction in routine O&M labor combined with an estimated reduction of 70% in wash water energy requirements (based on combined reduction in flow and pressure), EPA calculated that the O&M costs for dual-flow screens would be equal approximately 30% of the O&M costs for similarly sized through-flow screens with fine mesh overlays and fish handling and return systems. O&M costs for dual-flow screens were calculated as 30% of the O&M costs for similarly sized through-flow screens derived from the equations shown in Figures 3-26 and 3-27 (Scenario C freshwater and saltwater).

The O&M costs for adding fine mesh overlays to existing dual-flow screens (scenario A) is assumed to be the same as the net difference between through-flow screens with fish handling with and without fine mesh overlays (net O&M costs for scenario A versus scenario B). The majority of the net O&M costs are for deployment and removal of the fine mesh overlays.

Downtime for Dual-Flow Screens

As with through-flow screens dual-flow screens can be retrofitted with minimal generating unit downtime and can be scheduled to occur during routine maintenance downtime. While there may be some additional deck demolition work, this effort should add no more than one week to the two week estimate for multiple through-flow screens described above.

Technology Application

Capital Costs

The cost scenarios included here assume that the existing intake structure is designed for and includes through-flow (single entry, single exit) traveling screens, either with or without fish handling and return. For those systems with different types of traveling screens or fixed screens, the cost estimates derived here may also be applied. However, they should be viewed as a rough estimate for a retrofit that would result in similar performance enhancement. The cost scenario applied to each facility is based on the compliance action required and whether or not a fish handling and return system is in place. For those facilities with acceptable through-screen velocities no modification, other than described above, is considered as necessary. For those with high through-screen velocities that would result in unacceptable performance, costs for modifications/additions to the existing intake are developed through another cost module. The costs for new screens to be installed in these new intake structures will be based on the design criteria of the new structure.

Capital costs are applied based on waterbody type with costs for freshwater environments being applied to facilities in freshwater rivers/streams, lakes/reservoirs and the Great Lakes, and costs for saltwater environments being applied to facilities in estuaries/tidal rivers and oceans.

No distinction is being made here for freshwater environments with Zebra mussels. A vendor indicated that the mechanical movement and spray action of the traveling screens tend to prevent mussel attachment on the screens.

For facilities with intake canals, an added capital cost component for the additional length of the fish return flume (where applicable) are added. Where the canal length is not reported. The median canal length for other facilities with the same waterbody type are used.

O&M Costs

The compliance O&M costs are calculated as the net difference between the compliance scenario O&M costs and the baseline scenario O&M costs. For compliance scenarios that start with traveling screens where the traveling screens are then rendered unnecessary (e.g., relocating a shoreline intake to submerged offshore), the baseline scenario O&M costs presented here can be used to determine the net O&M cost difference for those technologies.

2.2 New Larger Intake Structure for Decreasing Intake Velocities

The efficacy of traveling screens can be affected by both through-screen and approach velocities. Through-screen velocity affects: the rate of debris accumulation; the potential for entrainment and impingement of swimming organisms; and the amount of injury that may occur when organisms become impinged and a fish return system is in use. Performance, with respect to impingement and entrainment, generally tends to deteriorate as intake velocities increase. For older intake structures, the primary function of the screen was to ensure downstream cooling system components continued to function without becoming plugged with debris. The design often did not take into consideration the effect of through-screen velocity on entrainment and impingement of aquatic organisms. For these older structures, the standard design value for through-screen velocity was in the range of 2.0 to 2.5 feet per second (Gathright 2002). These design velocities were based on the performance of coarse mesh traveling screens with respect to their ability to remove debris as quickly as it collected on the screen surface. As demonstrated in the Facility Questionnaire database, actual velocities may be even higher than standard design values. These higher velocities may result from cost-saving, site-specific designs or from an increased withdrawal rate compared to the original design.

As described previously, solutions considered for reducing entrainment on traveling screens are to replace the coarse mesh screens with finer mesh screens or to install fine mesh screen overlays. However, a potential problem with replacing the existing intake screens with finer mesh screens is that a finer mesh will accumulate larger quantities of debris. Thus, retrofitting existing coarse mesh screens with fine mesh may affect the ability of screens to remove debris quickly enough to function properly. Exacerbating this potential problem is finer mesh may result in slightly higher through-screen velocities (Gathright 2002). If the debris problems

associated with using fine mesh occur on a seasonal basis, then one possible solution (see section 2.1, above) is to use fine mesh overlays during the period when sensitive aquatic organisms are present. This solution is predicated on the assumption that the period of high debris loading does not substantially coincide with the period when sensitive aquatic organisms are most prevalent. When such an approach is not feasible, some means of decreasing the intake velocities may be necessary.

The primary intake attributes that determine intake through-screen velocities are the flow volume, effective screen area, and percent open area of the screen. The primary intake attributes that determine approach velocity are flow volume and cross-sectional area of the intake. In instances where flow volume cannot be reduced, a reduction in intake velocities can only be obtained in two ways: for through-screen velocities, an increased screen area and/or percent open area, or for approach velocity, an increased intake cross-sectional area. In general, there are practical limits regarding screen materials and percent open area. These limits prevent significant modification of this attribute to reduce through-screen velocities. Thus, an increase in the screen area and/or intake cross-sectional area generally must be accomplished in order to reduce intake velocities. Passive screen technology (such as T-screens) relies on lower screen velocities to improve performance with respect to impingement and entrainment and to reduce the rate of debris accumulation. For technology options that rely on the continued use of traveling screens, a means of increasing the effective area of the screens is warranted. EPA has researched this problem and has identified the following three approaches to increasing the screen size:

- Replace existing through flow (single entry-single exit) traveling screens with dual-flow (double entry-double exit) traveling screens. Dual-flow screens can be placed in the same screen well as existing through flow screens. However, they are oriented perpendicular to the orientation of the original through-flow screens and extend outward towards the front of the intake. Installation may require some demolition of the existing intake deck. This solution may work where screen velocities do not need to be reduced appreciably. This technology has a much improved performance with respect to debris carry over and is often selected based on this attribute alone (Gathright 2002; see also section 2.1.4 above).

- Replace the function of the existing intake screen wells with larger wells constructed in front of the existing intake and hydraulically connected to the intake front opening. This approach retains the use and function of the existing intake pumps and pump wells with little or no modification to the original structure. A concern with this approach (besides construction costs) is whether the construction can be performed without significant downtime for the generating units.

- Add a new intake structure adjacent to, or in close proximity to, the existing intake. The old intake remains functional, but with the drive system for the existing pumps modified to reduce the flow rate. The new structure will include new pumps sized to pump an additional flow. The new structure can be built without a significant shutdown of the existing intake. Shutdown would only be required at the final construction step, where the pipes from new pumps are connected to the existing piping and the pumps and/or pump drives for the existing pumps are modified or replaced. In this case, generating downtime is minimized. However, the need for new pumps, and the modification to existing pumps that reduce their original flow, entail significant additional costs.

Option 3 is a seemingly simple solution where the addition of new intake bays adjacent or in close proximity to the existing intake would add to the total intake and screen cross-sectional area. A problem with this approach is that the current pumping capacity needs to be distributed between the old and new intake bays. Utilizing the existing pump wells and pumps is desirable to help minimize costs. However, where the existing pumps utilize single speed drives, the distribution of flow to the new intake bays would require either an upstream hydraulic connection or a pump system modification. Where the existing intake has only one or two pump wells a hydraulic connection with a new adjacent intake bay could be created through demolition of a sidewall downstream of the traveling screen. While this approach is certainly feasible in certain instances, the limitations regarding intake configurations prevents EPA from considering this a viable regulatory compliance alternative for all but a few existing systems. A more widely applicable solution would be to reduce pump flow rate of the existing pumps either by modifying the pump drive to a multi-speed or variable speed drive system, or by replacing the existing pumps with smaller ones. The new intake bays would be constructed with new smaller pumps that produce lower flow rates. The combined flows of the new and older, modified pumps satisfies the existing intake flow requirement. The costs of modifying existing pumps, plus the new pumps and pump wells, represents a substantial cost component.

Option 2 does not require modifications or additions to the existing pumping equipment. In this approach a new intake structure to house more and/or larger screen wells would be constructed in front of the existing intake. The old and new intake structures could then be hydraulically connected by closing off the ends with sheet pile walls or similar structures. EPA is not aware of any installations that have performed this retrofit but it was proposed as an option in the Demonstration Study for the Salem Nuclear Plant (PSE&G 2001). In that proposal the new screens were to be dual-flow screens but the driving factor for the new structure was a need to increase the intake size.

EPA initially developed rough estimates of the comparative costs of applying option 2 versus option 3 (in the hypothetical case the intake area was doubled in size). The results indicated that adding a new screen well structure in front of the existing intake was less costly and therefore, this option was selected for consideration as a compliance technology option. This cost efficiency is primarily due to the reuse of the existing intake in a more cost efficient manner in option 2. However, option 2 has one important drawback: it may not be feasible where sufficient space is not available in front of the existing intake. To minimize construction downtime, EPA assumes the new intake structure is placed far enough in front of the existing intake to allow the existing intake to continue functioning until construction of the structure is completed. As a result of the need for sufficient space in front of the intake, the Agency has applied the technology in appropriate circumstances in developing model facility costs.

Scenario Description

In this scenario, modeled on option 2 described above, a new reinforced concrete structure is designed for new through-flow or dual-flow intake screens. This structure will be built directly in front of the existing intake. The structure will be built inside a temporary sheet pile coffer dam. Upon completion of the concrete structure, the coffer dam will be removed. A permanent sheet pile wall will be installed at both ends, connecting the rear of the new structure to the front of the old intake structure hydraulically. Such a configuration has the advantage of providing for flow equalization between multiple new intake screens and multiple existing pumps. The construction includes costs for site development for equipment access. Capital costs were developed for the same set of screen widths (2 feet through 140 feet) and depths (10 feet through 100 feet) used in the traveling screen cost methodology. Best-fit, second-order equations were used to estimated costs for each different screen well depth, using total screen width as the independent variable. Construction duration is estimated to be nine months.

Capital Costs

Capital costs were derived for different well depths and total screen widths based on the following assumptions.

Design Assumptions - On-shore Activities

- Clearing and grabbing: this is based on clearing with a dozer, and clearing light to medium brush to 4" diameter; clearing assumes a 40 feet width for equipment maneuverability near the shore line and 500 feet accessibility lengthwise at $3,075/acre (RS Means 2001); surveying costs are estimated at $1,673/ acre (RS Means 2001), covering twice the access area.
- Earth work costs: these include mobilization, excavation, and hauling, etc., along a water front width, with a 500-foot inland length; backfill with structural sand and grave (backfill structural based on using a 200 HP bulldozer, 300-foot haul, sand and gravel; unit earthwork cost is $395/ cu yd (RS Means 2001)
- Paving and surfacing, using concrete 10" thick; assuming a need for a 20-foot wide and 2- foot long equipment staging area at a unit cost of $33.5/ sq yd (RS Means 2001)
- Structural cost is calculated @ $1250/CY (RS Means 2001),assuming two wing walls 1.5 feet thick and 26 feet high, with 10 feet above ground level, and 36 feet long with 16 feet onshore (these walls are for tying in the connecting sheet pile walls).
- Sheet piling, steel, no wales, 38 psf, left in place; these are assumed to have a width twice the width of the screens + 20 feet, with onshore construction distance, and be 30 feet deep, at $24.5/ sq ft (RS Means 2001).

Design Assumptions - Offshore Components

- Structure width is 20% greater than total screen width and 20 ft front to back
- Structural support consists of the equivalent of four 3-foot by 3-foot reinforced concrete columns at $935/ cu yd RS Means 2001) plus two additional columns for each additional screen well (a 2-foot wide screen assumes an equivalent of 2-foot by 2 feet columns)
- Overall structure height is equal to the well depth plus 10%
- The elevated concrete deck is 1.5 ft thick at $48/ cu yd RS Means 2001)
- Dredging mobilization is $9,925 if total screen width is less than 10 feet; is $25,890 if total screen width is 10 feet to 25 feet; and is $52,500 if total screen width is greater than 25 ft RS Means 2001)
- The cost of dredging in the offshore work area is $23/cu yd to a depth of 10 feet
- The cost of the temporary coffer dam for the structure is $22.5/ sq ft RS Means 2001), with total length equal to the structure perimeter times a factor of 1.5 and the height equal to 1.3 times well depth.

Field Project Personnel Not Included in Unit Costs:

- Project Field Manager at $2,525 per week RS Means 2001)
- Project Field Superintendent at $2,375 per week RS Means 2001)
- Project Field Clerk at $440 per week RS Means 2001).

The above cost components were estimated and summed and the costs were expanded using the following cost factors.

Add-on and Indirect Costs:

- Construction Management is 4.5% of direct costs
- Engineering and Architectural fees for new construction is 17% of direct costs
- Contingency is 10% of direct costs
- Overhead and profit is 15% of direct costs
- Permits are 2% of direct costs
- Metalwork is 5% of direct costs
- Performance bond is 2.5% of direct costs
- Insurance is 1.5% of direct costs.

The total capital costs were then adjusted for inflation from 2001 dollars to July 2002 dollars using the ENR Construction Cost Index. Exhibit 3-46 presents the total capital costs for various screen well depths and total screen widths. No distinction was made between freshwater and brackish or saltwater environments. Figure 3-30 plots the data in Exhibit 3-46 and presents the best-fit cost equations. The shape of these curves indicates a need for separate equations for structures with widths less than and greater than 10 feet. In general, however, the Phase III compliance applications of this technology option included only new structures greater than 10 feet wide.

Exhibit 3-46. Total Capital Costs for Adding New Larger Intake Screen Well Structure in Front of Existing Shoreline Intake

Well Depth	10 Ft	25 Ft	50 Ft	75 ft	100 Ft
Width (Ft)					
2	$ 291,480	$ 562,140	$ 1,176,330	$ 1,842,570	$ 2,581,680
5	$ 333,120	$ 624,600	$ 1,290,840	$ 1,998,720	$ 2,800,290
10	$ 916,080	$ 1,957,080	$ 4,361,790	$ 6,922,650	$ 9,806,220
20	$ 1,051,410	$ 2,175,690	$ 4,757,370	$ 7,484,790	$ 10,545,330
30	$ 1,270,020	$ 2,487,990	$ 5,236,230	$ 8,130,210	$ 11,378,130
40	$ 1,426,170	$ 2,727,420	$ 5,642,220	$ 8,713,170	$ 12,138,060
50	$ 1,582,320	$ 2,977,260	$ 6,058,620	$ 9,306,540	$ 12,908,400
60	$ 1,748,880	$ 3,227,100	$ 6,485,430	$ 9,899,910	$ 13,689,150
70	$ 1,925,850	$ 3,487,350	$ 6,922,650	$ 10,503,690	$ 14,469,900
84	$ 2,165,280	$ 3,851,700	$ 7,536,840	$ 11,367,720	$ 15,583,770
98	$ 2,425,530	$ 4,236,870	$ 8,161,440	$ 12,242,160	$ 16,718,460
112	$ 2,696,190	$ 4,622,040	$ 8,994,240	$ 13,127,010	$ 17,863,560
126	$ 2,977,260	$ 5,028,030	$ 9,462,690	$ 14,032,680	$ 19,029,480
140	$ 3,268,740	$ 5,444,430	$ 10,139,340	$ 14,948,760	$ 20,205,810

O&M Costs

No separate O&M costs were derived for the structure itself since the majority of the O&M activities are covered in the O&M costs for the traveling screens to be installed in the new structure.

Construction Downtime

As described above, this scenario is modeled after an option described in a 316(b) Demonstration Study for the Salem Nuclear Plant (PSE&G 2001). In that scenario which applies to a very large nuclear facility, the existing intake continues to operate during the construction of the offshore intake structure inside the sheet pile cofferdam. Upon completion of the offshore structure and removal of the cofferdam, the final phase on the construction requires the shut down of the generating units for the placement of the sheet pile end walls. The feasibility study states that units 1 and 2 would be required to shut down for one month each. Based on this estimate and the size of the Salem facility (average daily flow of over 2 million gpm), EPA has concluded that a total construction downtime estimate in the range of 6 to 8 weeks is reasonable. EPA did not select a single downtime for all facilities installing an offshore structure. Instead, EPA applied a six- to eight-week downtime duration based on variations in project size, using design flow as a measure of size. EPA assumed a total downtime of six weeks for facilities with intake flow volumes of less than 400,000 gpm; seven weeks for facilities with intake flow volumes greater than 400,000 gpm but less than 800,000 gpm; and eight weeks for facilities with intake flow volumes greater than 800,000 gpm.

Application

The input value for the cost equation is the screen well depth and the total screen width (see section 1.1 for a discussion of the methodology for determining the screen well depth). The width of the new larger screen well intake structure was based on the design flow, and an assumed through-screen velocity of 1.0 feet per second and a percent open area of 50%. The 50 % open area value used is consistent with the percent open area of a fine mesh screen. The same well depth and width values are used for estimating the costs of new screen equipment for the new structure. New screen equipment consisted of fine mesh dual flow (double entry single exit) traveling screens with fish handling and return system.

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Exhibit 3-25. Total Capital Costs for Scenario A - Adding Fine Mesh Without Fish Handling Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$7,989	$9,079	$11,853	$23,706	$35,559	$47,412	$59,265	$71,117	$81,865	$98,237	$114,610	$143,806	$147,356	$163,729
25'-0	$11,162	$12,932	$17,952	$35,905	$53,857	$71,810	$89,762	$107,714	$134,162	$160,994	$187,827	$242,278	$241,492	$268,324
50'-0	$17,707	$20,977	$30,295	$60,590	$90,885	$121,180	$151,475	$181,769	$206,825	$248,189	$289,554	$383,198	$372,284	$413,649
75'-0	$24,262	$29,302	$40,467	$80,935	$121,402	$161,870	$202,337	$242,804	$273,987	$328,784	$383,582	$515,318	$493,177	$547,974
100'-0	$32,997	$37,627	$50,630	$101,260	$151,890	$202,520	$253,150	$303,779	$338,450	$406,139	$473,829	$643,118	$609,209	$676,899

Exhibit 3-26. Total Capital Costs for Scenario A - Adding Fine Mesh Without Fish Handling Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$14,909	$17,089	$22,103	$44,206	$66,309	$88,412	$110,515	$132,617	$155,715	$186,857	$218,000	$249,143	$280,286	$311,429
25'-0	$20,022	$23,562	$32,452	$64,905	$97,357	$129,810	$162,262	$194,714	$251,062	$301,274	$351,487	$401,699	$451,912	$502,124
50'-0	$31,057	$37,597	$54,055	$108,110	$162,165	$216,220	$270,275	$324,329	$380,975	$457,169	$533,364	$609,559	$685,754	$761,949
75'-0	$42,112	$52,192	$71,317	$142,635	$213,952	$285,270	$356,587	$427,904	$499,887	$599,864	$699,842	$799,819	$899,797	$999,774
100'-0	$57,527	$66,787	$88,560	$177,120	$265,680	$354,240	$442,800	$531,359	$613,400	$736,079	$858,759	$981,439	$1,104,119	$1,226,799

Exhibit 3-27. Total Capital Costs for Scenario B - Adding Fish Handling and Return Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$105,872	$126,362	$164,443	$301,224	$438,105	$572,141	$703,131	$837,367	$967,658	$1,151,993	$1,333,484	$1,518,320	$1,700,210	$1,882,401
25'-0	$132,772	$161,562	$217,443	$407,224	$597,105	$784,141	$968,131	$1,155,367	$1,460,658	$1,743,593	$2,023,684	$2,307,120	$2,587,610	$2,868,401
50'-0	$185,172	$230,462	$320,543	$613,424	$906,405	$1,196,541	$1,483,631	$1,773,967	$2,095,658	$2,505,593	$2,912,684	$3,323,120	$3,730,610	$4,138,401
75'-0	$237,672	$302,162	$401,943	$776,224	$1,150,605	$1,522,141	$1,890,631	$2,262,367	$2,675,658	$3,201,593	$3,724,684	$4,251,120	$4,774,610	$5,298,401
100'-0	$311,972	$373,862	$483,243	$938,824	$1,394,505	$1,847,341	$2,297,131	$2,750,167	$3,228,658	$3,865,193	$4,498,884	$5,135,920	$5,770,010	$6,404,401

Exhibit 3-28. Total Capital Costs for Scenario B - Adding Fish Handling and Return Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$175,072	$206,462	$266,943	$506,224	$745,605	$982,141	$1,215,631	$1,452,367	$1,706,158	$2,038,193	$2,367,384	$2,699,920	$3,029,510	$3,359,401
25'-0	$221,372	$267,862	$362,443	$697,224	$1,032,105	$1,364,141	$1,693,131	$2,025,367	$2,629,658	$3,146,393	$3,660,284	$4,177,520	$4,691,810	$5,206,401
50'-0	$318,672	$396,662	$558,143	$1,088,624	$1,619,205	$2,146,941	$2,671,631	$3,199,567	$3,837,158	$4,595,393	$5,350,784	$6,109,520	$6,865,310	$7,621,401
75'-0	$416,172	$531,062	$710,443	$1,393,224	$2,076,105	$2,756,141	$3,433,131	$4,113,367	$4,934,658	$5,912,393	$6,887,284	$7,865,520	$8,840,810	$9,816,401
100'-0	$557,272	$665,462	$862,543	$1,697,424	$2,532,405	$3,364,541	$4,193,631	$5,025,967	$5,978,158	$7,164,593	$8,348,184	$9,535,120	$10,719,110	$11,903,401

Exhibit 3-29. Total Capital Costs for Scenario C - Adding Fine Mesh with Fish Handling and Return Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$112,772	$134,362	$174,743	$321,824	$469,005	$613,341	$754,631	$899,167	$1,041,658	$1,240,793	$1,437,084	$1,636,720	$1,833,410	$2,030,401
25'-0	$141,672	$172,162	$231,943	$436,224	$640,605	$842,141	$1,040,631	$1,242,367	$1,577,658	$1,883,993	$2,187,484	$2,494,320	$2,798,210	$3,102,401
50'-0	$198,572	$247,062	$344,343	$661,024	$977,805	$1,291,741	$1,602,631	$1,916,767	$2,269,658	$2,714,393	$3,156,284	$3,601,520	$4,043,810	$4,486,401
75'-0	$255,572	$325,062	$432,843	$838,024	$1,243,305	$1,645,741	$2,045,131	$2,447,767	$2,901,658	$3,472,793	$4,041,084	$4,612,720	$5,181,410	$5,750,401
100'-0	$336,472	$403,062	$521,143	$1,014,624	$1,508,205	$1,998,941	$2,486,631	$2,977,567	$3,503,658	$4,195,193	$4,883,884	$5,575,920	$6,265,010	$6,954,401

Exhibit 3-30. Total Capital Costs for Scenario C - Adding Fine Mesh with Fish Handling and Return Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$188,872	$222,462	$287,543	$547,424	$807,405	$1,064,541	$1,318,631	$1,575,967	$1,854,158	$2,215,793	$2,574,584	$2,936,720	$3,295,910	$3,655,401
25'-0	$239,172	$289,062	$391,443	$755,224	$1,119,105	$1,480,141	$1,838,131	$2,199,367	$2,863,658	$3,427,193	$3,987,884	$4,551,920	$5,113,010	$5,674,401
50'-0	$345,472	$429,862	$605,743	$1,183,824	$1,762,005	$2,337,341	$2,909,631	$3,485,167	$4,185,158	$5,012,993	$5,837,984	$6,666,320	$7,491,710	$8,317,401
75'-0	$451,972	$576,862	$772,243	$1,516,824	$2,261,505	$3,003,341	$3,742,131	$4,484,167	$5,386,658	$6,454,793	$7,520,084	$8,588,720	$9,654,410	$10,720,401
100'-0	$606,272	$723,862	$938,343	$1,849,024	$2,759,805	$3,667,741	$4,572,631	$5,480,767	$6,528,158	$7,824,593	$9,118,184	$10,415,120	$11,709,110	$13,003,401

Exhibit 3-38. Baseline O&M Costs for Traveling Screens Without Fish Handling Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$5,419	$8,103	$10,223	$20,445	$30,668	$40,891	$51,113	$61,336	$62,805	$75,367	$87,928	$100,489	$113,050	$125,611
25	$6,433	$9,499	$11,880	$23,760	$35,640	$47,520	$59,400	$71,280	$75,667	$90,800	$105,933	$121,067	$136,200	$151,333
50	$7,591	$11,483	$14,741	$29,482	$44,223	$58,964	$73,705	$88,446	$89,781	$107,737	$125,693	$143,650	$161,606	$179,562
75	$8,786	$13,687	$16,865	$33,729	$50,594	$67,458	$84,323	$101,187	$101,216	$121,459	$141,702	$161,946	$182,189	$202,432
100	$10,597	$15,833	$18,985	$37,970	$56,956	$75,941	$94,926	$113,911	$112,279	$134,735	$157,191	$179,647	$202,103	$224,558

Exhibit 3-39. Baseline O&M Costs for Traveling Screens Without Fish Handling Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$6,400	$9,247	$11,694	$23,388	$35,083	$46,777	$58,471	$70,165	$73,433	$88,120	$102,806	$117,493	$132,179	$146,866
25	$7,577	$10,971	$13,842	$27,684	$41,526	$55,368	$69,210	$83,052	$92,834	$111,401	$129,968	$148,535	$167,101	$185,668
50	$9,389	$13,772	$18,175	$36,349	$54,524	$72,698	$90,873	$109,047	$113,498	$136,186	$158,884	$181,582	$204,279	$226,977
75	$11,238	$16,957	$21,116	$42,231	$63,347	$84,462	$105,578	$126,693	$129,829	$155,794	$181,760	$207,726	$233,691	$259,657
100	$14,357	$20,084	$24,054	$48,107	$72,161	$96,215	$120,269	$144,322	$144,979	$173,975	$202,971	$231,967	$260,963	$289,958

Exhibit 3-40. Baseline & Scenario B Compliance O&M Totals for Traveling Screens With Fish Handling Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$15,391	$24,551	$35,231	$70,462	$105,693	$140,924	$176,155	$211,386	$230,185	$276,221	$322,258	$368,295	$414,332	$460,369
25	$18,333	$28,378	$40,504	$81,009	$121,513	$162,018	$202,522	$243,027	$271,971	$326,365	$380,759	$435,154	$489,548	$543,942
50	$22,295	$34,696	$49,853	$99,707	$149,560	$199,413	$249,267	$299,120	$328,293	$393,952	$459,611	$525,269	$590,928	$656,587
75	$26,441	$41,449	$57,499	$114,998	$172,498	$229,997	$287,496	$344,995	$376,302	$451,563	$526,823	$602,084	$677,344	$752,605
100	$31,712	$47,927	$65,126	$130,251	$195,377	$260,503	$325,628	$390,754	$424,831	$509,797	$594,763	$679,729	$764,695	$849,661

Exhibit 3-41. Baseline & Scenario B Compliance O&M Totals for Traveling Screens With Fish Handling Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$19,543	$29,357	$41,381	$82,762	$124,143	$165,524	$206,905	$248,286	$274,495	$329,393	$384,292	$439,191	$494,090	$548,989
25	$23,649	$34,756	$49,204	$98,409	$147,613	$196,818	$246,022	$295,227	$342,111	$410,533	$478,955	$547,378	$615,800	$684,222
50	$30,305	$44,668	$64,109	$128,219	$192,328	$256,437	$320,547	$384,656	$432,783	$519,340	$605,897	$692,453	$779,010	$865,567
75	$37,151	$55,183	$76,009	$152,018	$228,028	$304,037	$380,046	$456,055	$511,842	$614,211	$716,579	$818,948	$921,316	$1,023,685
100	$46,430	$65,423	$87,884	$175,767	$263,651	$351,535	$439,418	$527,302	$589,801	$707,761	$825,721	$943,681	$1,061,641	$1,179,601

Exhibit 3-42. Scenario A & C Compliance O&M Totals for Traveling Screens With Fish Handling Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$17,529	$26,688	$38,437	$76,874	$115,311	$153,747	$192,184	$230,621	$246,214	$295,456	$344,699	$393,942	$443,184	$492,427
25	$22,936	$32,982	$47,409	$94,819	$142,228	$189,637	$237,046	$284,456	$306,495	$367,794	$429,093	$490,392	$551,691	$612,990
50	$31,008	$43,409	$62,923	$125,846	$188,769	$251,693	$314,616	$377,539	$393,642	$472,371	$551,099	$629,828	$708,556	$787,285
75	$39,264	$54,272	$76,734	$153,468	$230,202	$306,936	$383,670	$460,404	$472,476	$566,972	$661,467	$755,962	$850,458	$944,953
100	$48,645	$64,861	$90,525	$181,051	$271,576	$362,102	$452,627	$543,153	$551,830	$662,195	$772,561	$882,927	$993,293	$1,103,659

Exhibit 3-43. Scenario A & C Compliance O&M Totals for Traveling Screens With Fish Handling Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$21,681	$31,494	$44,587	$89,174	$133,761	$178,347	$222,934	$267,521	$290,524	$348,628	$406,733	$464,838	$522,942	$581,047
25	$28,252	$39,360	$56,109	$112,219	$168,328	$224,437	$280,546	$336,656	$376,635	$451,962	$527,289	$602,616	$677,943	$753,270
50	$39,018	$53,381	$77,179	$154,358	$231,537	$308,717	$385,896	$463,075	$498,132	$597,759	$697,385	$797,012	$896,638	$996,265
75	$49,974	$68,006	$95,244	$190,488	$285,732	$380,976	$476,220	$571,464	$608,016	$729,620	$851,223	$972,826	$1,094,430	$1,216,033
100	$63,363	$82,357	$113,283	$226,567	$339,850	$453,134	$566,417	$679,701	$716,800	$860,159	$1,003,519	$1,146,879	$1,290,239	$1,433,599

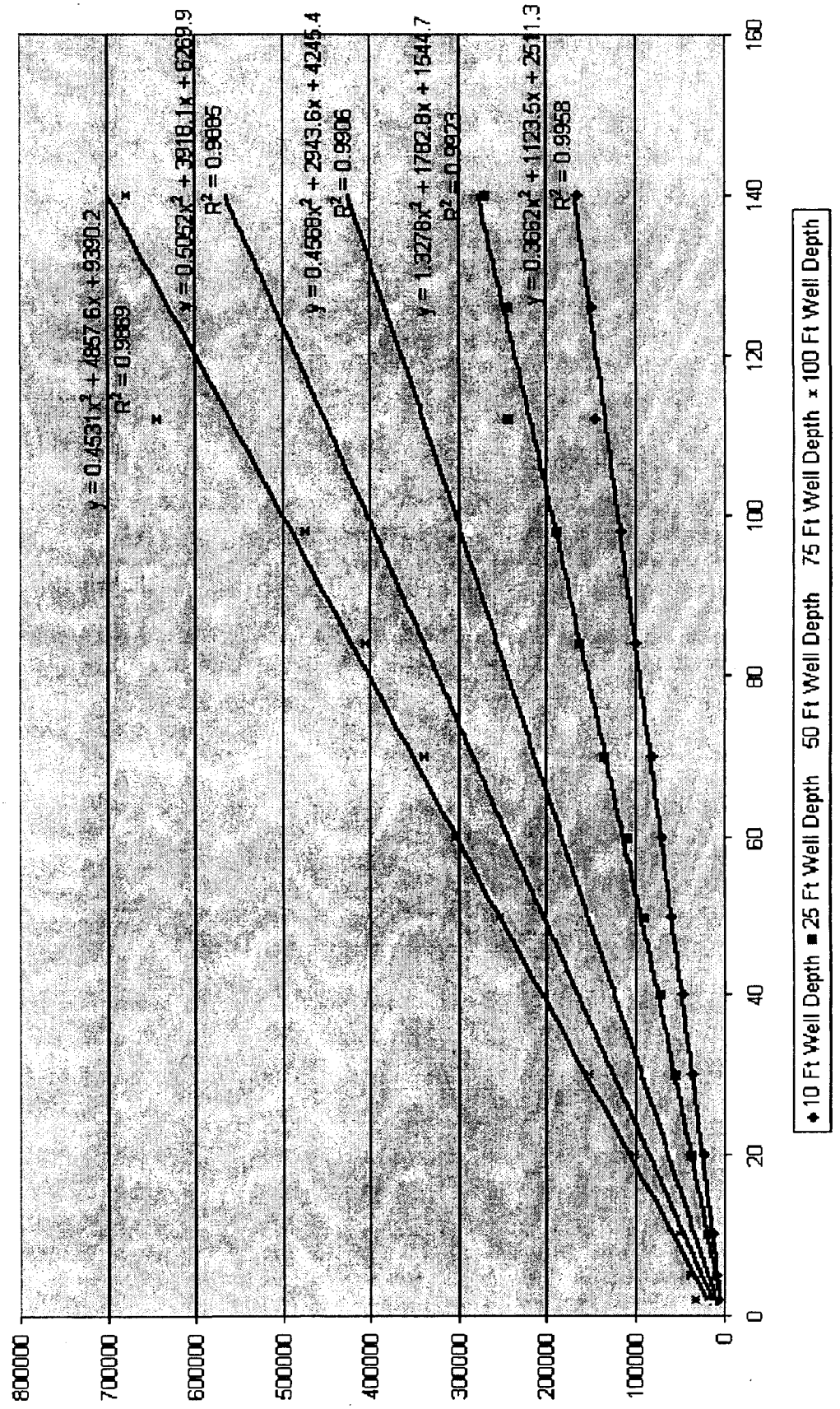


Figure 3-18. Scenario A - Capital Cost -Add Fine Mesh Replacement Screen Panels Freshwater

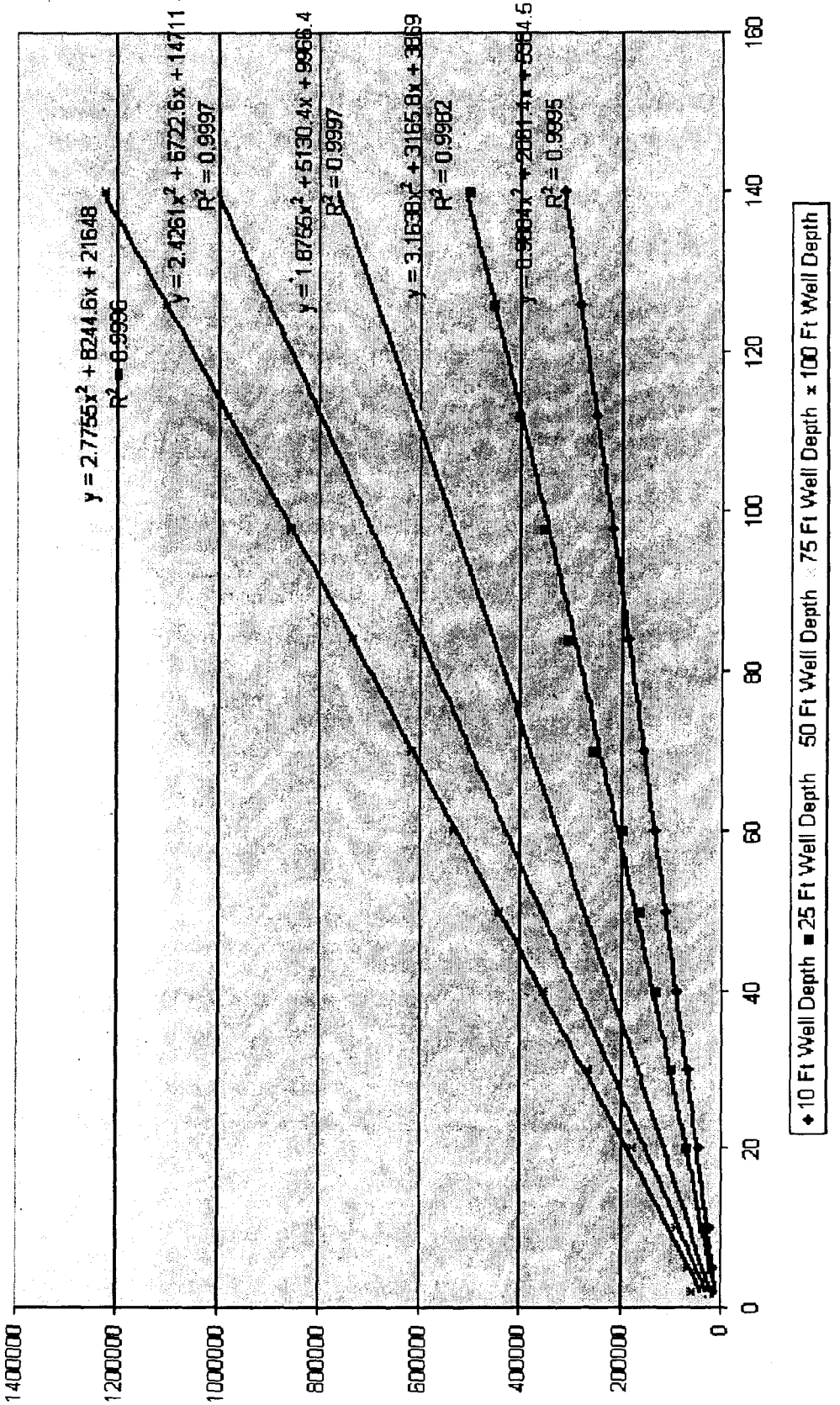
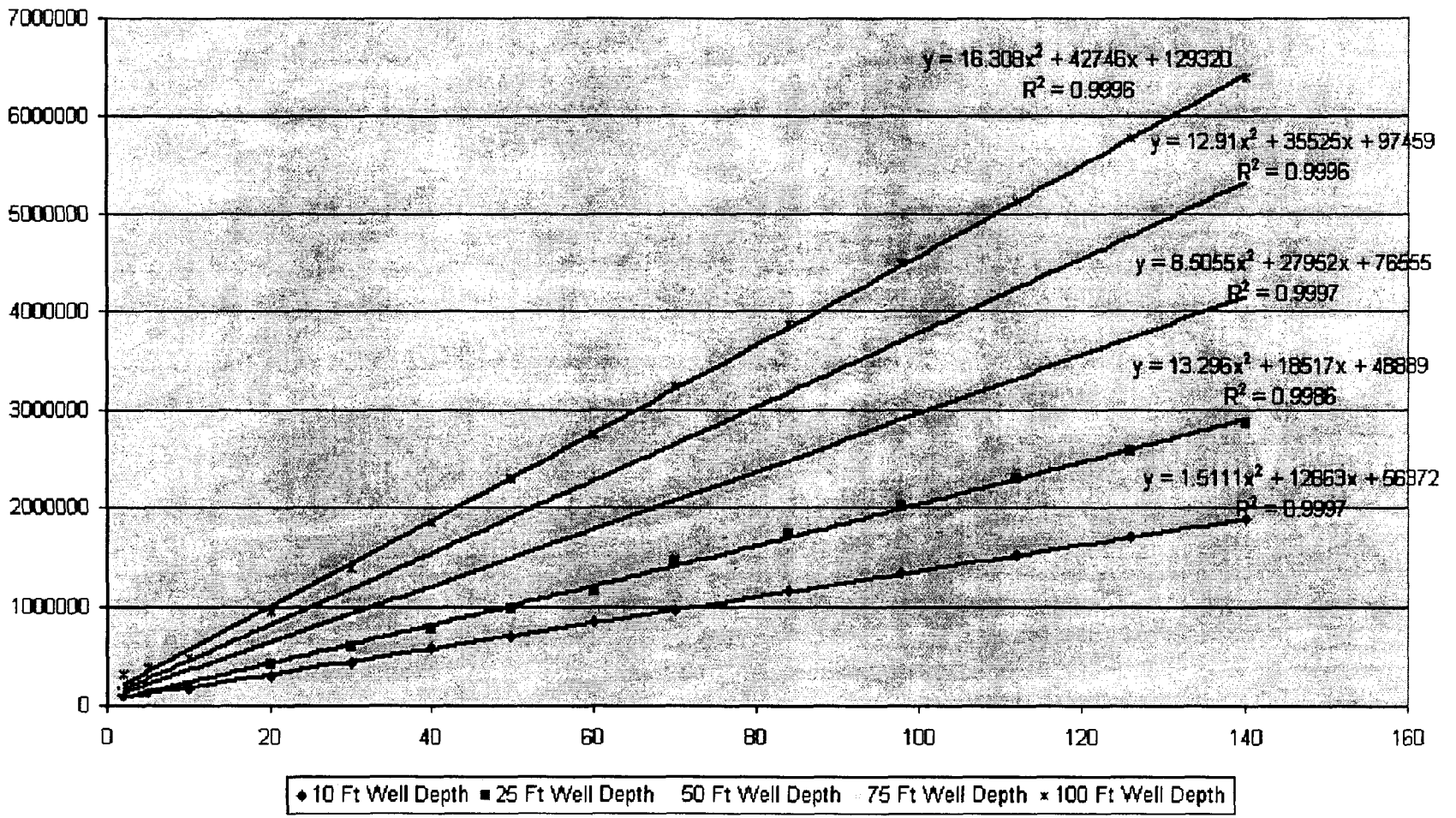


Figure 3-19. Scenario A - Capital Cost -Add Fine Mesh Replacement Screen Panels - Saltwater

Figure 3-20. Scenario B - Capital Cost -Add Traveling Screen with Fish Handling and Return - Freshwater



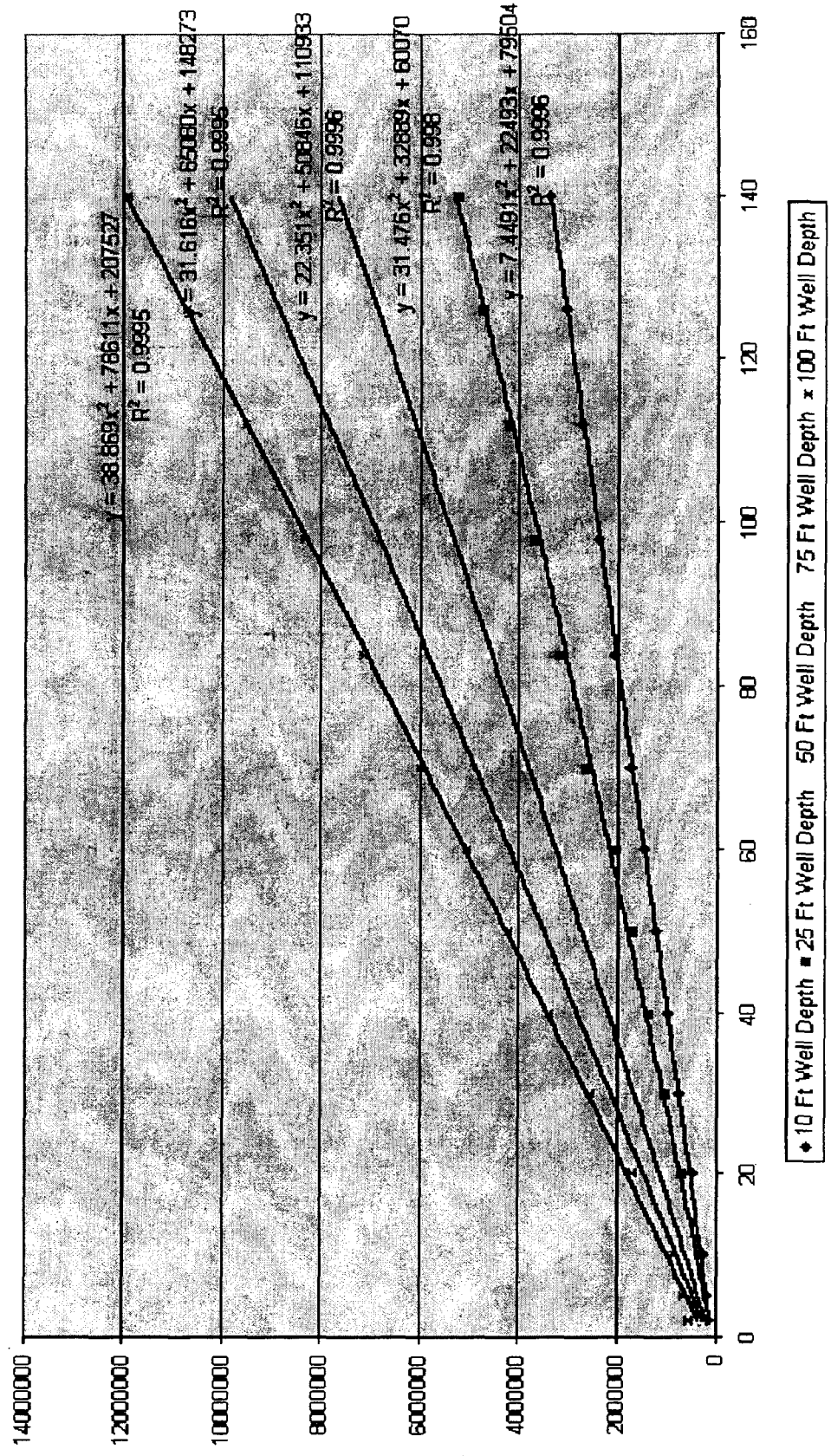
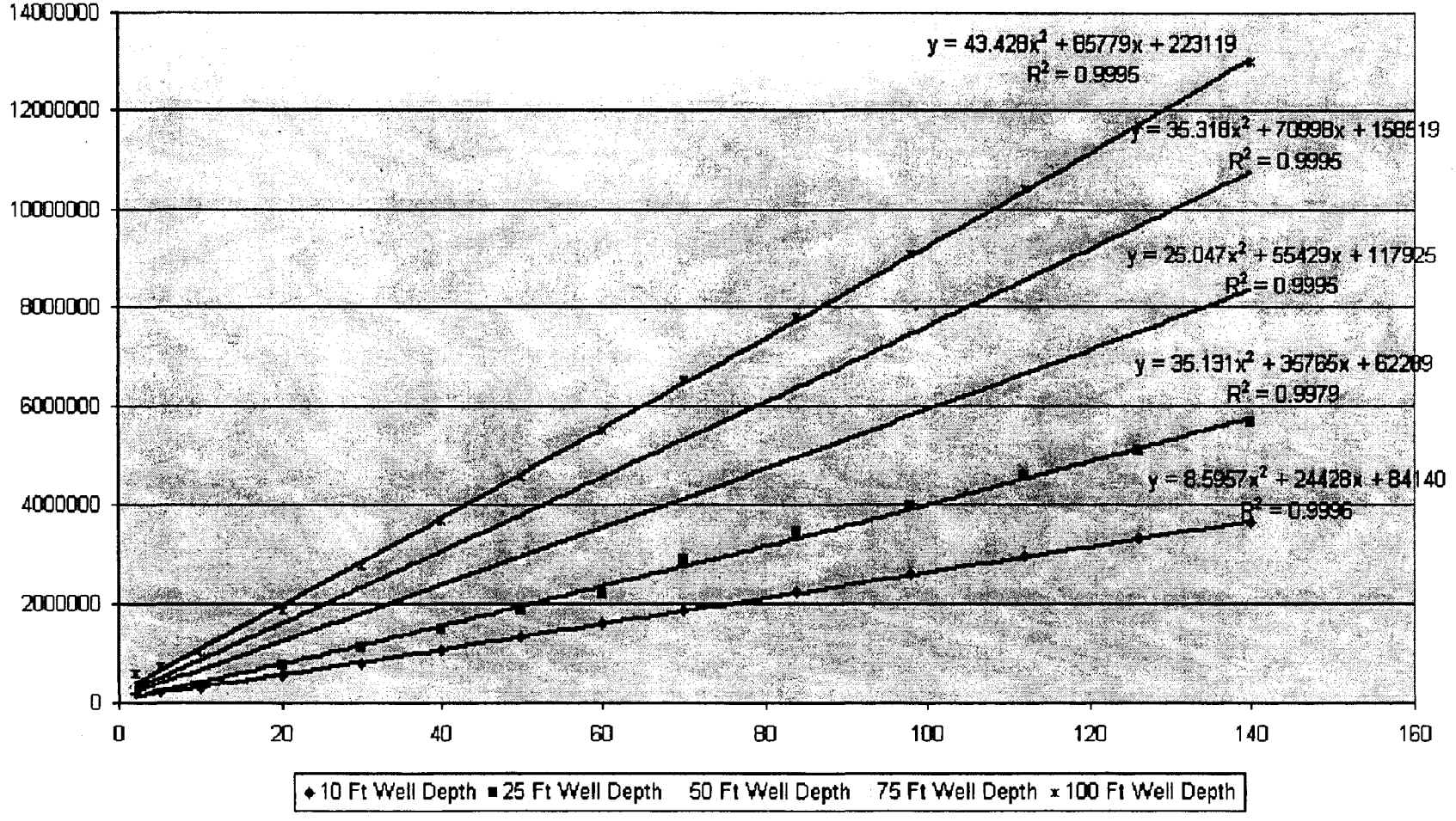


Figure 3-21. Scenario B - Capital Cost - Add Traveling Screen with Fish Handling and Return - Saltwater

Figure 3-22. Scenario C - Capital Cost -Add Fine Mesh Traveling Screen With and Fish Handling and Return - Saltwater



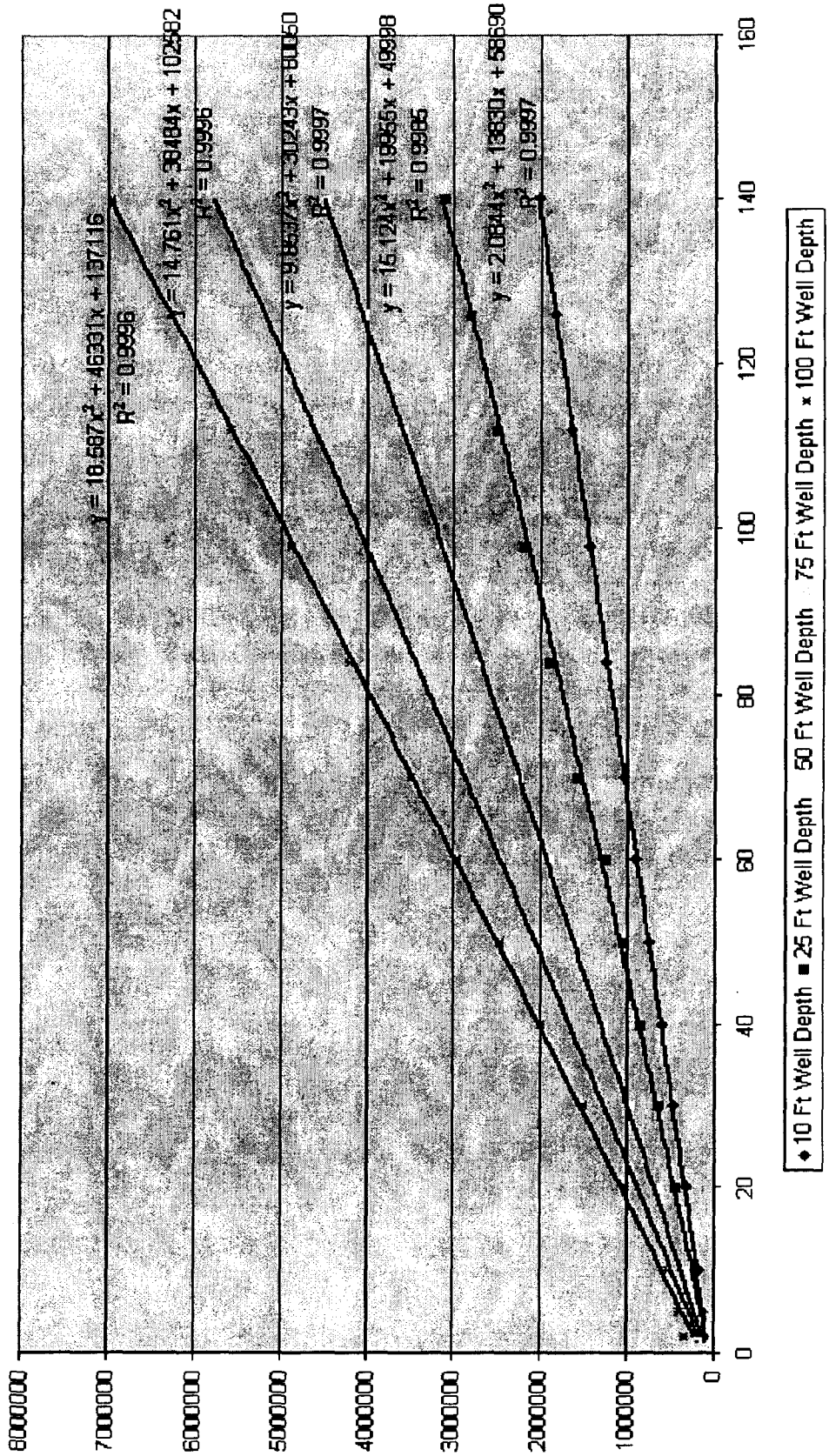


Figure 3-23. Scenario C - Capital Cost - Add Fine Mesh Traveling Screen With and Fish Handling and Return Freshwater

Figure 3-24. Baseline O&M Costs for Traveling Screens Without Fish Handling - Freshwater Environments

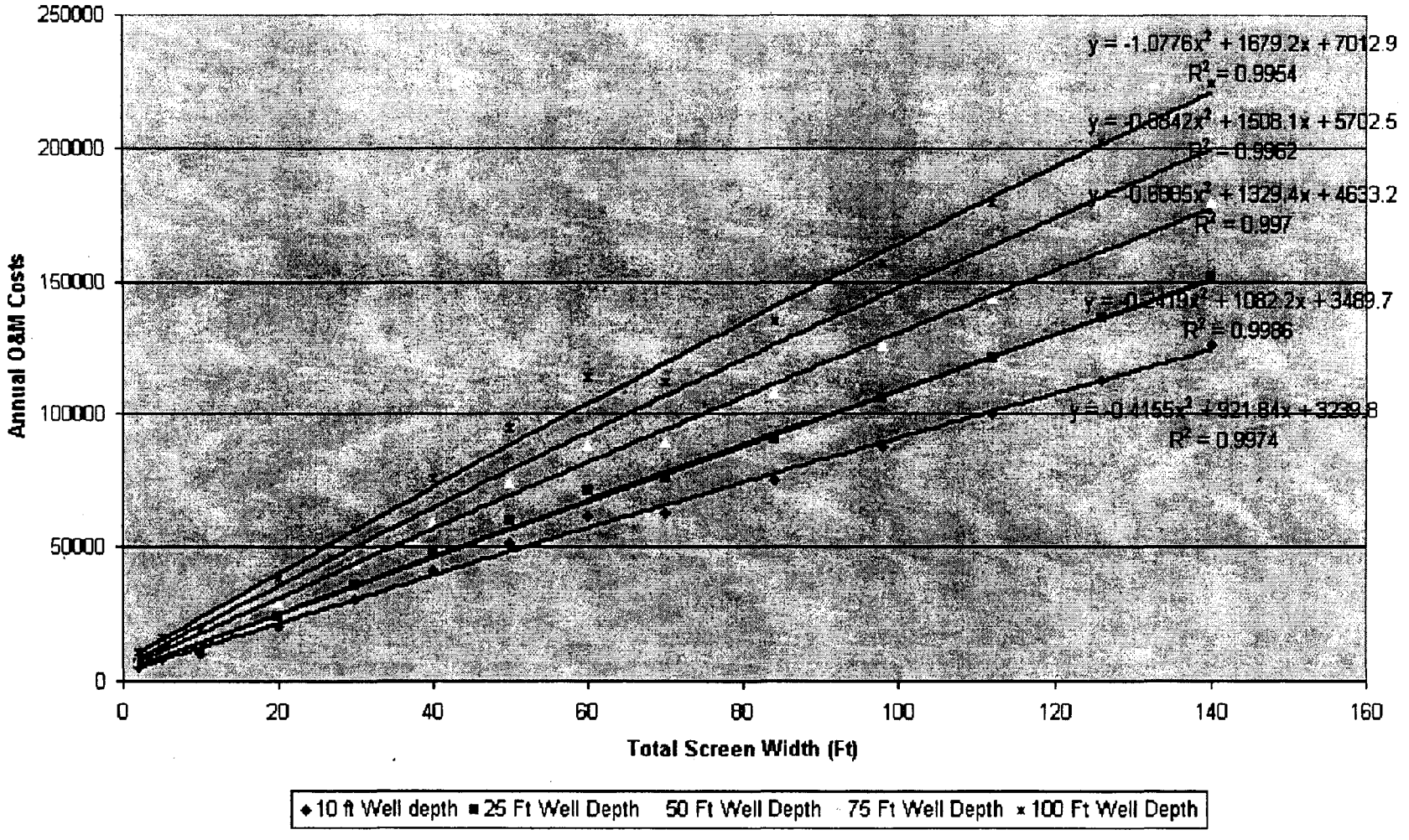


Figure 3-25. Baseline O&M Costs for Traveling Screens Without Fish Handling - Saltwater Environments

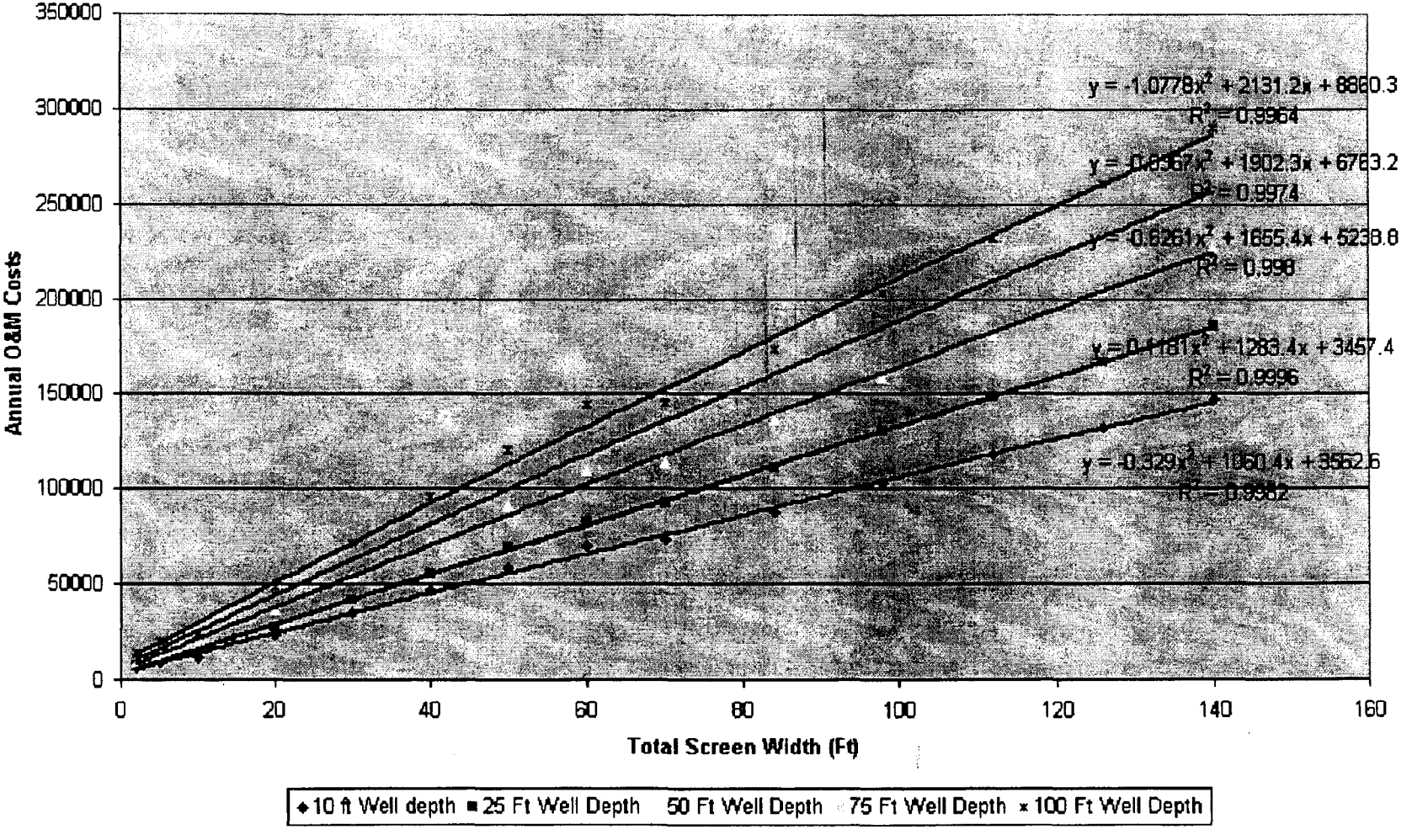


Figure 3-26. Scenarios A & C Compliance O&M Total Costs for Traveling Screens With Fish Handling Freshwater Environments

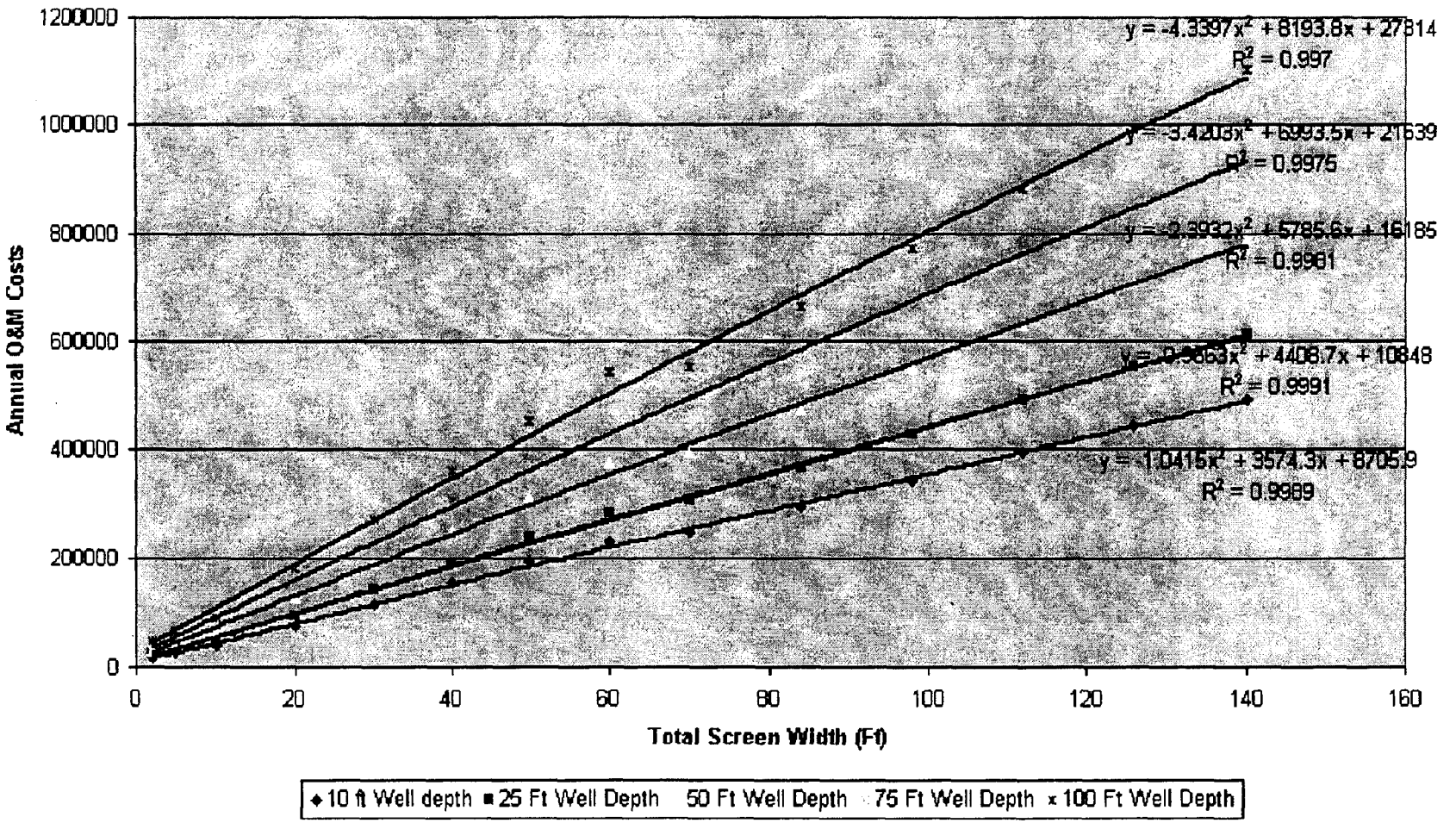


Figure 3-27. Scenarios A & C Compliance O&M Total Costs for Traveling Screens With Fish Handling - Saltwater Environments

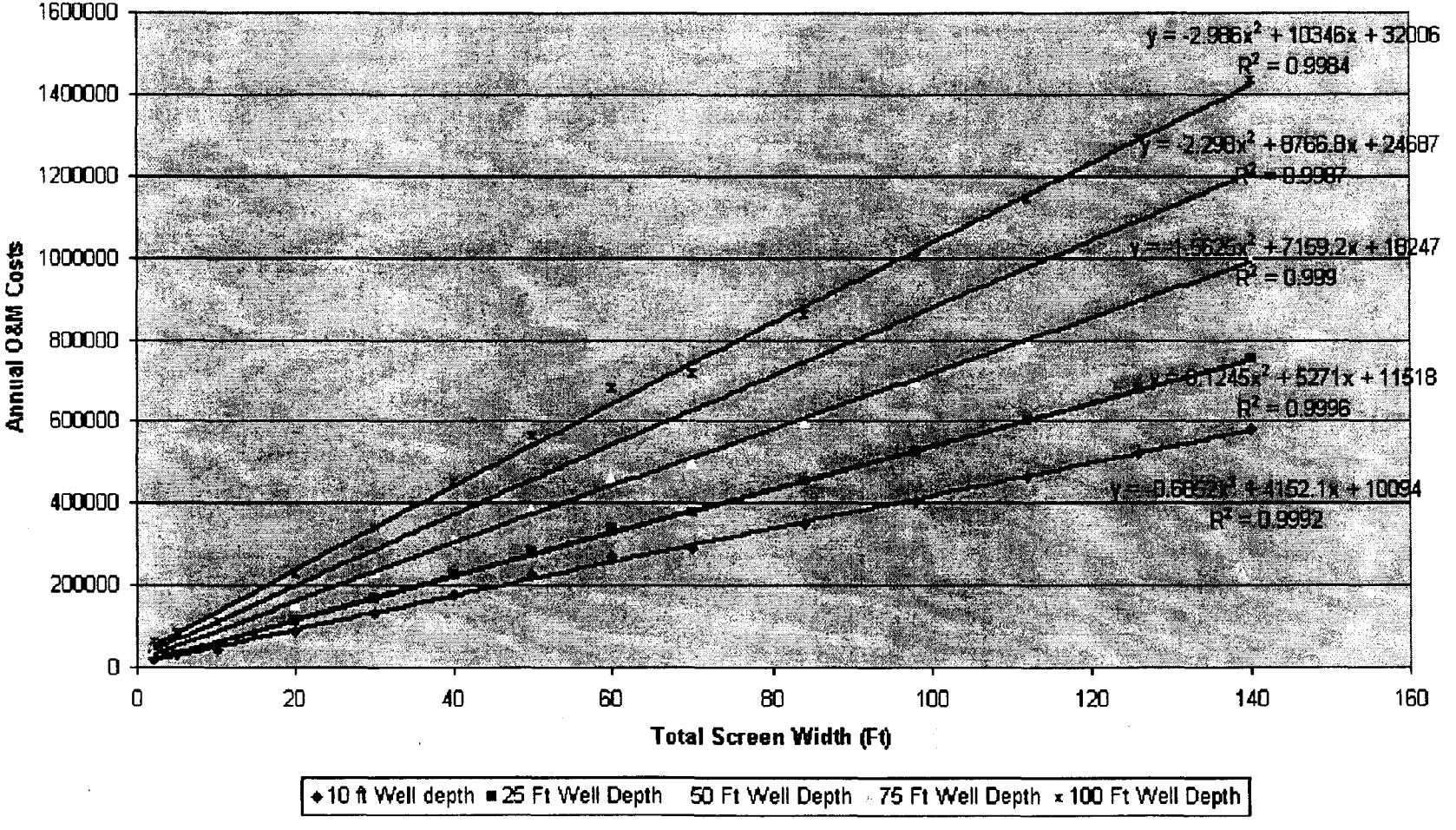


Figure 3-28. Baseline & Scenarios B Compliance O&M Total Costs for Traveling Screens With Fish Handling Freshwater Environments

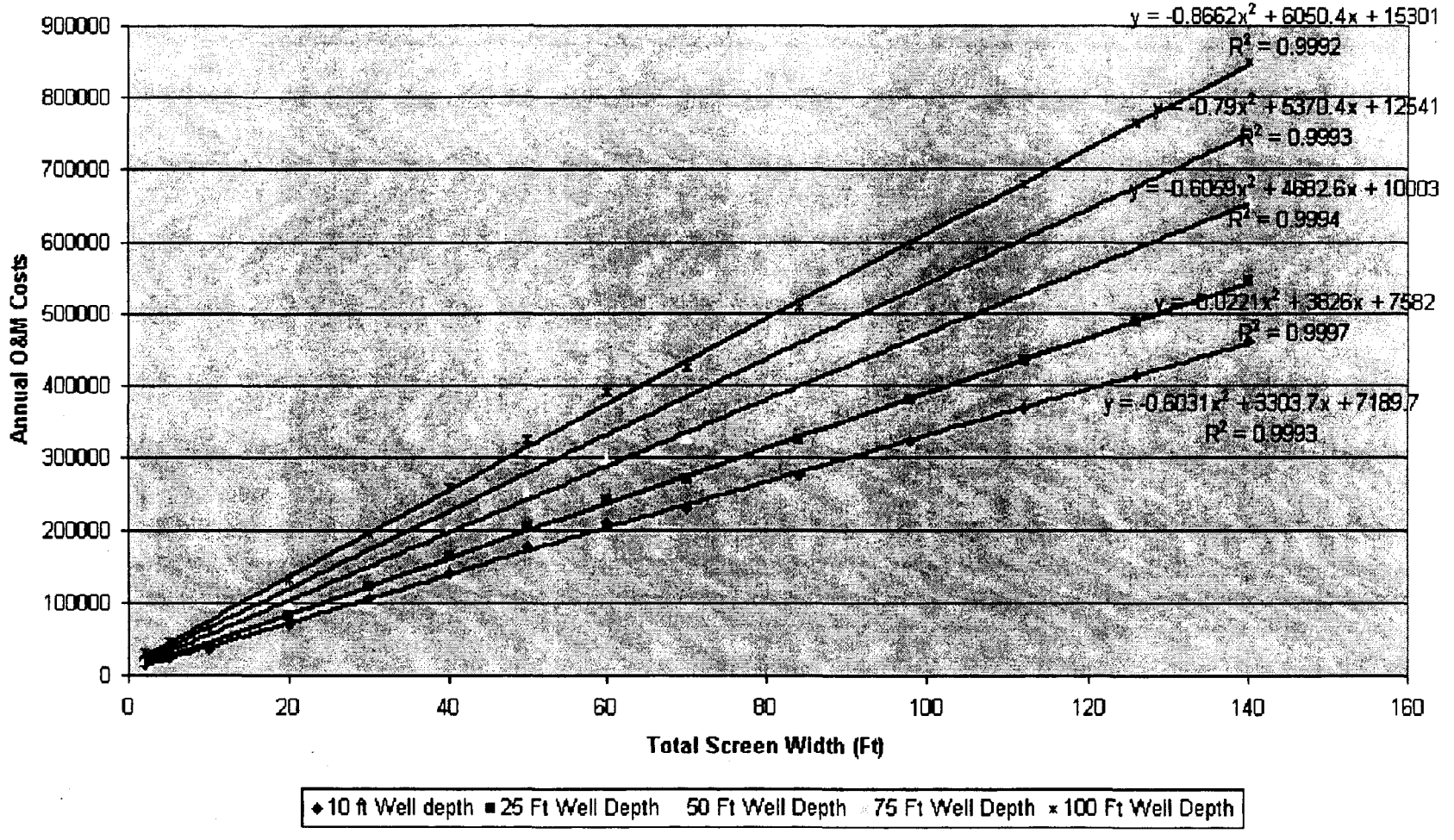


Figure 3-29. Baseline & Scenarios B Compliance O&M Total Costs for Traveling Screens With Fish Handling Saltwater Environments

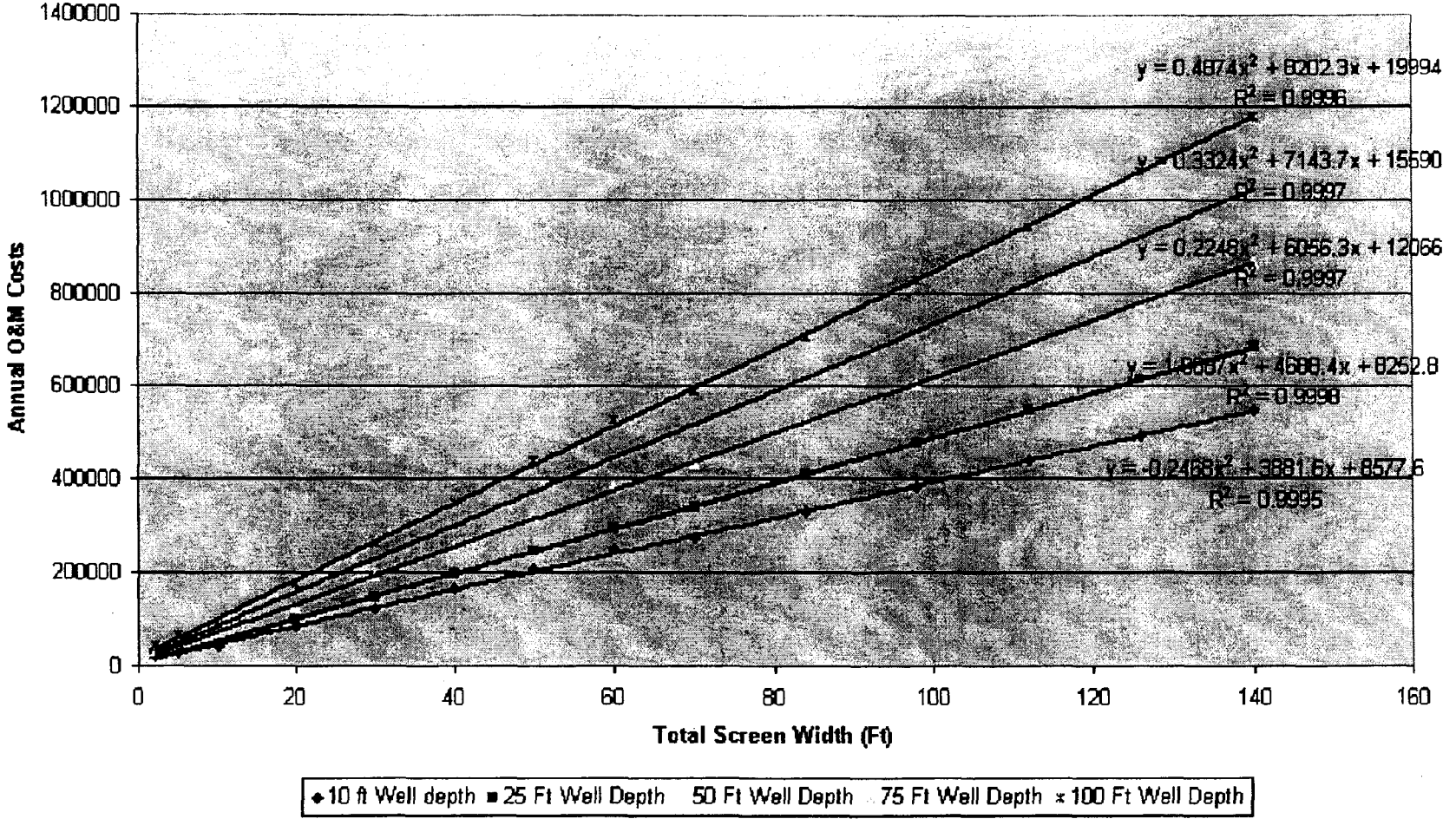
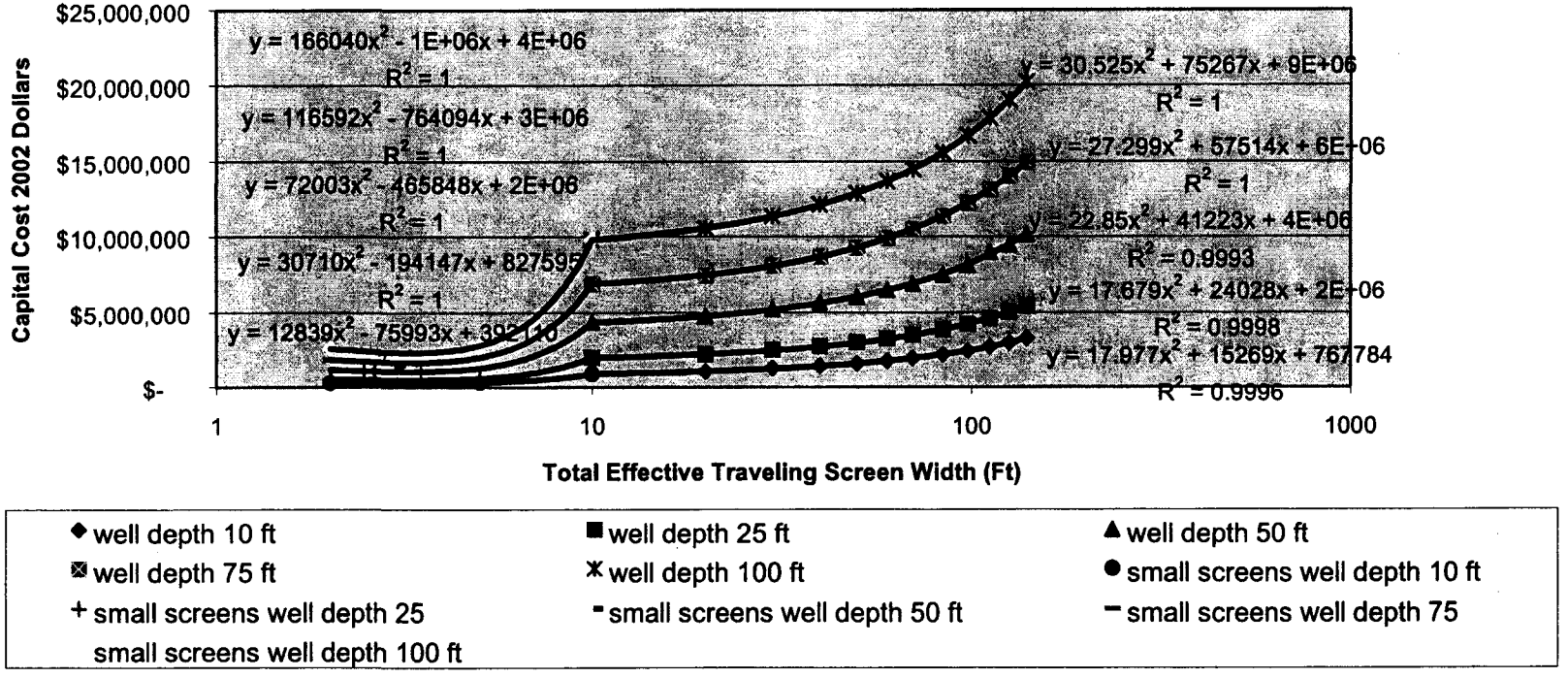


Figure 3-30. Total Capital Costs of New Larger Intake Structure



3.0 EXISTING SUBMERGED OFFSHORE INTAKES - ADD VELOCITY CAPS

Velocity caps are applicable to submerged offshore intakes. Adding velocity caps to facilities with existing or new submerged offshore intakes can provide appreciable impingement reduction. Therefore, this module may be most applicable when the compliance option only requires impingement controls and the intake requires upgrading. However depending on site-specific conditions, velocity caps could conceivably be used in conjunction with onshore screening systems tailored for entrainment reduction.

Research on velocity cap vendors identified only one vendor, which is located in Canada. (A possible reason for this scarcity in vendors is that many velocity caps are designed and fabricated on a site-specific basis, often called "intake cribs".) This vendor manufactures a velocity cap called the "Invisihead," and was contacted for cost information (Elarbash 2002a and 2002b). The Invisihead is designed with a final entrance velocity of 0.3 feet per second and has a curved cross-section that gradually increases the velocity as water is drawn farther into the head. The manufacturer states the gradual increase in velocity though the velocity cap minimizes entrainment of sediment and suspended matter and minimizes inlet pressure losses (Elmosa 2002). All costs presented below are in July 2002 dollars.

3.1 Capital Costs

The vendor provided information for estimating retrofit costs for velocity caps manufactured both from carbon steel and from stainless steel. Stainless steel construction is recommended for saltwater conditions to minimize corrosion. Carbon steel is recommended for freshwater systems. Due to the rather large opening, Invisihead performance is not affected by the attachment of Zebra mussels, so no special materials of construction are required where Zebra mussels are present.

Installation costs include the cost for a support vessel and divers to cut, weld and/or bolt the fitting flange for the velocity cap; make any needed minor reinforcements of the existing intake; and install the cap itself. Installation was said to take between two and seven days, depending on the size and number of heads in addition to the retrofit steps listed above. Costs also include mobilization and demobilization of the installation personnel, barge, and crane. The vendor indicated these costs included engineering and contractor overhead and profit, but did not provide break-outs or percentages for these cost components. EPA has concluded that the installation costs for adding a velocity cap on a new intake (relocated offshore) and on an existing offshore intake should be similar because most of the costs involve similar personnel and equipment. (See the "Application" section below for a discussion of new/existing submerged offshore intake cost components.)

Exhibit 3-47 presents the component (material, installation, and mobilization/demobilization) and total capital costs for stainless steel and carbon steel velocity caps provided by the vendor (Elarbash 2002a and 2002b). Data are presented for flows ranging from 5,000 gpm to 350,000 gpm. Figure 3-31 presents a plot of these data. The upper end of this flow range covers existing submerged pipes up to 15 feet in diameter at pipe velocities of approximately 5 feet per second. Second-order polynomial equations provided the best fit to the data and were used to produce cost curves. These cost curves serve as the basis for estimating capital costs for installing velocity caps on existing or new intakes submerged offshore at Phase III facilities. When applying these cost curves, if the intake flow exceeds 350,000 gpm plus 10% (385,000 gpm), the flow is divided into equal increments and these lower flows costed. The costs for these individual incremental flows are summed to estimate total capital cost. In these cases, costs are assumed to be applied to multiple intake pipes. If the intake flow is less than 5,000 gpm, the capital cost for 5,000 gpm will be used rather than extrapolating beyond the bottom end of the cost curve.

3.2 O&M Costs

For velocity caps, O&M costs generally include routine inspection and cleaning of the intake head. As noted above, biofouling does not affect velocity cap performance, so rigorous cleaning is not necessary. The vendor stated that their equipment is relatively maintenance free. However, O&M costs based on an annual inspection and cleaning of offshore intakes by divers were cited by facilities with existing offshore intakes, including some with velocity caps and especially those with bar racks at the intake. Therefore, estimated O&M costs are presented for an annual inspection and cleaning by divers because EPA believes this is common practice for submerged offshore intakes of all types.

Exhibit 3-48 presents the component and total O&M costs for the diver inspection and cleaning, for one to four days (Paroby 1999). In general, O&M costs are based on less than one day per head for inspection and cleaning of smaller intake heads and one day per head for the largest intake head. There is a minimum of one day for each inspection event. Inspection and cleaning events are assumed to occur once per year. Figure 3-32 presents the plot of the O&M costs by flow. A second-order polynomial equation provided the best fit to this data and serves as the basis for estimating the O&M costs.

Figure 3-32 also shows data for two facilities that reported actual O&M costs based on diver inspection and cleaning of submerged offshore intakes. While these two facilities use different intake technologies (passive screens for the smaller flow and bar rack type intakes for the larger flow), the inspection and cleaning effort should be similar for all three types of intakes. For both facilities, the actual reported O&M costs were less than the costs estimated using the cost curves, indicating that the estimated O&M costs should be considered as high-side estimates.

3.3 Application

As Retrofit of Existing Offshore Intake

Adding velocity caps to facilities with existing offshore intakes will provide impingement reduction only. For facilities withdrawing from saltwater/brackish waters (ocean and estuarine/tidal rivers), the capital cost curve for stainless steel caps will be applied. For the remaining facilities withdrawing freshwater (freshwater rivers/streams, reservoirs/lakes, Great Lakes), the capital cost curve for carbon steel caps will be applied. The same O&M cost curve will be used for both freshwater and saltwater systems. It is assumed that the existing intake is in a location that will provide sufficient clearance and is away from damaging wave action.

As Component of Relocating Existing Shoreline Intake to Submerged Offshore

These same velocity cap retrofit costs can be incorporated into retrofits where an existing shoreline intake is relocated to submerged offshore. In this application, some of the same equipment and personnel used in velocity cap installation may also be used to install other intake components, such as the pipe. Therefore, the mobilization/demobilization component could be reduced if these tasks are determined to occur close together in time. However, a high-side costing approach would be to cost each step separately, using the same velocity cap costs for both new and existing offshore intake pipes. In this case, the installation costs for velocity caps at existing offshore intakes (which include costs for cutting, and welding and/or bolting the velocity cap in place) are assumed to also cover costs of installing connection flanges at new offshore intakes. Costs for other components of relocating existing shoreline intakes to submerged offshore are developed as a separate cost module associated with passive screens. The compliance cost estimates did not include this scenario.

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Elmosa. Website at http://www.imasar.com/elmosa/invisiheaddetails.htm accessed May 9, 2002.

Paroby, Rich. Personal communication between Rich Paroby, District Sales Manager, Water Process Group and Deborah Nagle, USEPA E-mail dated May 12, 1999.

Exhibit 3-47. Velocity Cap Retrofit Capital and O&M Costs (2002 $)

Velocity Cap Retrofit Capital and O&M Costs (2002 $)

Flow (gpm) Water Type	# Heads All	Material Costs - Stainless Steel /Head Saltwater	Material Costs - Stainless Steel Total Saltwater	Material Costs - Carbon Steel /Head Freshwater	Material Costs - Carbon Steel Total Freshwater	Installation All	Mobilization/ Demobilization All	Total Capital Costs - Stainless Steel Saltwater	Total Capital Costs - Carbon Steel Freshwater	Total O&M All
5,000	1	$30,000	$30,000	$22,500	$22,500	$25,000	$10,000	$65,000	$57,500	$5,260
10,000	1	$30,000	$30,000	$22,500	$22,500	$30,000	$15,000	$75,000	$67,500	$5,260
25,000	1	$40,000	$40,000	$30,000	$30,000	$35,000	$15,000	$90,000	$80,000	$5,260
50,000	2	$35,000	$70,000	$26,250	$52,500	$49,000	$25,000	$144,000	$126,500	$7,250
100,000	2	$80,000	$160,000	$60,000	$120,000	$49,000	$25,000	$234,000	$194,000	$7,250
200,000	4	$80,000	$320,000	$60,000	$240,000	$98,000	$30,000	$448,000	$368,000	$11,230
350,000	4	$106,000	$424,000	$79,500	$318,000	$98,000	$30,000	$552,000	$446,000	$11,230

Note: Vendor indicated installation took 2 to 7 days

Note: Installation includes retrofit activities such as cutting pipe and & attaching connection flange on intake inlet pipe.

Exhibit 3-48. Installation and Maintenance Diver Team Costs

Installation and Maintenance Diver Team Costs

Item	Daily Cost*	One Time Cost*	Total	Adjusted Total			
Duration			One Day	One Day	Two Day	Three Day	Four Day
Cost Year			1999	2002	2002	2002	2002
Supervisor	$575		$575	$627	$1,254	$1,880	$2,507
Tender	$200		$200	$218	$436	$654	$872
Diver	$375		$750	$818	$1,635	$2,453	$3,270
Air Packs	$100		$100	$109	$218	$327	$436
Boat	$200		$200	$218	$436	$654	$872
Mob/Demob		$3,000	$3,000	$3,270	$3,270	$3,270	$3,270
Total			$4,825	$5,260	$7,250	$9,240	$11,230

*Source: Paroby 1999 (cost adjusted to 2002 dollars).

Figure 3-31. Velocity Cap Capital Costs 2002 Dollars

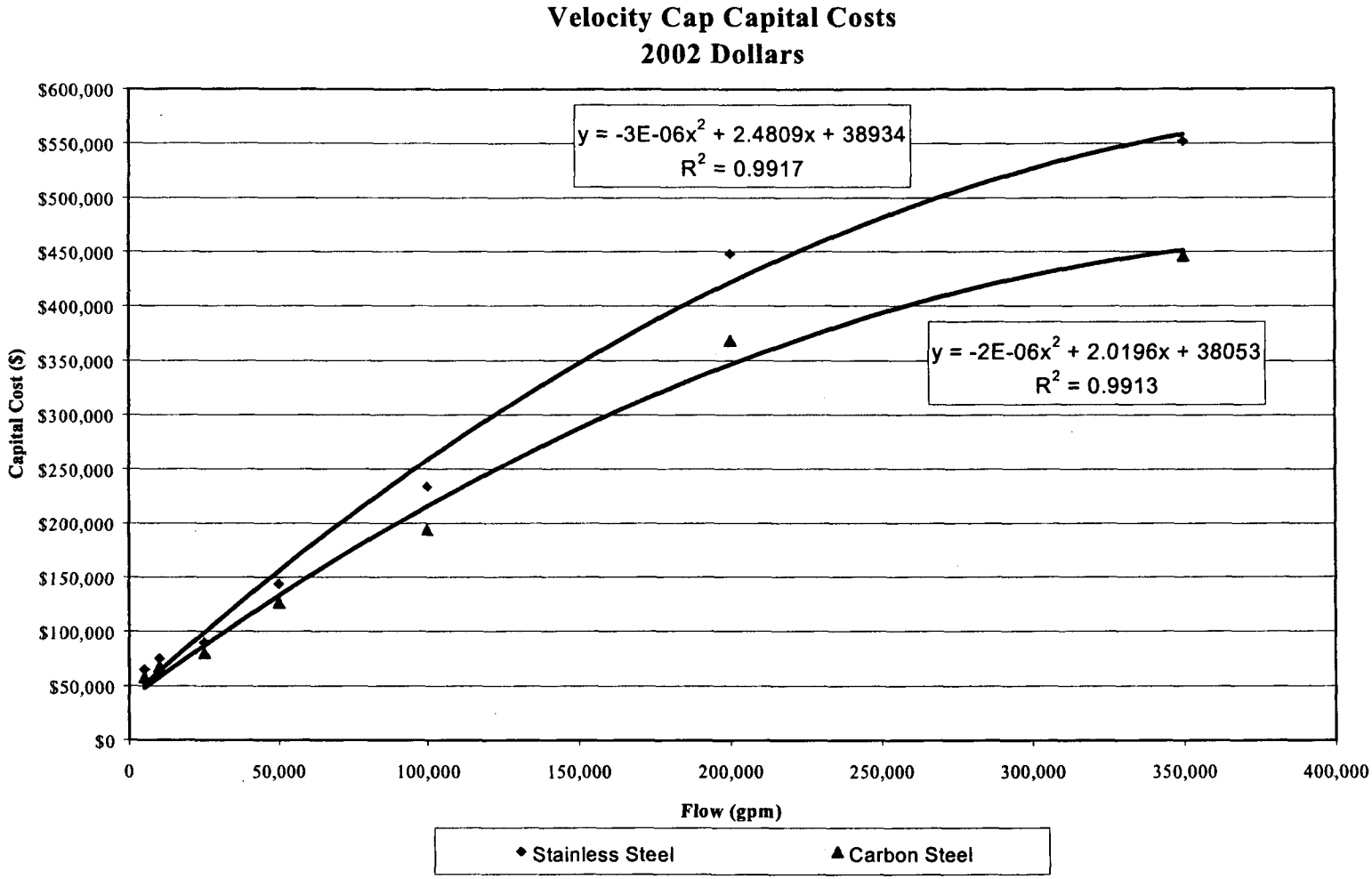
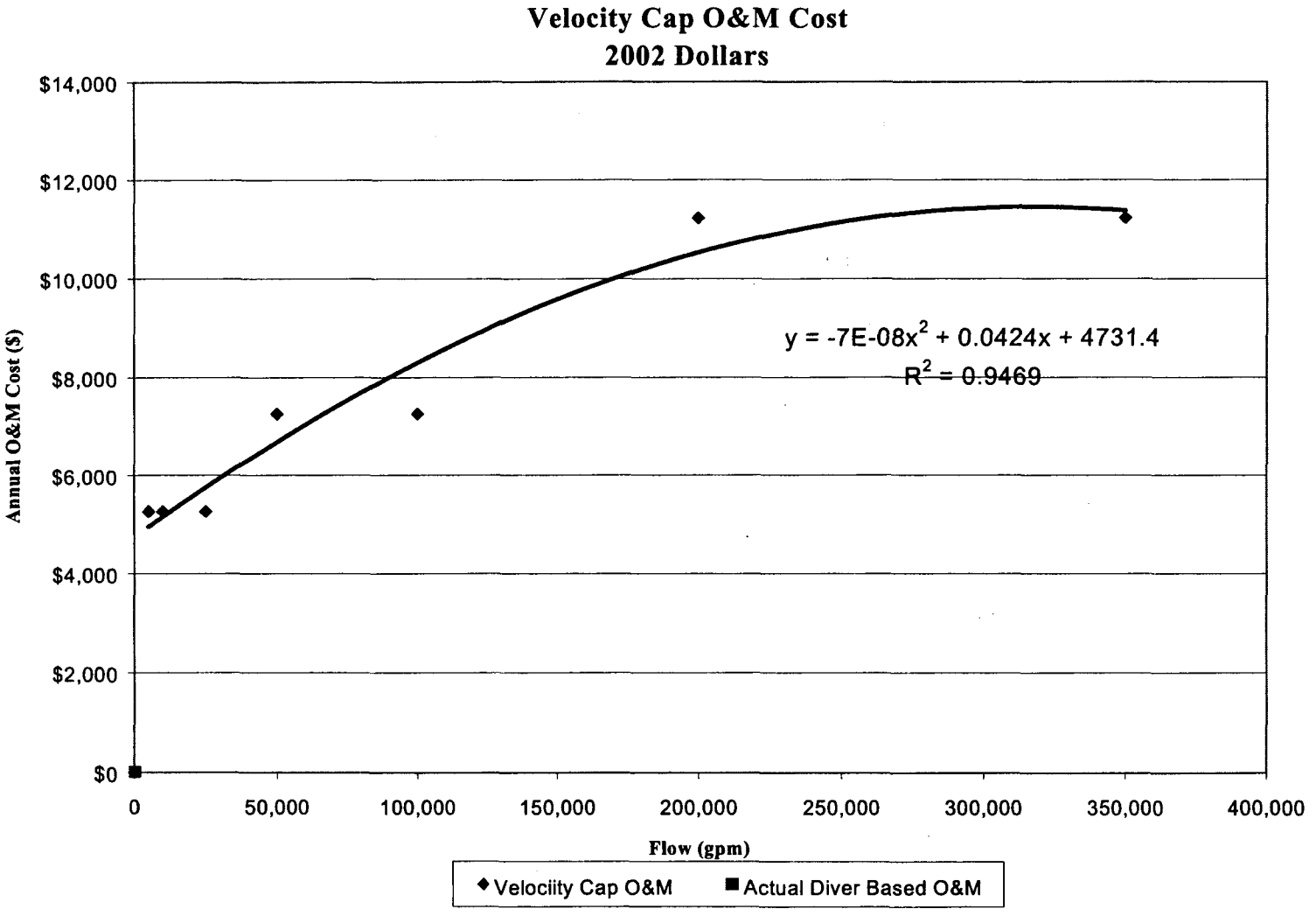


Figure 3-32. Velocity Cap O&M Cost 2002 Dollars



4.0 FISH BARRIER NETS

Fish barrier net can be used where improvements to impingement performance is needed. Because barrier nets can be installed independently of intake structures, there is no need to include any costs for modifications to the existing intake or technology employed. Costs are assumed to be the same for both new and existing facilities. Barrier nets can be installed while the facility is operating. Thus, there is no need to coordinate barrier net installation with generating unit downtime.

Fish Barrier Net Questionnaire

EPA identified seven facilities from its database that employed fish barrier nets and sent them a brief questionnaire requesting barrier net design and cost data (EPA 2002). The following four facilities received but did not submit a response:

Bethlehem Steel - Sparrows Point
Consumers Energy Co. - J.R. Whiting Plant
Exelon Corp. (formerly Commonwealth Edison) - LaSalle County Station
Southern Energy - Bowline Generating Station

The following three facilities submitted completed questionnaires:

Entergy Arkansas, Inc. - Arkansas Nuclear One
Potomac Electric Power Co. - Chalk Point
Minnesota Power - Laskin Energy Center

Net Velocity

An important design criterion for determining the size of fish barrier nets is the velocity of the water as it passes through the net. Net velocity (which is similar to the approach velocity for a traveling screen) determines how quickly debris will collect on the nets. Net velocity also determines the force exerted on the net, especially if it becomes clogged with debris. For facilities that supplied technical data, Exhibit 3-49 presents the design intake flow (estimated by EPA) and facility data reported in the Barrier Net Questionnaire. These data include net size, average daily intake flow, and calculated net velocities based on average and design flows. Note that the Chalk Point net specifications used for purchasing the net, indicated a net width of 27 ft (Langley 2002) while the Net Questionnaire reported a net width of 30 ft. A net width of 27 ft was used for estimating net velocities and unit net costs. The two larger facilities have similar design net velocity values that, based on design flow, is equal to 0.06 feet per second. This values are roughly an order of magnitude lower than compliance velocities used for rigid screens in the Phase I Rule as well as design velocities recommended for passive screens. There are two reasons for this difference. One difference is rigid screens can withstand greater pressure differentials because they are firmly held in place. The second is rigid screens can afford to collect debris at a more rapid rate because they have an active means for removing debris collected on the surface.

Based on the data presented in Exhibit 3-49, EPA has selected a net velocity of 0.06 feet per second (using the design flow) as the basis for developing compliance costs for fish barrier nets. Nets tested at a high velocity (> 1.3 feet per second) at a power plant in Monroe Michigan clogged and collapsed. Velocities higher than 0.06 feet per second may be acceptable at locations where the debris loading is low or where additional measures are taken to remove debris. While tidal locations can have significant water velocities, the periodic reversal of flow direction can help dislodge some of the debris that collects on the nets. The technology scenario described below, for tidal waterbodies, is designed to accommodate significant debris loading through the use of dual nets and frequent replacement with cleaned nets.

Exhibit 3-49. Net Velocity Data Derived from Barrier Net Questionnaire Data

Facility Owner	Facility Name	Depth*	Length*	Area	EPA Design Flow	Net Velocity at Design Flow	Average Daily Flow*	Net Velocity at Daily Flow
		Ft	Ft	sq ft	gpm	fps	gpm	fps
PEPCO	Chalk Point	27	1000	27,000	762,500	0.06	500,000	0.04
Entergy	Arkansas Nuclear One	20	1500	30,000	805,600	0.06	593,750	0.04
Minn. Power	Laskin Energy Center	16	600	9,600	101,900	0.02	94,250	0.02

* Source: 2002 EPA Fish Barrier Net Questionnaire and Langley 2002

Mesh Size

Mesh size determines the fish species and juvenile stages that will be excluded by the net. While smaller mesh size has the ability to exclude more organisms, it will plug more quickly with debris. The Chalk Point facility tried to use 0.5-inch stretch mesh netting and found that too much debris collected on the netting; it instead uses 0.75 inch stretch (0.375 inch mesh) netting (Langley 2002). Unlike rigid screens, fish nets are much more susceptible to lateral forces which can collapse the net.

Mesh size is specified in one of two ways, either as a "bar" or "stretch" dimension. A "stretch" measurement refers to the distance between two opposing knots in the net openings when they are stretched apart. Thus, assuming a diamond shaped netting, when the netting is relaxed the distance between two opposing sides of an opening will be roughly ½ the stretch diameter. A "bar" measurement is the length of one of the four sides of the net opening and would be roughly equal to ½ the stretch measurement. The term "mesh size" as used in this document refers to either ½ the "stretch" measurement or is equal to the "bar" measurement

Exhibit 3-50 presents reported mesh sizes from several power plant facilities that either now or in the past employed fish barrier nets. An evaluation report of the use of barrier fish nets at the Bowline Plant in New York cited that 0.374 inch mesh was more effective than 0.5 inch mesh at reducing the number of fish entering the plant intake (Hutcheson 1988). Both fish barrier net cost scenarios described below are based on nets with a mesh size of 0.375 in. (9.5 mm) and corresponds to the median mesh size of those identified by EPA.

Exhibit 3-50. Available Barrier Net Mesh Size Data

Facility	Description	Reported Mesh Size		Type of Measurement and Source	Effective Mesh Size	
		Inch	mm		Inch	mm
Chalk Point	Inner Net	0.75	19	Stretch (1)	0.375	9.5
	Outer Net	1.25	32	Stretch (1)	0.625	15.9
Entergy Arkansas	Low	0.375	10	Mesh (Bar) (1)	0.375	9.5
Nuclear One	High (preferred)	0.5	13	Mesh (Bar) (1)	0.5	12.7
Laskin Energy		0.25	6.4	Mesh (Bar) (1)	0.25	6.4
Bowline Point	More Effective Size	0.374	9.5	Bar (3)	0.374	9.5
J.P. Pulliam		0.25	6.4	Stretch (2)	0.126	3.2
				Median	0.374	9.5

(1): 2002 EPA Fish Barrier Survey
(2):ASCE 1982
(3): Hutcheson 1988

Twine

Twine size mostly determines the strength and weight of the fish netting. Only the Chalk Point facility reported twine size data (#252) knotless nylon netting. Netting #252 is a 75-lb test braided nylon twine in which the twine joints are braided together rather than knotted (Murelle 2002). The netting used at the Bowline Power Plant was cited as multi-filament knotted nylon, chosen because of its low cost and high strength (Hutcheson 1988).

Support/Anchoring System

In general, two different types of support and anchoring systems have been identified by EPA. In the simplest system the nets are held in-place and the bottom is sealed with weights running the length of the bottom usually consisting of a chain or a lead line. The weights may be supplemented with anchors placed at intervals. Vendors indicated the requirement for anchors varies depending on the application and waterbody conditions. The nets are anchored along the shore and generally placed in a semi-circle or arc in front of the intake. The Bowline Facility net used a v-shape configuration with an anchor and buoy at the apex and additional anchors placed midway along the 91 meter length sides. In some applications anchors may not be needed at all. If the nets are moved by current or waves, they can be set back into the proper position using a boat. The nets are supported along the surface with buoys and floats. The buoys may support signs warning boaters of the presence of the net. The required spacing and size of the anchors and buoys is somewhat dependent on the size of the net and lateral water velocities. The majority of facilities investigated used this

float/anchor method of installation. This net support configuration, using weights, anchors, floats, and buoys, is the basis for compliance scenario A.

A second method is to support nets between evenly spaced pilings. This method is more appropriate for water bodies with currents. The Chalk Point Power Plant uses this method in a tidal river. The Chalk Point facility uses two concentric nets. Each has a separate set of support pilings with a spacing between pilings of about 18 feet to 20 feet (Langley 2002). Nets are hung on the outside of the pilings with spikes and are weighted on the bottom with galvanized chain. During the winter top of the net is suspended below the water surface to avoid ice damage but generally thick ice does not persist during the winter months at the facility location.

Debris

Debris problems generally come in two forms. In one case large floating debris can get caught in the netting near the surface and result in tearing of the netting. In the other cases, floating and submerged debris can plug the openings in the net. This increases the hydraulic gradient across the net, resulting in net being pulled in the downstream direction. The force can become so great that it can collapse the net, and water flows over the top and/or beneath the bottom. If the net is held in place by only anchors and weights it may be moved out of place. At the Chalk Point facility, debris that catches on the nets mostly comes in the form of jellyfish and colonial hydroids (Langley 2002).

Several solutions are described for mitigating problems created by debris. At the Chalk Point Power Plant two concentric nets are deployed. The outer net has a larger mesh opening designed to capture and deflect larger debris so it does not encounter the inner net, which catches smaller debris. This configuration reduces the debris buildup on any one net extending the time period before net cleaning is required. Growth of algae and colonization with other organisms (biofouling) can also increase the drag force on the nets. Periodic removal and storage out of the water can solve this problem. At Chalk Point both nets are changed out with cleaned nets on a periodic basis. This approach is considered to be appropriate for high debris locations.

Another solution is to periodically lift the netting and manually remove debris. A solution for floating debris is to place a debris boom in front of the net (Hutcheson 1988).

Ice

During the wintertime ice can create problems in that the net can become embedded in surface ice with the net subject to tear forces when the ice breaks up or begins to move. Flowing ice can create similar problems as floating debris. Ice will also affect the ability to perform net maintenance such as debris removal. Solutions include:

- Removing the nets during winter
- Drop the upper end of the net to a submerged location; can only be used with fixed support, such as pilings and in locations where thick ice is uncommon
- Installing an air bubbler below the surface. Does not solve problems with flowing ice.

Net Deployment

EPA assumes that barrier nets will be used to augment performance of the existing shore-based intake technology such as traveling screens. The float/anchor supported nets are assumed to be deployed on a seasonal basis to reduce impingement of fish present during seasonal migration. The Arkansas Energy Arkansas Nuclear One Plant deploys their net for about 120 days during winter months. The Minnesota Power Laskin Energy Center, which is located on a lake, deploys the net when ice has broken up in spring and removes the net in the fall before ice forms. Thus, the actual deployment period will vary depending on presence of ice and seasonal migration of fish. For the compliance scenario that relies upon float/anchor supported nets, a total deployment period of eight months (240 day) is assumed. This is equal to or greater than most of the deployment periods observed by EPA.

EPA notes that the Chalk Point facility currently uses year round deployment and avoids problems with ice in the winter time by lowering the net top to a location below the surface. Prior to devising this approach, nets were remove during the winter months. This option is available because the nets are supported on pilings. Thus, the surface support rope (with floats removed) can be stretched between the pilings several feet below the surface. Therefore, a scenario where nets are supported by pilings may include year round deployment as was the case for the Chalk Point Power Plant. However, in northern climates the sustained presence of thick ice during the winter may prevent net removal and cleaning and therefore, it may still be necessary to remove the nets during this period.

4.1 Capital Cost Development

Compliance costs are developed for the two different net scenarios.

Scenario A Installation at Freshwater Lake Using Anchors and Buoys/Floats

This scenario is intended for application in freshwater waterbodies where low water velocities and low debris levels occur such as lakes and reservoirs. This scenario is modeled on the barrier net data from the Entergy Arkansas Nuclear One facility but has been modified to double the annual deployment period from 120 days to 240 days. Along with doubling the deployment period, the labor costs were increased to include an additional net removal and replacement step midpoint through this period. To facilitate the mid season net replacement, the initial net capital costs will include purchase of a replacement net.

Scenario B Installation Using Pilings.

This scenario is modeled after the system used at Chalk Point. In this case two nets are deployed in concentric semi-circles with the inner net having a smaller mesh (0.375 in) and the outer net having a larger mesh. Deployment is assumed to be year round. A marine contractor performs all O&M, which mostly involves periodically removing and the replacing both nets with nets they have cleaned. The initial capital net costs will include purchase of a set of replacement nets. This scenario is intended for application in waterbodies with low or varying currents such as tidal rivers and estuaries. Two different O&M cost estimates are developed for this scenario. In one the deployment is assumed to be year round as is the case at Chalk Point. In the second, the net is deployed for only 240 days being taken out during the winter months. This would apply to facilities northern regions where ice formation would make net maintenance difficult.

Net Costs

The capital costs for each scenario includes two components, the net and the support. The net portion includes a rope and floats spaced along the top and weights along the bottom consisting of either a "leadline"or chain. If similar netting specifications are used the cost of the netting is generally proportional to the size of the netting and can be expressed in a unitized manner such as "dollars/sq ft." Exhibit 3-51 presents the reported net costs and calculated unit costs. While different water depths will change the general ratio of net area to length of rope/floats and bottom weights, the differences in depth also result in different float and weight requirements. For example, a shallower net will require more length of surface rope and floats and weights per unit net area but a shallower depth net will also exert less force and require smaller floats and weights.

EPA is using the cost of nets in the average depth range of 20 to 30 feet as the basis for costing. This approach is consistent with the median Phase III facility shoreline intake depth of 18 feet and median "average bay depth" of 20 feet. While nets are deployed offshore in water deeper than a shoreline intake, costs are for average depths, which include the shallow sections at the ends, and net placement can be configured to minimize depth. To see how shallower depths may affect unit costs, the costs for a shallower 10-foot net with specifications similar to the Chalk Point net (depth of 27 feet) were obtained from the facility's net supplier. As shown in Exhibit 3-51, the unit cost per square foot for the shallower net was less than the deeper net. Therefore, EPA has concluded that the use of shallower nets does not increase unit costs and has chosen to apply the unit costs, based on the 20-foot and 30-foot depth nets, to shallower depths.

Exhibit 3-51 presents costs obtained for the net portion only from the facilities that completed the Barrier Net Questionnaire. These costs have been increased by 12% over what was reported to include shipping costs. This 12% value was obtained from the Chalk Point net supplier who confirmed that the costs reported by Chalk Point did not include shipping. (Murelle 2002) The unit net costs range from $0.17/sq ft to $0.78/sq ft. Consultation with net vendors indicates that the barrier net specifications vary considerably and that there is no standard approach. Although no net specification data (besides mesh size) was submitted with the Laskin Energy Center data, EPA has concluded that the data for this net probably represents lower strength netting which would be suitable for applications where the netting is not exposed to significant forces. Because the compliance cost scenarios will be applied to facilities with a variety net strength requirements, EPA has chosen to use the higher net costs that correspond to higher net strength requirements. As such, EPA has chosen to use the cost data for the Chalk Point and Arkansas Nuclear One facilities as the basis for each scenario.

Exhibit 3-51 Net Size and Cost Data

Facility	Depth	Length	Area	Component	Cost/net	Cost/sq ft
	ft	ft	sq ft			
Chalk Point	27	300	8,100	Replacement Net 0.675 in.*	$4,640	$0.57
	27	300	8,100	Replacement Net 0.375 in.*	$4,410	$0.54
Chalk Point (equivalent	10	300	3,000	Replacement Net*	$1,510	$0.50
Entergy Arkansas	20	250	5,000	Replacement Net*	$3,920	$0.78
Entergy Arkansas	20	1500	30,000	Net & Support Costs**	$36,620	$1.22
Laskin Energy Center	16	600	9,600	Net Costs***	$1,600	$0.17

*Costs include floats and lead line or chain and are based on replacement costs plus 12% shipping.

** Costs include replacement net components plus anchors, buoys & cable plus 12% shipping

***Cost based on reported 1980 costs adjusted to 2002 dollars plus 12% for shipping.

Scenario A Net Costs

In this scenario the net and net support components are included in the unit costs. At the Arkansas Nuclear One facility unitized costs for the net and anchors/buoys are $1.22/sq ft plus $0.78/sq ft for the replacement net, resulting in a total initial unit net costs of $2.00/sq ft for both nets. Because the data in Exhibit 3-50 indicate that, if anything, unit costs for nets may decrease with shallower depths, EPA concluded that this unit cost was representative of most of the deeper nets and may slightly overestimate the costs for shallower nets.

Scenario A Net Installation costs

Installation costs for Arkansas Nuclear One (Scenario A) were reported as $30,000 (in 1999 dollars; $32,700 when adjusted for inflation to 2002 dollars) for the 30,000 sq ft net. This included placement of anchors and cable including labor. In order to extrapolate the installation costs for different net sizes, EPA has assumed that approximately 20% ($6,540) of this installation cost represents fixed costs (e.g., mobilization/demobilization). The remainder ($26,160) divided by the net area results in an installation unit cost of $0.87/sq ft to be added to the fixed cost.

Scenario A Total Capital Costs

Exhibit 3-52 presents the component and total capital costs for Scenario A. Indirect costs are added for engineering (10%) and contingency/allowance (10%). Contractor labor and overhead are already included in the component costs. Because most of the operation occurs offshore no cost for sitework are included.

Exhibit 3-52. Capital Costs for Scenario A Fish Barrier Net With Anchors/Buoys as Support Structure

Flow (gpm)	2,000	10,000	50,000	100,000	250,000	500,000	750,000	1,000,000	1,250,000
Net Area (sq ft)	74	371	1,857	3,714	9,284	18,568	27,852	37,136	46,420
Net Costs	$149	$744	$3,722	$7,445	$18,611	$37,223	$55,834	$74,445	$93,057
Installation Costs Fixed	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540
Installation Costs Variable	$65	$324	$1,619	$3,238	$8,096	$16,191	$24,287	$32,383	$40,478
Total Direct Capital Costs	$6,754	$7,608	$11,881	$17,223	$33,247	$59,954	$86,661	$113,368	$140,075
Indirect Costs	$1,351	$1,522	$2,376	$3,445	$6,649	$11,991	$17,332	$22,674	$28,015
Total Capital Costs	$8,104	$9,130	$14,258	$20,667	$39,896	$71,945	$103,993	$136,042	$168,090

Scenario B Net Costs

In this scenario the net costs are computed separately from the net support (pilings) costs. In this scenario there are two separate nets and an extra set of replacement nets for each. This, the unit costs for the nets will be two times the sum of the units net costs for each of the large and small mesh nets. As shown in Exhibit 3-52, the unit costs for each net was $0.57/sq ft and $0.54/sq ft resulting in a total cost for all four nets of $2.24/sq ft for the area of a single net.

Scenario B Installation Costs

Installation costs were not provided for the Chalk Point facility. Initial net installation is assumed to be performed by the O&M contractor and is assumed to be a fixed cost regardless of net size. EPA assumed the initial installation costs to be two-thirds of the contractor, single net replacement job cost of $1,400 or $933 (See O&M Costs - Scenario B).

Scenario B Piling Costs

The cost for the pilings at the Chalk Point facility were not provided. The piling costs for scenario B is based primarily on the estimated cost for installing two concentric set of treated wooden pilings with a spacing of 20 ft between pilings. To see how water depth affects piling costs, separate costs were developed at water depths of 10 feet, 20 feet, and 30 feet. Piling costs are based on the following assumptions:

- Costs for pilings is based on a unit cost of $28.50/ ft of piling (RS Means, 2001)
- Piling installation mobilization costs are equal to $2,325 based on a mobilization rate of $46.50/mile for barge mounted pile driving equipment (RS Means 2001) and an assumed distance of 50 miles
- Each pile length includes the water depth plus a 6-foot extension above the water surface plus a penetration depth (at two-thirds the water depth); the calculated length was rounded up to the next even whole number
- The two concentric nets are nearly equal in length with one pile for every 20 feet in length and one extra pile to anchor the end of each net.

Exhibit 3-53 presents the individual pile costs and intake flow for each net section between two pilings (at 0.06 feet per second).

Exhibit 3-53. Pile Costs and Net Section Flow

Water Depth	Total Pile Length	Cost Per Pile	Flow Per 20 ft Net Section	Fixed Cost Mobilization
Ft	Ft		gpm	
10	24	684	5385.6	2325
20	40	1140	10771.2	2325
30	56	1596	16156.8	2325

Exhibits 3-54, 3-55, and 3-56 present the total capital costs and cost components for the installed nets and pilings. Indirect costs are added for engineering (10%) and contingency/allowance (10%). Contractor labor and overhead are already included in the component costs. Because most of the operation occurs offshore no cost for sitework are included. The costs were derived for nets with multiple 20 ft sections. Because the net costs are derived such that the cost equations are linear with respect to flow, the maximum number of sections shown are selected so they cover a similar flow range. Values that exceed this range can use the same cost equation.

Exhibit 3-54. Capital Costs for Fish Barrier Net With Piling Support Structure for 10 Ft Deep Nets

Number of 20 ft Sections	2	4	8	12	25	50	75	100	200
Total Number of Pilings	6	10	18	26	52	102	152	202	402
Single Net Length (ft)	40	80	160	240	500	1000	1500	2000	4000
Net Area (sq ft)	400	800	1,600	2,400	5,000	10,000	15,000	20,000	40,000
Flow (gpm)	10,771	21,542	43,085	64,627	134,640	269,280	403,920	538,560	1,077,120
Total Piling Cost	$6,429	$9,165	$14,637	$20,109	$37,893	$72,093	$106,293	$140,493	$277,293
Net Costs	$1,380	$1,827	$2,721	$3,614	$6,519	$12,106	$17,692	$23,279	$45,624
Total Direct Costs	$7,809	$10,992	$17,358	$23,723	$44,412	$84,199	$123,985	$163,772	$322,917
Indirect Costs	$1,562	$2,198	$3,472	$4,745	$8,882	$16,840	$24,797	$32,754	$64,583
Total Capital Costs	$9,371	$13,190	$20,829	$28,468	$53,295	$101,039	$148,782	$196,526	$387,501

Exhibit 3-55 Capital Costs for Fish Barrier Net With Piling Support Structure for 20 Ft Deep Nets

Number of 20 ft Sections	2	4	8	12	25	50	75	100
Total Number of Pilings	6	10	18	26	52	102	152	202
Single Net Length (ft)	40	80	160	240	500	1000	1500	2000
Net Area (sq ft)	800	1600	3200	4800	10000	20000	30000	40000
Flow (gpm)	21,542	43,085	86,170	129,254	269,280	538,560	807,840	1,077,120
Total Piling Cost	$9,165	$13,725	$22,845	$31,965	$61,605	$118,605	$175,605	$232,605
Net Costs	$1,827	$2,721	$4,508	$6,296	$12,106	$23,279	$34,452	$45,624
Total Direct Costs	$10,992	$16,446	$27,353	$38,261	$73,711	$141,884	$210,057	$278,229
Indirect Costs	$2,198	$3,289	$5,471	$7,652	$14,742	$28,377	$42,011	$55,646
Total Capital Costs	$13,190	$19,735	$32,824	$45,913	$88,453	$170,260	$252,068	$333,875

Exhibit 3-56. Capital Costs for Fish Barrier Net With Piling Support Structure for 30 Ft Deep Nets

Number of 20 ft Sections	2	4	8	12	25	50	75
Total Number of Pilings	6	10	18	26	52	102	152
Single Net Length (ft)	40	80	160	240	500	1000	1500
Net Area (sq ft)	1,200	2,400	4,800	7,200	15,000	30,000	45,000
Flow (gpm)	32,314	64,627	129,254	193,882	403,920	807,840	1,211,760
Total Piling Cost	$9,576	$15,960	$28,728	$41,496	$82,992	$162,792	$242,592
Net Costs	$2,274	$3,614	$6,296	$8,977	$17,692	$34,452	$51,211
Total Direct Costs	$11,850	$19,574	$35,024	$50,473	$100,684	$197,244	$293,803
Indirect Costs	$2,370	$3,915	$7,005	$10,095	$20,137	$39,449	$58,761
Total Capital Costs	$14,220	$23,489	$42,029	$60,568	$120,821	$236,692	$352,563

Figure 3-33 presents the total capital costs for scenarios A and B from Exhibits 3-52 through 3-56, plotted against design flow. Figure 3-33 also presents the best-fit linear equations used top estimate compliance costs. EPA notes that pilings for shallower depths costed out more, due to the need for many more pilings. Scenario B costs for 10-foot deep nets will be applied wherever the intake depth is less than 12 ft. For scenario B applications in water much deeper than 12 feet, EPA will use the cost equation for 20-foot deep nets.

4.2 O&M Costs Development

Scenario A O&M Costs - Float/Anchor Supported Nets

Barrier net O&M costs generally include costs for replacement netting, labor for net inspection, repair, and cleaning, and labor for net placement and removal. The Arkansas Nuclear One facility supplied data that estimate all three components for its 1500 ft long by 20 ft deep net located on a reservoir. Net deployment, however, was for only a 120-day period. This net is installed in November and removed in March (in-place for 120 days total). Each year two 250-foot sections of the net (one-third of the total) are replaced due to normal wear and tear.

EPA assumes the labor rate is similar to the estimate for traveling screen maintenance labor ($41.10/hr). The reported Arkansas Nuclear One O&M labor requirements includes 3 hrs per day during the time the net is deployed for inspection & cleaning by personnel on a boat (calculated at $14,800). This involves lifting and partially cleaning the nets on a periodic basis. Labor to deploy and remove the net was reported at 240 hrs (calculated at $9,860). Two sections of the six total net sections were replaced annually at a cost of $7,830 total (including shipping). Total annual O&M costs are calculated to be $32,500.

Because other facilities on lakes reported longer deployment periods (generally when ice is not present), EPA chose to adjust O&M costs to account for longer deployment. EPA chose to base O&M costs for scenario A on a deployment period of 240 days (approximately double the Arkansas Nuclear One facility deployment period). EPA also added costs for an additional net removal and deployment step using the second replacement net midway through the annual deployment period. The result is a calculated annual O&M cost of $57,200.

Scenario B O&M Costs - Piling Supported Nets

Nearly all of the O&M labor for Chalk Point facility is performed by a marine contractor who charges $1,400 per job to simultaneously remove the existing net and replace it with a cleaned net. This is done with two boats where one boat removes the existing net followed quickly by the second that places the cleaned net keeping the open area between nets minimized. The contractors fee includes cleaning the removed nets between jobs. This net replacement is performed about 52 to 54 times per years. It is performed about twice per week during the summer and once every two weeks during the winter. The facility relies upon the contractor to monitor the net. Approximately one third of the nets are replaced each year, resulting in a net replacement cost of $9,050.

Using an average of 53 contractor jobs per year and a net replacement cost of $9,050 the resulting annual O&M cost was $83,250. EPA notes that some facilities that employ scenario B technology may choose to remove the nets during the winter. As such, EPA has also estimated the scenario B O&M costs based on a deployment period of approximately 240 days by reducing the estimated number of contractor jobs from 53 to 43 (deducting 10 jobs using the winter frequency of roughly 1 job every 2 weeks). The resulting O&M costs are shown in Exhibits 3-56 and 3-57.

EPA notes that other O&M costs reported in literature are often less than what is shown in Exhibit 3-56. For example, 1985 O&M cost estimates for the JP Pulliam plant ($7,500/year, adjusted to 2002 dollars) calculate to $11,800 for a design flow roughly half that of Arkansas Entergy. This suggests the scenario A and B estimates represent the high end of the range of barrier net O&M costs. Other O&M estimates, however, do not indicate the cost components that are included and may not represent all cost components.

In order to extrapolate costs for other flow rates, EPA has assumed that roughly 20% of the Scenario A and B O&M costs represent fixed costs. Exhibit 3-57 presents the fixed and unit costs based on this assumption for both scenarios.

Exhibit 3-57. Cost Basis for O&M Costs

	Deployment	Net Replacement	O&M Labor	Model Facility O&M	Fixed Cost	Variable Costs	Unit Variable O&M Costs
	Days						$/sq ft
Scenario A	240	$7,830	$49,320	$57,150	$11,430	$45,720	$1.52
Scenario B	365	$9,050	$74,200	$83,250	$16,650	$66,600	$2.47
Scenario B	240	$9,050	$60,200	$69,250	$13,850	$55,400	$2.05

Note that Unit Variable O&M Costs are based on a total net area of 30,000 sq ft (Entergy Arkansas) for scenario A and 27,000 sq ft for scenario B (Chalk Point).

Exhibit 3-58 presents the calculated O&M costs based on the cost factors in Exhibit 3-57 and Figure 3-34 presents the plotted O&M costs and the linear equations fitted to the cost estimates.

Exhibit 3-58. Annual O&M Cost Estimates

Flow (gpm)		2,000	10,000	50,000	100,000	250,000	500,000	750,000	1,000,000	1,250,000
Net Area (sq ft)		74	371	1,857	3,714	9,284	18,568	27,852	37,136	46,420
Scenario A	240 days	$11,543	$11,996	$14,260	$17,090	$25,579	$39,728	$53,877	$68,025	$82,174
Scenario B	365 days	$16,833	$17,566	$21,230	$25,810	$39,551	$62,451	$85,352	$108,252	$131,153
Scenario B	240 days	$14,002	$14,612	$17,660	$21,470	$32,899	$51,949	$70,998	$90,048	$109,097

4.3 Nuclear Facilities

Even though the scenario A costs are modeled after the barriers nets installed at a nuclear facility, the higher unit net costs cited by the Arkansas Nuclear One facility include components that are not included with the non-nuclear Chalk Point nets and thus the differences may be attributed to equipment differences and not differences between nuclear and non-nuclear facilities. In addition, the labor rates used for scenario A and B O&M were for non-nuclear facilities. Because the function of barrier nets is purely for environmental benefit, and not critical to the continued function of the cooling system (as would be technologies such as traveling screens). EPA does not believe that a much more rigorous design is warranted at nuclear facilities. However, higher labor rates plus greater paperwork and security requirements at nuclear facilities should result in higher costs. As such, EPA has concluded that the capital costs for nuclear facilities should be increased by a factor of 1.58 (lower end of range cited in passive screen section). Because O&M costs rely heavily on labor costs, EPA has concluded that the O&M costs should be increased by a factor of 1.24 (based on nuclear vs non-nuclear operator labor costs).

4.4 Application

Fish barrier net technology will augment, but not replace, the function of any existing technology. Therefore, the calculated net O&M costs will include the O&M costs described here without any deductions for reduction in existing technology O&M costs. Fish barrier nets may not be applicable in locations where they would interfere with navigation channels or boat traffic.

Fish barrier nets require low waterbody currents in order to avoid becoming plugged with debris that could collapse the net. Such conditions can be found in most lakes and reservoirs, as well as some tidal waterbodies such as tidal rivers and estuaries. Placing barrier nets in a location with sustained lateral currents in one direction may cause problems because the section of net facing the current will continually collect debris at higher rate than the remainder of the net. In this case, net maintenance cleaning efforts must be able to keep up with debris accumulation. As such, barrier nets are suitable for intake locations that are sheltered from currents, e.g., locations within an embayment, bay, or cove. On freshwater rivers and streams only those facilities within an embayment, bay, or cove will be considered as candidates for barrier nets. The sheltered area needs to be large enough for the net sizes described above. The fish barrier net designs considered here would not be suitable for waterbodies with the strong wave action typically found in ocean environments.

Scenario A is most suitable for lakes and reservoirs where water currents are low or almost nonexistent. Scenario B is more suitable for tidal waterbodies and any other location where higher quantities of debris and light or fluctuating currents may be encountered. In northern regions where formation of thick ice in winter would prevent access to the nets, and scenario B may be applied, the scenario B O&M costs for a 240-day deployment should be used. However, because this scenario results in reduced costs, EPA has chose to apply the scenario B 365 days deployment for all facilities in suitable waterbodies.

EPA notes that nets with net velocities higher than 0.07 feet per second have been successfully employed (EPRI 1985). While such nets will be smaller than those described here, they will accumulate debris at a faster rate. Because the majority of the O&M costs are related to cleaning nets, EPA expects the increase in frequency of cleaning smaller nets will be offset by the smaller net size such that the smaller nets should require similar costs to maintain.

Facilities with Canals

Most facilities with canals have in-canal velocities of between 0.5 and 1 feet per second based on average flow. These velocities are an order of magnitude greater than the design net velocity used here. If nets with mesh sizes in the range considered here were placed within the canals they will likely experience problems with debris. Therefore, if barrier nets are used at facilities with canals, the net would need to be placed in the waterbody just outside the canal entrance.

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Figure 3-33. Total Capital Costs for Fish Barrier Nets

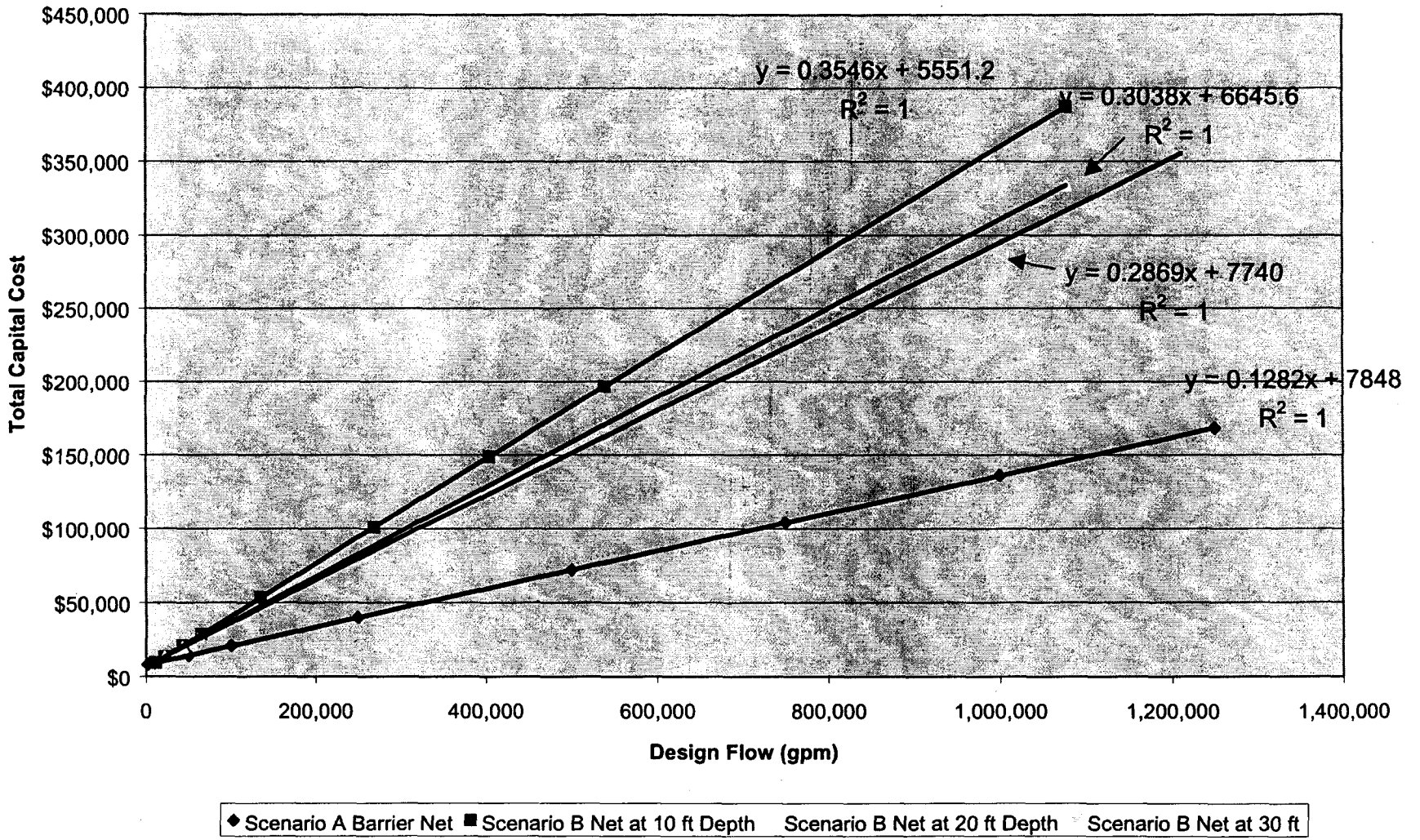
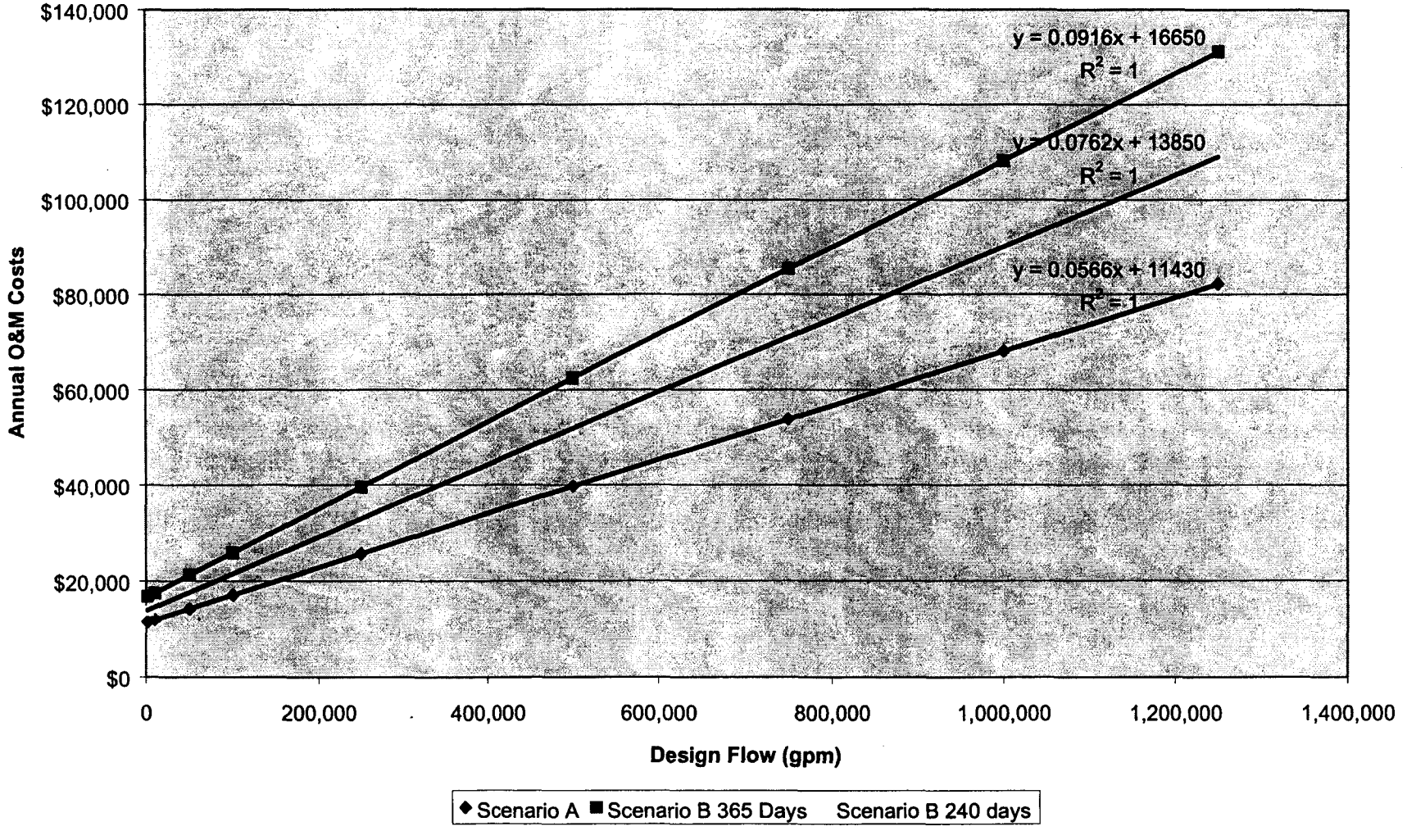


Figure 3-34. Barrier Net Annual O&M Costs



5.0 AQUATIC FILTER BARRIERS

Filter Barrier

Aquatic filter barrier systems are barriers that employ a filter fabric designed to allow passage of water into a cooling water intake structure, while excluding aquatic organisms. One company, Gunderboom, Inc., has a patented system, the Marine/Aquatic Life Exclusion System (MLES)™ that can be deployed as a full-water-depth filter curtain suspended from floating booms extending out in the waterway or supported on a fixed structure as described below. The filter fabric material is constructed of matted unwoven synthetic fibers.

Pore Size and Surface Loading Rate

Filter fabric materials with different pore sizes can be employed depending on performance requirements. In the MLES™ system two layers of fabric are used. Because the material is a fabric and thus the openings are irregular, the measure of the mesh or pore size is determined by an ASTM method that relies on a sieve analysis of the passage of tiny glass beads. The results of this analysis is referred to as apparent opening size. The standard MLES ™ filter fabric material has an apparent opening size (AOS) of 0.15 mm. (McCusker 2003b). Gunderboom can also provides filter fabric material that has been perforated to increase the apparent opening size. Available perforation sizes range from 0.4 mm to 2.0 mm AOS. The "apparent opening size" is referred to as the "pore size" in the discussion below. While smaller pore sizes can protect a greater variety of aquatic organisms, smaller the pore sizes also increase the proportion of suspended solids collected and thus the rate at which it collects. In addition, smaller pore sizes tend to impede the flow of water through the filter fabric which becomes even more pronounced as solids collect on the surface. This impedance of flow results in an increase in the lateral forces acting on the AFB. The filter surface loading rate (gpm/ sq ft) or equivalent approach velocity (feet per second) determines both the rate at which suspended particles collect on the filter fabric and the intensity of the lateral forces pushing against the AFB. While the airburst system (see description below) is designed to help dislodge and removed such suspended particles, there are practical limits regarding pore size and surface loading rate. For filter fabric of any given pore size, decreasing the surface loading rate will reduce the rate of solids accumulation and the lateral forces acting upon the AFB. Thus, pore size is an important design parameter in that it determines the types of organisms excluded as well as contributes to the selection of an acceptable surface loading rate. The surface loading rate combined with the cooling water intake design flow determines the required AFB surface area. This total filter fabric area requirement when combined with the local bathymetry determines the area that resides within the AFB.

Since the AFB isolates and essentially restricts the function of a portion of the local ecosystem, anything that increases the AFB total surface area will also increase the size of the isolated portion of the ecosystem. As such, there is an environmental trade off between minimizing the pore size to protect small size organisms/lifestages versus minimizing the size of the area being isolated. Additionally, requirements for large AFB surface areas may preclude its use where conflicts with other waterbody uses (e.g., navigation) or where the waterbody size or configuration restricts the area that can be impacted. Vendors can employ portable test equipment or pilot scale installations to test pore size selection and performance which can aid in the selection of the optimal pore size. Acceptable design filter loading rates will vary with the pore size and the amount of sediment and debris present. An initial target loading rate of 3 to 5 gpm/sq ft have been suggested (EPA 2001). This is equivalent to approach or net face velocities of 0.007 to 0.01 feet per second which is nearly an order of magnitude lower than the 0.06 feet per second design velocity used by EPA for barrier nets. This difference is consistent with the fact that barrier net use much greater mesh sizes. Use of larger AFB pore sizes can result in greater net velocities. Since the cost estimates as presented here are based on design flow, differences in design filter loading rates will affect the size of the AFB which directly affects the costs. The range between the high and low estimates in capital and O&M costs presented below account at least in part for the differences associated with variations in pore size as well as other design variations that result from differences in site conditions.

Floating Boom

For large volume intakes such as once-through systems, an AFB supported at the top by a floating boom that extends out into the waterbody and anchored onshore at each end is the most likely design configuration to be employed because of the large surface area required. In this design, a filter fabric curtain is supported by the floating boom at the top and is held against the bottom of the waterbody by weights such as a heavy chain. The whole thing is held in place by cables attached to fixed anchor points placed at regular intervals along the bottom. The Gunderboom MLES design employ a two layer filter fabric curtain that is divided vertically into sections to allow for replacement of an individual sections when necessary. The estimated capital and O&M costs described below are for an AFB using this floating boom-type construction.

Fixed Support

The AFB vendor, Gunderboom Inc., also provides an AFB supported by rigid panels that can be placed across the opening of existing intake structures. This technology is generally applicable to existing intakes where the intake design flow has been substantially reduced such as where once-through systems are being converted to recirculating cooling towers. For other installations, Gunderboom has developed what they refer to as a cartridge-type system which consists of rigid structures surrounded by filter fabric with filtered water removed from the center (McCusker 2003). Costs for either of these rigid type of installation have not been provided.

Air Backwash

The Gunderboom MLES™ employs an automated air burst technology that periodically discharges air bubbles between the two layers of fabric at the bottom of each MLES curtain panel. The air bubbles create turbulence and vibrations that help dislodge particulates that become entrained in the filter fabric. The airburst system can be set to purge individual curtain panels on a sequential basis automatically or can be operated manually. The airburst technology is included in the both the capital and O&M costs provided by the vendor.

5.1 Capital Cost Development

Estimated capital costs were provided by the only known aquatic filter barrier manufacturer, Gunderboom, Inc. Cost estimates were provided for AFBs supported by floating booms representing a range of costs; low, high, and average that may result from differences in construction requirements that result from different site specific requirements and conditions. Such requirements can include whether sheetwall piles or other structures are needed and whether dredging is required which can result in substantial disposal costs. Costs were provided for three design intake flow values: 10,000 gpm, 104,000 gpm, and 347,000 gpm. Theses costs were provided in 1999 dollars and have been adjusted for inflation to July 2002 dollars using the ENR construction cost index. The capital costs are total project costs including installation. Figure 3-35 presents a plot of the data in Exhibit 3-59 along with the second order equation fitted to this data.

The vendor recently provided a total capital cost estimate of 8 to 10 million dollars for full scale MLES™ system at the Arthur Kill Power Station in Staten Island, NY (McCusker 2003a). The vendor is in the process of conducting a pilot study with an estimated cost of $750,000. The NYDEC reported the permitted cooling water flow rate for the Arthur Kill facility as 713 mgd or 495,000 gpm. Applying the cost equations in Figure 3-35 results in a total capital cost of $8.7, $10.1 and $12.4 million dollars for low, average and high costs, respectively. These data indicate that the inflation adjusted cost estimates are consistent with this more recent estimate provided by the vendor. Note that since the Arthur Kill intake flow exceeded the range of the cost equation input values the cost estimates presented above for this facility were derived by first dividing the flow by two and then adding the answer.

Exhibit 3-59. Capital Costs for Aquatic Filter Barrier Provided by Vendor

	Floating Boom		
Flow	Capital Cost (2002 Dollars)		
gpm	Low	High	Average
10,000	$545,000	$980,900	$762,900
104,000	$1,961,800	$2,724,800	$2,343,300
347,000	$6,212,500	$8,501,300	$7,356,900

5.2 O&M Costs

Estimated O&M costs were also provided by Gunderboom Inc., As with the capital costs the O&M costs provided apply to floating boom type AFBs and include costs to operate an air burst system. Exhibit 3-60 presents a range of O&M costs from low to high and the average which served as the basis for cost estimates. As with the capital costs, the costs presented in Exhibit 3-60 have been adjusted for inflation to July 2002 dollars. Figure 3-35 presents a plot of the data in Exhibit 3-60 along with the second order equation fitted to this data.

Exhibit 3-60. Estimated AFB Annual O&M Costs

Flow gpm	O&M Low	O&M High	O&M Average
10,000	$109,000	$327,000	$218,000
104,000	$163,500	$327,000	$245,200
347,000	$545,000	$762,900	$653,900

5.3 Application

Aquatic filter barriers (AFBs) can be used where improvements to impingement performance is needed. Because they can be installed independently of intake structures, there is no need to include any costs for modifications to the existing intake structure or technology employed. Costs are assumed to be the same for both new and existing facilities. AFBs can be installed while the facility is operating. Thus, there is no need to coordinate AFB installation with generating unit downtime. Capital cost estimates used in the economic impact analysis used average costs.

EPA assumed that the existing screen technology would be retained as a backup following the installation of floating boom AFBs. Therefore, as with barrier nets, the O&M costs of the existing technology was not deducted from the estimated net O&M cost used in the Phase III economic impact analysis. Upon further consideration, EPA has concluded that at a minimum there should be a reduction in O&M cost of the existing intake screen technology equivalent to the variable O&M cost component estimated for that technology.

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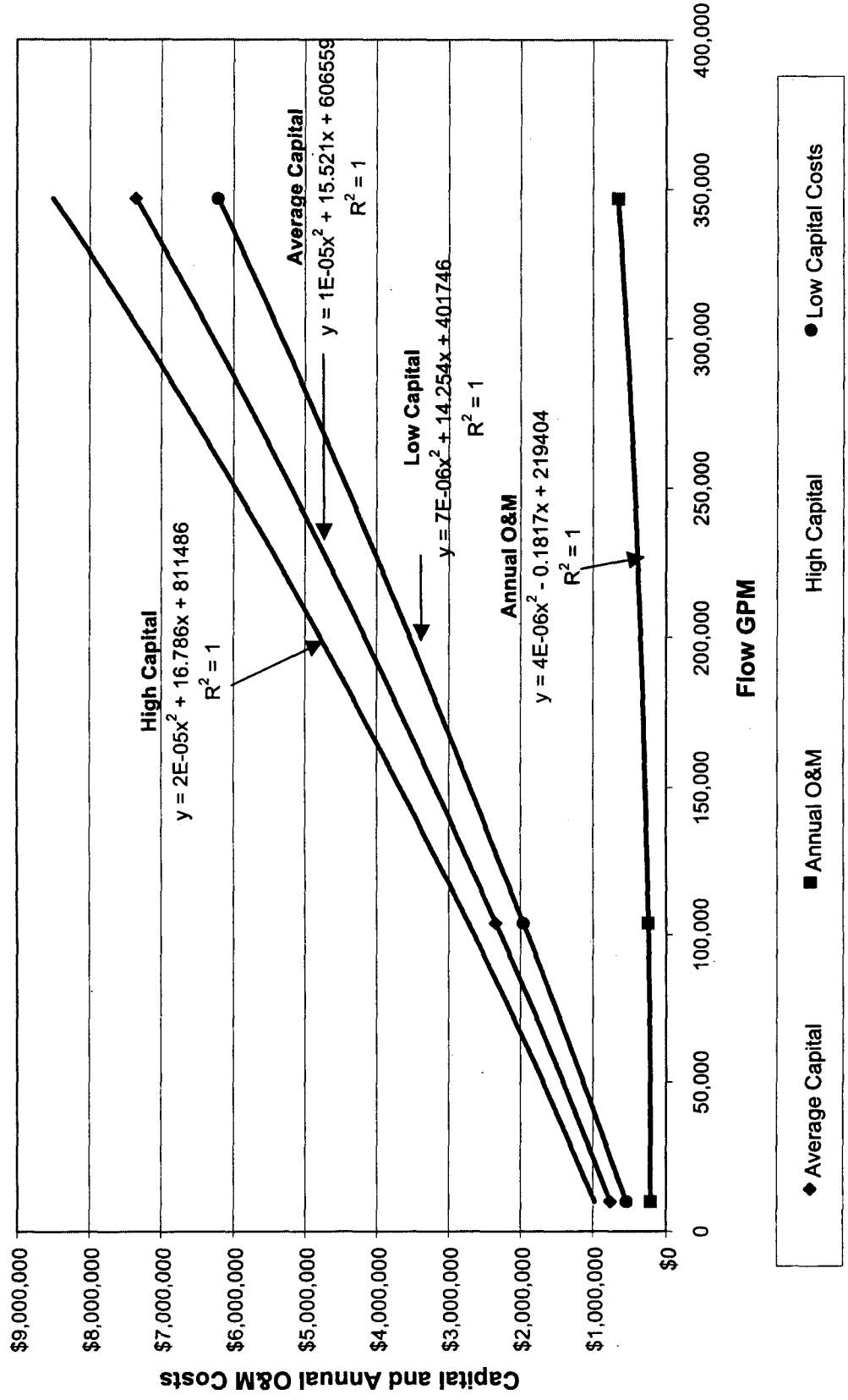


Figure 3-35. Gunderboom Capital and O&M Costs for Floating Structure in 2002 Dollars

II. TECHNOLOGY COST MODULES FOR SEAFOOD PROCESSING VESSELS

APPLICATION OF THE PROPOSED RULE

Under each of the co-proposed options, no seafood processing vessels would be subject to national performance standards.

INTRODUCTION

EPA has identified a typical 280-foot catcher-processor as an indicative vessel to assemble cost estimates for retrofitting fine mesh screens for cooling water intake structures. Information gathered during interviews with industry representatives will be used to characterize the intake structure of a typical 280-foot vessel. It is reasonable to assume that the majority of these vessels use a sea chest arrangement for cooling water intake.

Four primary fine mesh configurations have been costed:

1. Replace the existing grill with a fine mesh screen, without any other modifications;

2. Enlarge the intake structure internally to achieve 0.5 feet per second through screen velocity. Under this option, the screen will be in flush with the hull;

3. Install a fine mesh screen intake structure externally to achieve 0.5 feet per second through screen velocity. The screen protrudes outside of the hull under this option; and

4. Install a horizontal flow modifier externally to the intake structure to achieve 0.5 feet per second through screen velocity. The flow modifier protrudes outside of the hull. Cost estimates for two configurations, one for vessels with bottom sea chests and one for side sea chests are presented.

Material costs for both 316 stainless steel and copper-nickel (CuNi) alloy fine mesh screens were obtained from venders. In addition, material costs for steel fabrication and associated labor rates, including diver team costs were obtained using various vender sources. The capital costs estimated in this report are incremental costs for a facility. A 10% engineering and 10% contingency sum has been included in the cost estimates. One of the key assumptions for the development of capital costs is that the vessel is in dry dock for routine maintenance and that this work does not prolong the dry dock time for the vessel. No allowances have been made for docking fees.

Inspection frequency for fine mesh screens and horizontal flow modifiers are assumed to be one per year. This is based on typical inspection frequencies for onshore and coastal facilities. The estimates for inspection and cleaning frequencies are based on vendor data and data from operators of similar equipment in high marine growth areas. It is assumed that the existing sea chests are inspected annually with the use of divers. The inspection and maintenance of the proposed enlarged intake structures will take significantly longer than current practices. An allowance of an additional day per intake has been included for these intake modification options for divers to inspect and clean the new intake structures. However, for the option where no enlargement of the intake is proposed, a lump sum cost of $100 is estimated for annual inspection and maintenance. An allowance of 6% of the capital cost has been allowed as annual replacement costs for parts. Mobilization or demobilization costs are not included in this estimate. The O & M costs estimated in this report are incremental costs for the facility.

1.0 REPLACE EXISTING GRILL WITH FINE MESH SCREEN

1.1 Capital Cost Development

In this option, the existing grill is replaced with a larger (typically 32" diameter) fine mesh screen. Costs are estimated for replacing the existing coarse grill with 316 stainless steel and Cu/Ni alloy fine mesh screens. In addition to the material cost of the screen, installation costs are included in this cost estimate.

1.2 O & M Cost Development

A lump sum cost of $100 is estimated as the annual O & M costs to inspect and clean the fine mesh screen. Exhibit 3-61 below presents the summary of incremental capital and O & M costs to replace the existing grill with fine mesh screen. These costs are presented for three design intake flow values.

Exhibit 3-61. Capital and O & M costs for Replacing Existing Coarse Screen with Fine Mesh Screen

Design Flow (MGD)	Stainless Steel Fine Mesh Screen		Cu/Ni Fine Mesh Screen	
	Capital Cost ($)	O & M Cost ($)	Capital Cost ($)	O & M Cost ($)
0.6	404	100	423	100
6.3	764	100	965	100
12.7	1,190	100	1,604	100

Figures 3-47 and 3-48 (at the end of this section) show the cost curves for replacing an existing grill.

2.0 ENLARGE THE INTAKE STRUCTURE INTERNALLY

2.1 Capital Cost Development

It is proposed to modify the existing 32" intake with a new intake structure that has a large enough surface area to reduce the through screen velocity to 0.5 feet per second. The primary problem with this type of intake modification is that there is typically very little room at the intake. As such, a low profile design has been developed to minimize the impacts on surrounding equipment and services of the vessel. The intake pipe suction is dispersed across the face of a large mesh using a diffuser arrangement. This type of flow modifier is often used to limit vortex problems on suction lines. It will only marginally increase the head loss through the system, as the available flow area is still large (but at right angles to the pipe flow). The similarity with a velocity cap is easily noted. This design also accounts for the structural members of the vessel's hull. The insertion of a large intake will typically require the cutting of several hull stiffeners. The design presented is intended to transfer the loads directly through the main frame. Figures 3-36 through 3-40 present the proposed modification for the existing intake.

2.2 O & M Cost Development

The O & M costs are based on the labor cost for a team of divers, including the cost of equipment and boat to inspect and clean the intake once per year and an allowance of 6 % of the capital cost for parts replacement. The estimates for inspection and cleaning frequencies are based on vendor data and data from operators of similar equipment in high marine growth areas.

Exhibit 3-62 below presents the summary of incremental capital and O & M costs to enlarge the intake structure internally with fine mesh screen. These costs are presented for three design intake flow values.

Exhibit 3-62. Capital and O & M Costs for Enlarging Intake Internally

Design Flow (MGD)	Stainless Steel Fine Mesh Screen		Cu/Ni Fine Mesh Screen	
	Capital Cost ($)	O & M Cost ($)	Capital Cost ($)	O & M Cost ($)
0.6	26,882	2,365	27,010	2,371
6.3	50,923	3,431	52,218	3,496
12.7	70,652	4,332	73,235	4,461

Figure 3-49 through 3-52 (at the end of this section) show the cost curves for enlarging an intake.

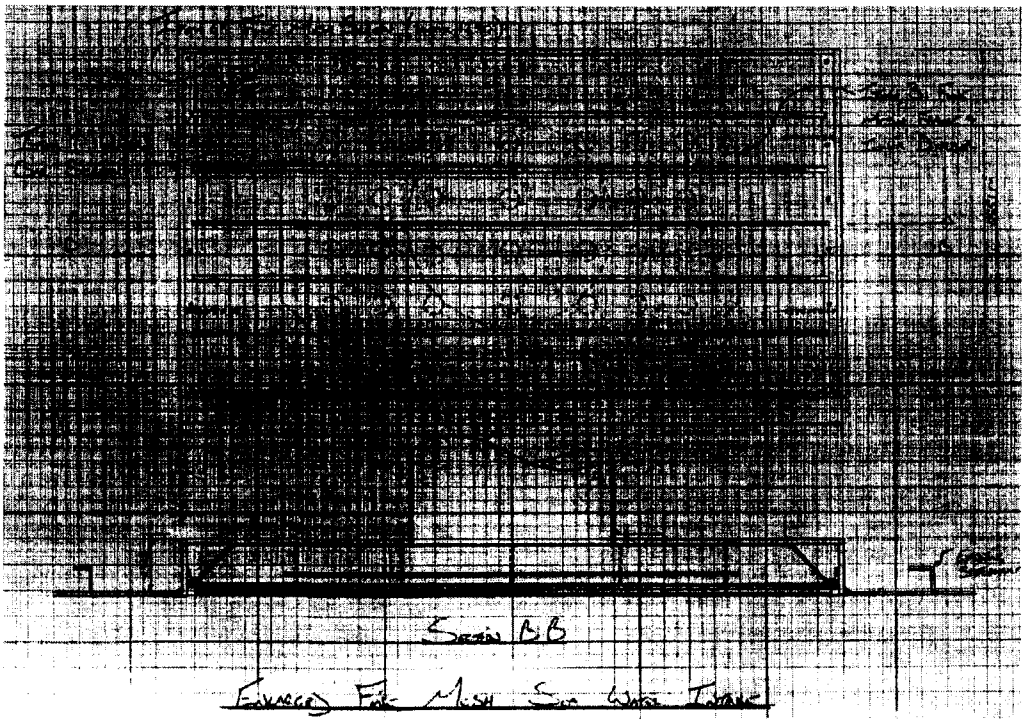


Figure 3-36. Enlarged (Internal) Fine Mesh Sea Water Intake Configuration

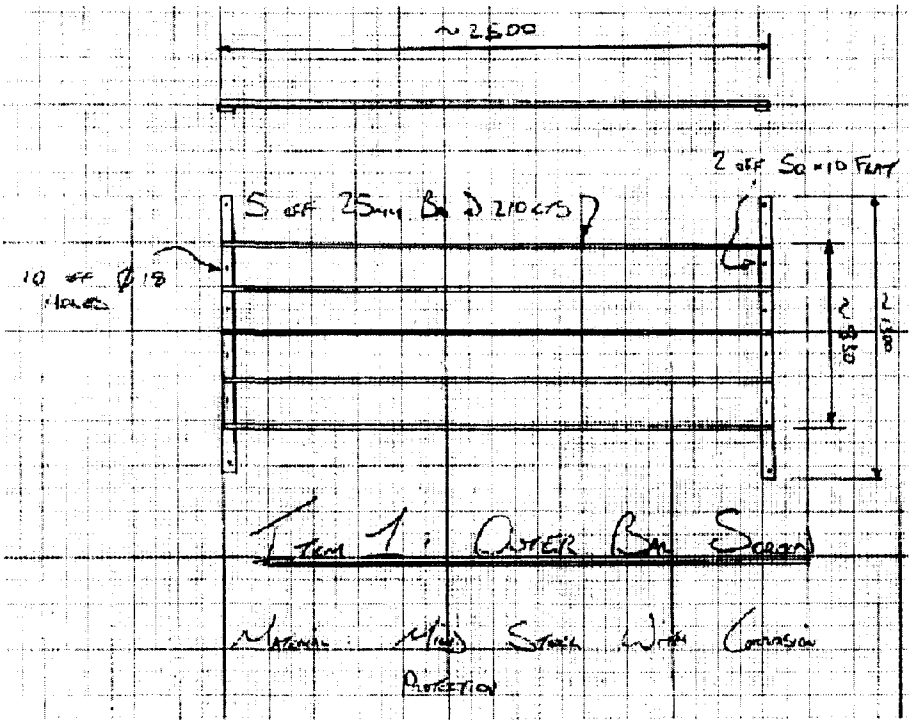


Figure 3-37. Outer Bar Screen (for Internal and External Intake Modification)

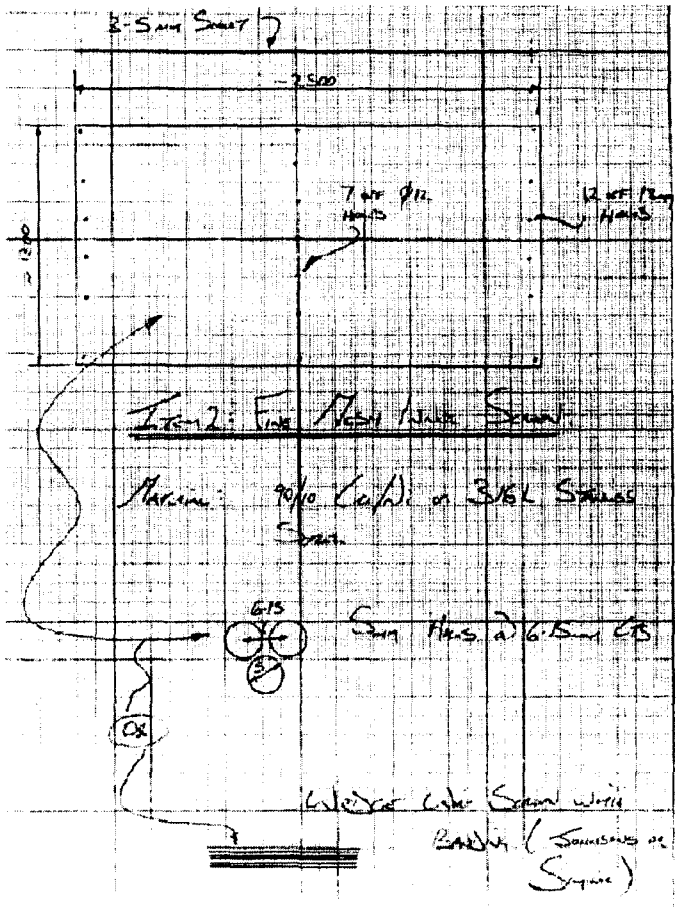


Figure 3-38. Fine Mesh Inner Screen (for Internal and External Intake Modification)

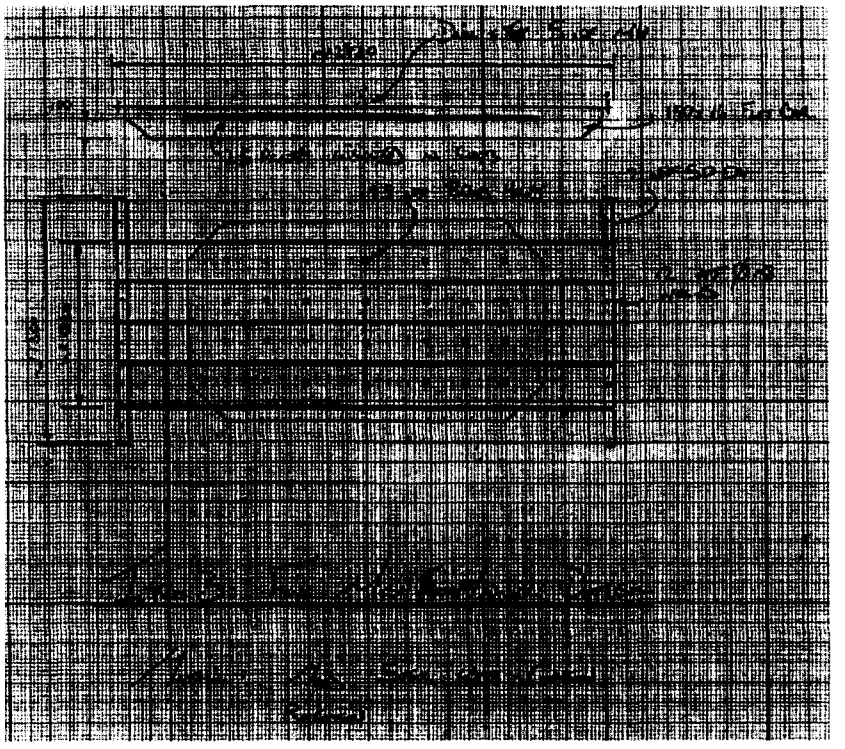


Figure 3-39. Fine Mesh Frame and Inner Diffuser (for Internal and External Intake Modification)

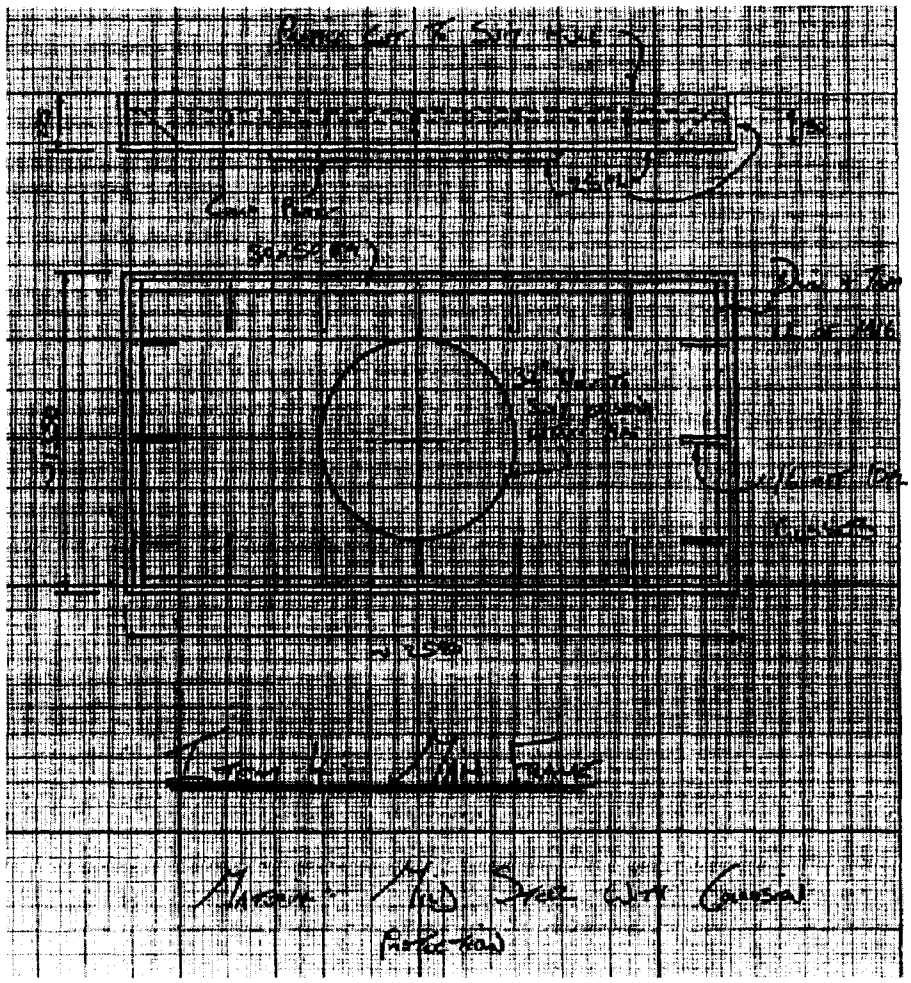


Figure 3-40. Main Frame for Internal Intake Modification

3.0 ENLARGE THE INTAKE STRUCTURE EXTERNALLY

3.1 Capital Cost Development

In this proposed modification, the existing 32" intake is replaced with a new external intake structure that has a large enough surface area to reduce the through screen velocity to 0.5 feet per second. An external intake does not affect the structure of the vessel and it is fairly simple and economical to retrofit the proposed intake to an existing vessel. However, with this type of intake modification, additional drag would be induced by its inclusion on the hull. Consequently, the low profile approach similar to the proposed internal enlargement is applicable for this configuration as well. Consultation with a naval architect confirmed that the additional drag induced by this modification would be negligible and that the cost benefit and ease of installation would likely outweigh any detrimental effects. The naval architect also confirmed that this design was reasonable for the stated purpose. Figures 3-37 through 3-39 and Figures 3-41 and 3-42 present the proposed modification to enlarge the existing intake externally.

3.2 O&M Cost Development

The O&M costs are based on the labor cost for a team of divers, including the cost of equipment and boat to inspect and clean the intake once per year, and an allowance of 6 % of the capital cost for parts replacement. The estimates for inspection and cleaning frequencies are based on vendor data and data from operators of similar equipment in high marine growth areas.

Exhibit 3-63 presents the summary of incremental capital and O & M costs to enlarge the intake structure externally with fine mesh screen. These costs are presented for three design intake flow values.

Exhibit 3-63. Capital and O&M Costs for Enlarging Intake Externally

Design Flow (MGD)	Stainless Steel Fine Mesh Screen		Cu/Ni Fine Mesh Screen	
	Capital Cost ($)	O & M Cost ($)	Capital Cost ($)	O & M Cost ($)
0.6	12541	2021	12669	2027
6.3	28862	2752	30157	2817
12.7	43444	3429	46027	3558

Figures 3-53 through 3-56 (at the end of this section) show the cost curves for enlarging an intake externally.

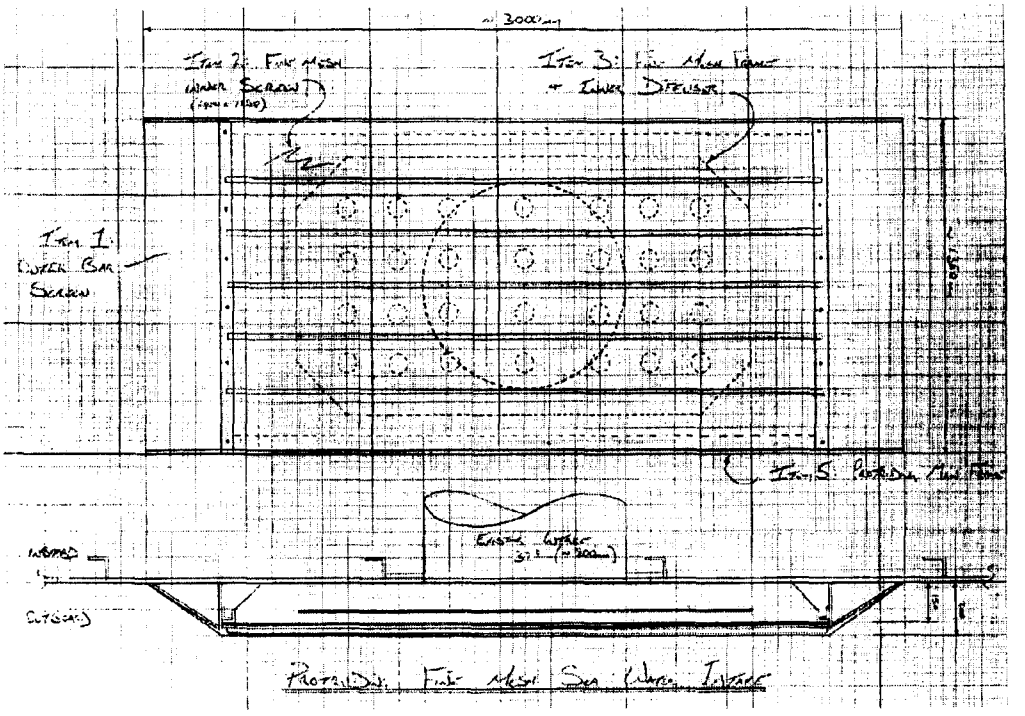


Figure 3-41. External (Protruding) Fine Mesh Sea Water Intake Configuration

Refer to Figures 3-37 through 3-39 for details of Outer Bar Screen, Fine Mesh Inner Screen and Fine Mesh Frame and Inner Diffuser, respectively

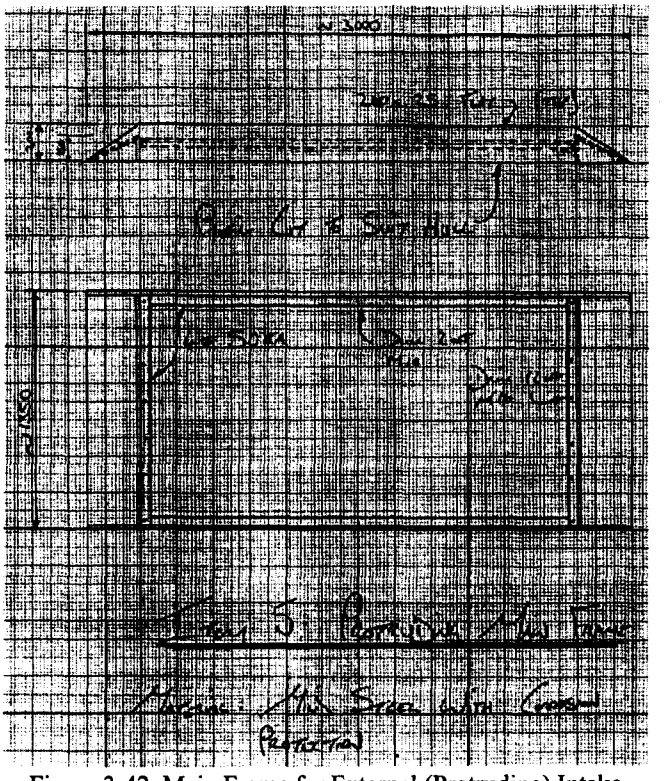


Figure 3-42. Main Frame for External (Protruding) Intake Modification

4.0 HORIZONTAL FLOW MODIFIER

4.1 Capital Cost Development

The horizontal flow modifier is a panel that ensures horizontal flow into the intake structure at a velocity of 0.5 feet per second or less. This is a derivative of the velocity cap technology.

The horizontal flow modifier option is divided up into two basic configurations: one for sea chests located on the bottom of the vessel and the other for sea chests located on the sidewalls of the vessel. The arrangement on the bottom sea chests closely resembles a standard velocity cap configuration. A plate is located over the intake opening to direct the flow in the horizontal direction between the plate and the hull. This arrangement will be suitable for hull angles up to 30° to the horizontal (87% of velocity will still be horizontal). For hull angles exceeding 30° and up to completely vertical, the side sea chest configuration will be required. This design includes a flow diffuser to spread the flow over a large area and louvres to direct the flow in the horizontal direction. Both of these designs are low profile in order to reduce any fluid dynamic effects on the hull of the vessel. The existing coarse grill over the sea chest will be retained. It is intended that the assembled horizontal flow diverter be attached using hinges to the hull to allow easy access to the existing intake structure. All materials used for the construction of this item will be mild steel coated in anti-fouling paint.

4.1.1 Vessels with Bottom Sea Chests

The proposed modification consists of a flow modifier plate that is stiffened using 4" flat bar welded to the under side. These flat bar stiffeners also assists in funneling the flow into the existing intake structure. A coarse mesh has been included around the perimeter of the new intake structure. This is to prevent larger animals (like turtles) getting trapped in the gap between the hull and the flow modifier plate (looks similar to a reef ledge to some animals). Eight brackets (4" PFC) are permanently welded to the hull as the primary attachment points. Eight legs off the flow modifier plate (1/2" plate) attach to the brackets on the hull. Three of the bracket to leg connections use hinge pins, the other 5 legs use bolts. Releasing the bolts allows the flow modifier to swing down for maintenance or cleaning of the sea chest intake. A lifting lug should be added to the hull to allow lifting equipment can be used to safely open and close this new structure. A lifting lug has been incorporated in the costs for this item. Figures 3-43 and 3-44 present the proposed configuration to modify the existing intake with horizontal flow modifiers for vessels with bottom sea chests.

4.1.2 Vessels with Side Sea Chests

The basic assembly consists of a diffuser plate nested in a number of flow louvres. The diffuser ensures that the flow is evenly distributed across the louvres and the louvres ensure that the flow is horizontal at a velocity of 0.5 feet per second or less. Two brackets (2" equal angles) are permanently welded to the hull as the primary attachment points. These run the entire width and at each end of the sea chest modification. The horizontal flow modifier is attached to the brackets on the hull by way of a hinge on one side and bolts on the other. By releasing the bolts, the horizontal flow modifier may be swung out away from the hull for access to the existing sea chest. All materials used for the construction of this item will be mild steel coated in anti-fouling paint. The direction of the flow louvres should be adjusted during the design and construction of this equipment such that they are horizontal. Figures 3-45 and 3-46 present the proposed configuration to modify the existing intake with horizontal flow modifiers for vessels with bottom sea chests.

4.2 O & M Cost Development

The O & M costs are based on the labor cost for a team of divers, including the cost of equipment and boat to inspect and clean the intake once per year and an allowance of 6 % of the capital cost for parts replacement. The estimates for inspection and cleaning frequencies are based on vendor data and data from operators of similar equipment in high marine growth areas.

Exhibits 3-64 and 3-65 below present the summary of incremental capital and O & M costs to enlarge the intake structure with flow modifier for vessels with bottom sea chests and side sea chests, respectively. These costs are presented for three design intake flow values.

Exhibit 3-64. Capital and O & M Costs for Intake Modification Using Flow Modifier for Vessels with Bottom Sea Chests

Design Flow (MGD)	Stainless Steel Fine Mesh Screen	
	Capital Cost ($)	O & M Cost ($)
0.6	6221	1915
6.3	11437	2228
12.7	17048	2565

Exhibit 3-65. Capital and O & M Costs for Intake Modification Using Flow Modifier for Vessels with Side Sea Chests

Design Flow (MGD)	Stainless Steel Fine Mesh Screen	
	Capital Cost ($)	O & M Cost ($)
0.6	5343	1863
6.3	13266	2338
12.7	22240	2876

Figures 3-57 through 3-60 (at the end of this section) show the cost curves for using a flow modifier.

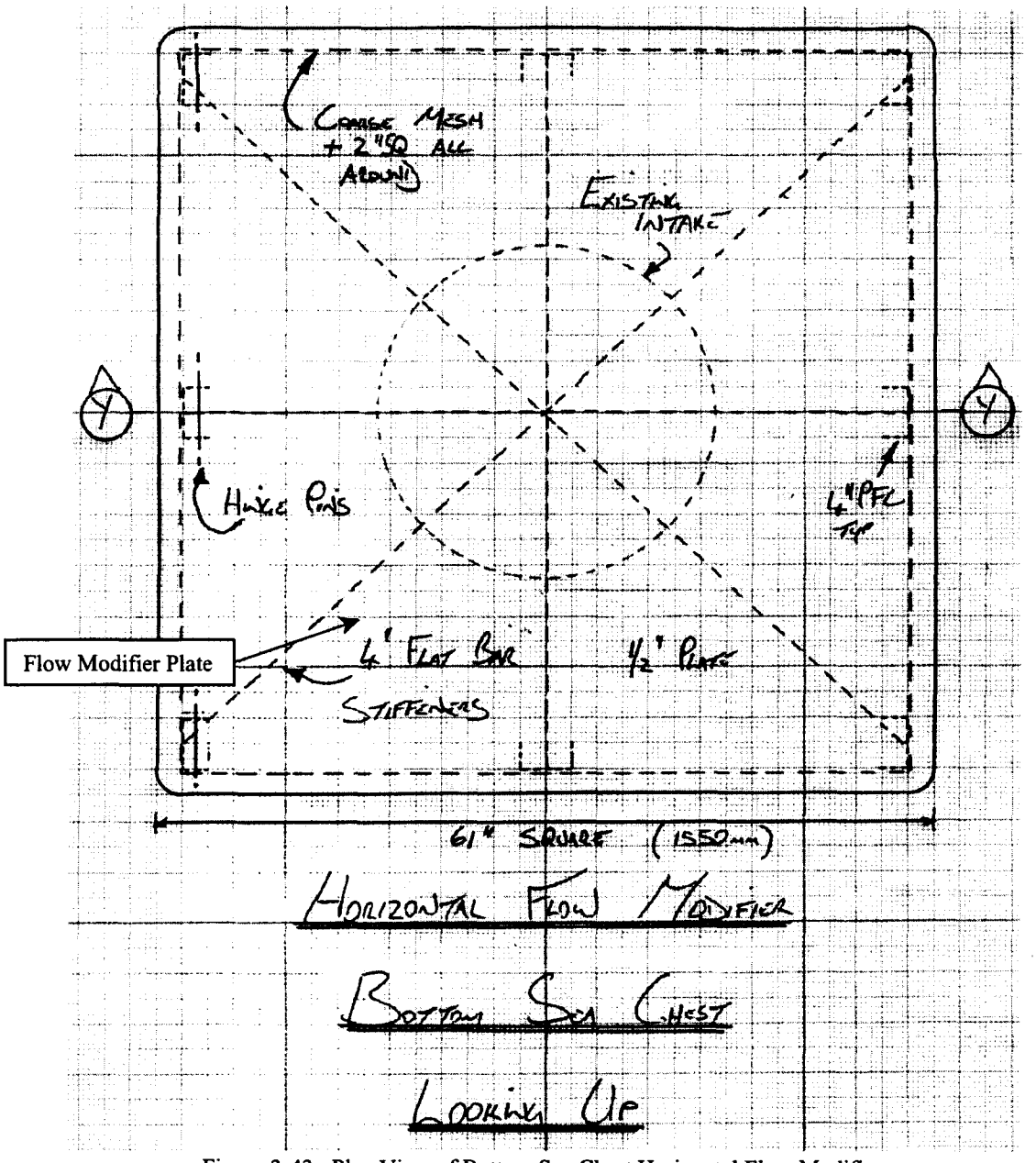


Figure 3-43. Plan View of Bottom Sea Chest Horizontal Flow Modifier

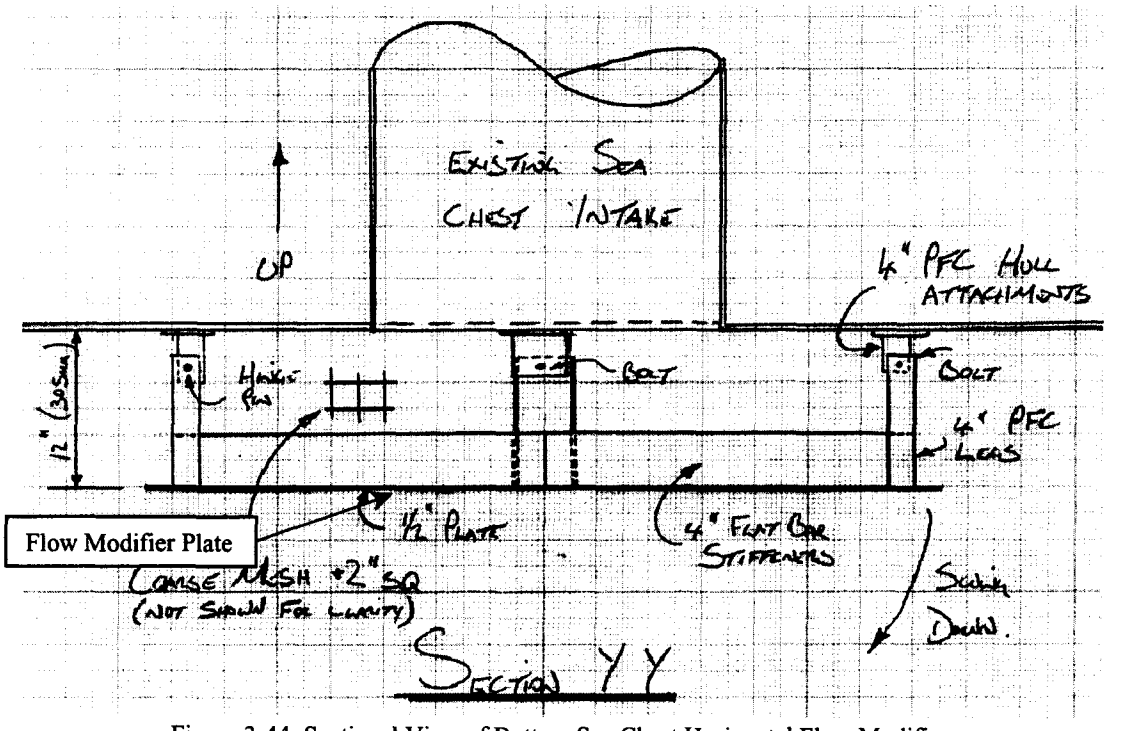


Figure 3-44. Sectional View of Bottom Sea Chest Horizontal Flow Modifier

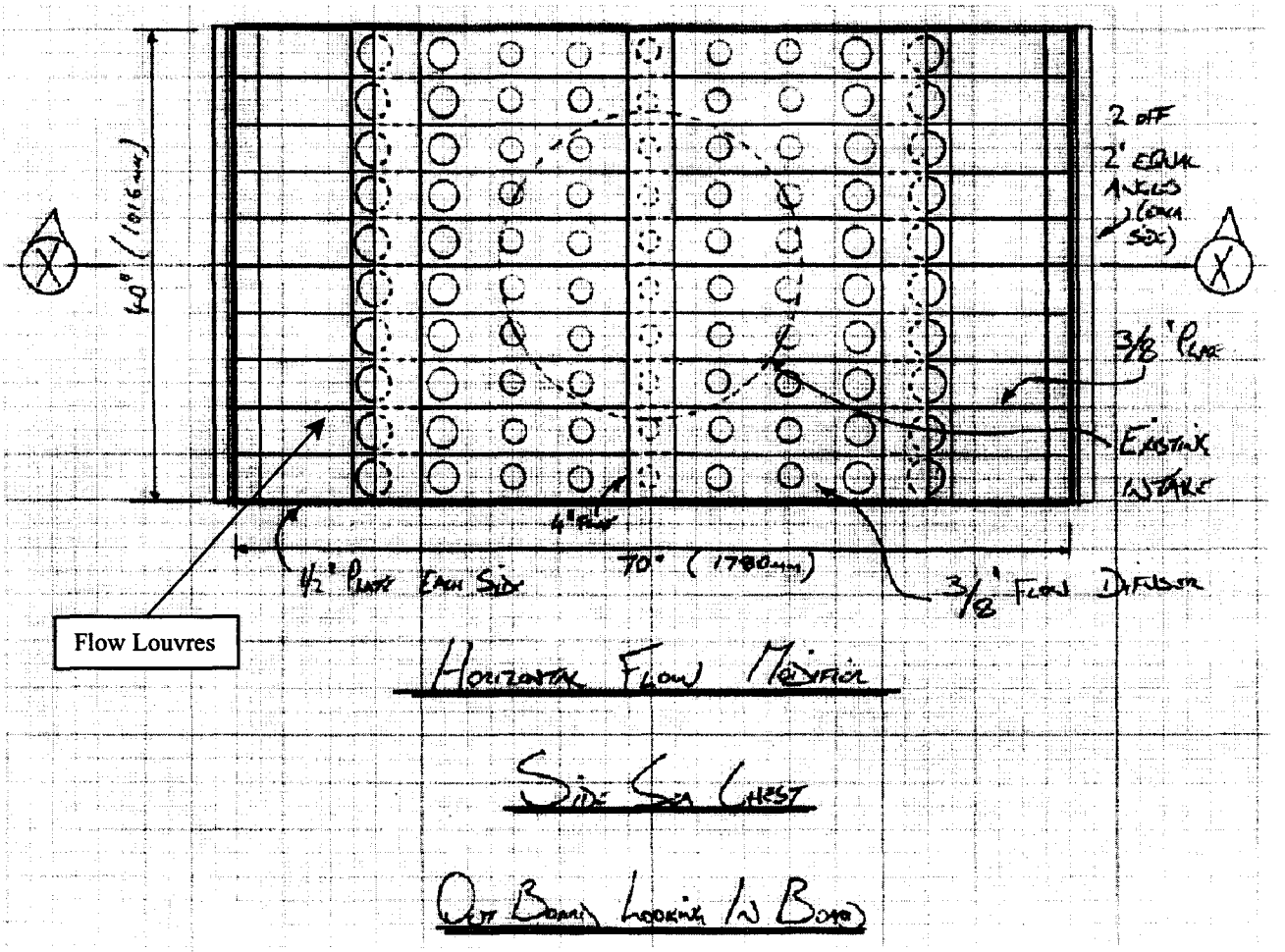


Figure 3-45. Plan View of Side Sea Chest Horizontal Flow Modifier

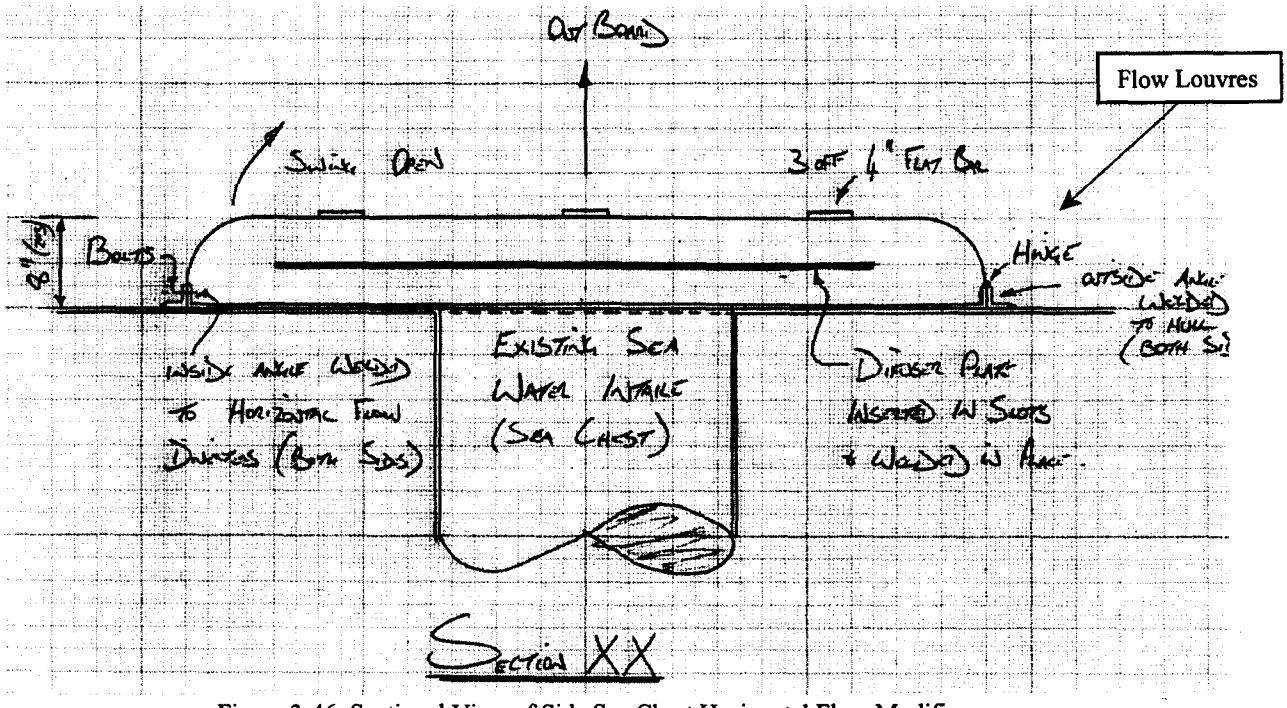
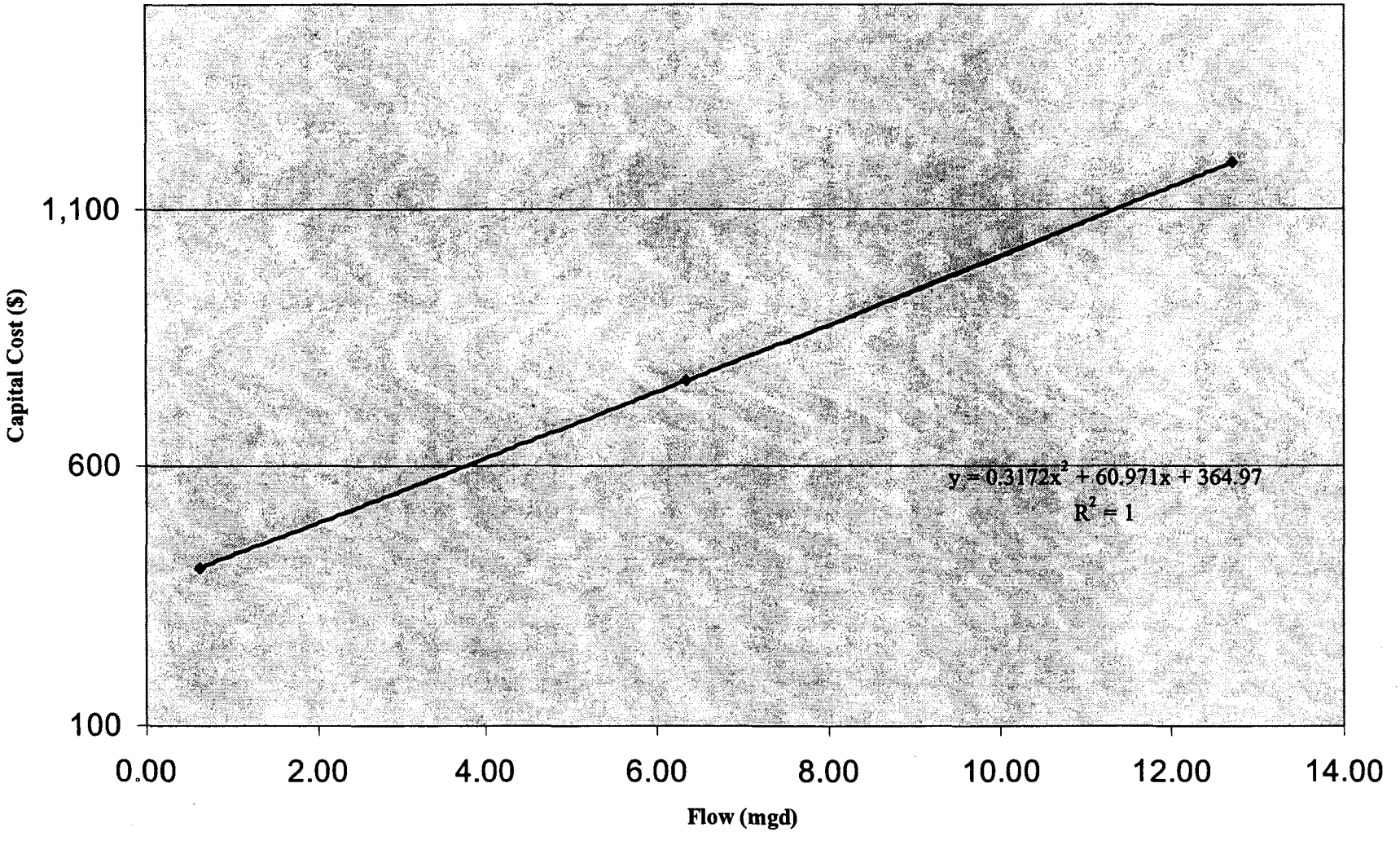


Figure 3-46. Sectional View of Side Sea Chest Horizontal Flow Modifier

Figure 3-47 Capital Cost for Replacing Existing Grill with Fine Mesh Stainless Steel Screen



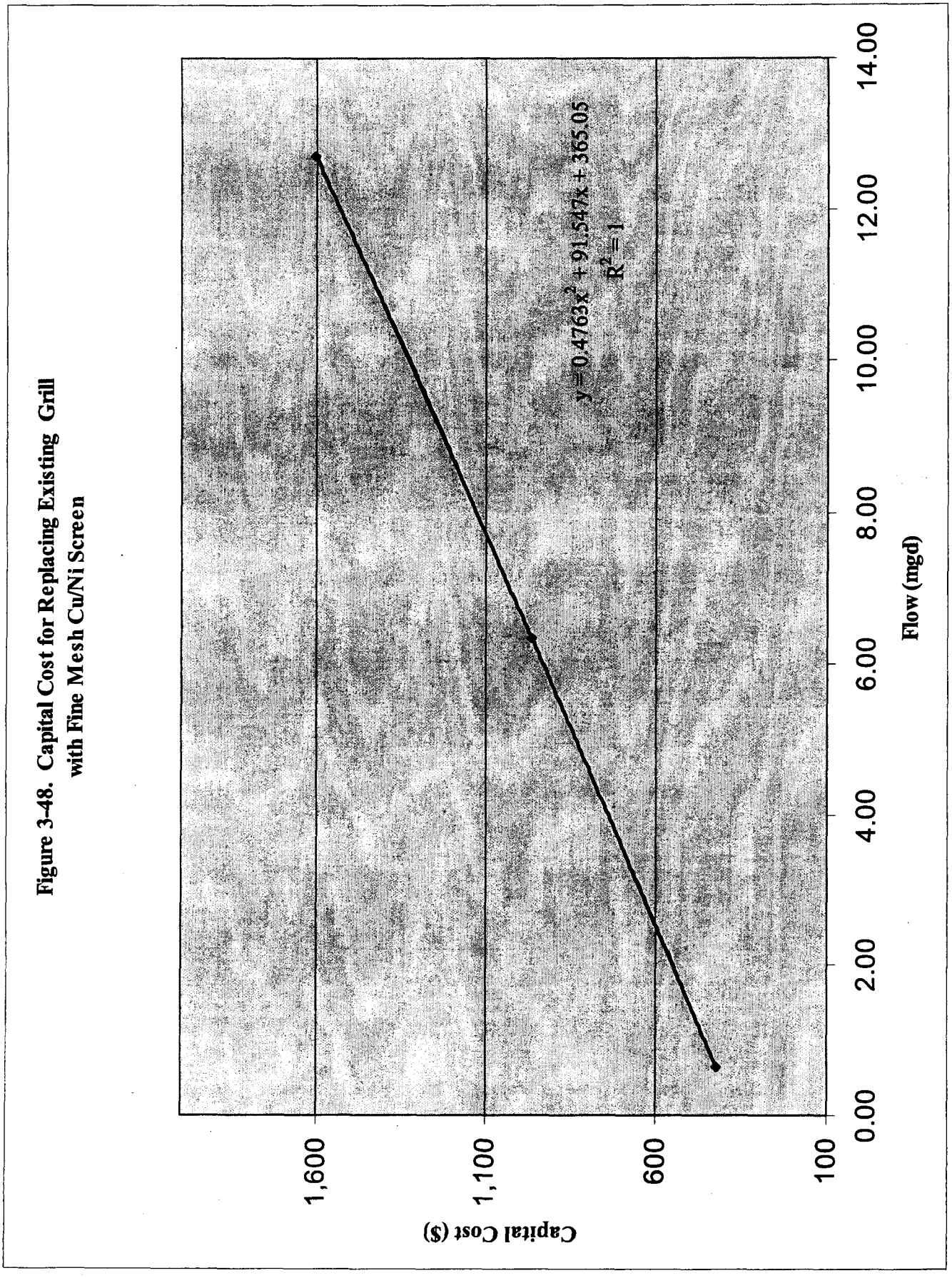


Figure 3-48. Capital Cost for Replacing Existing Grill with Fine Mesh Cu/Ni Screen

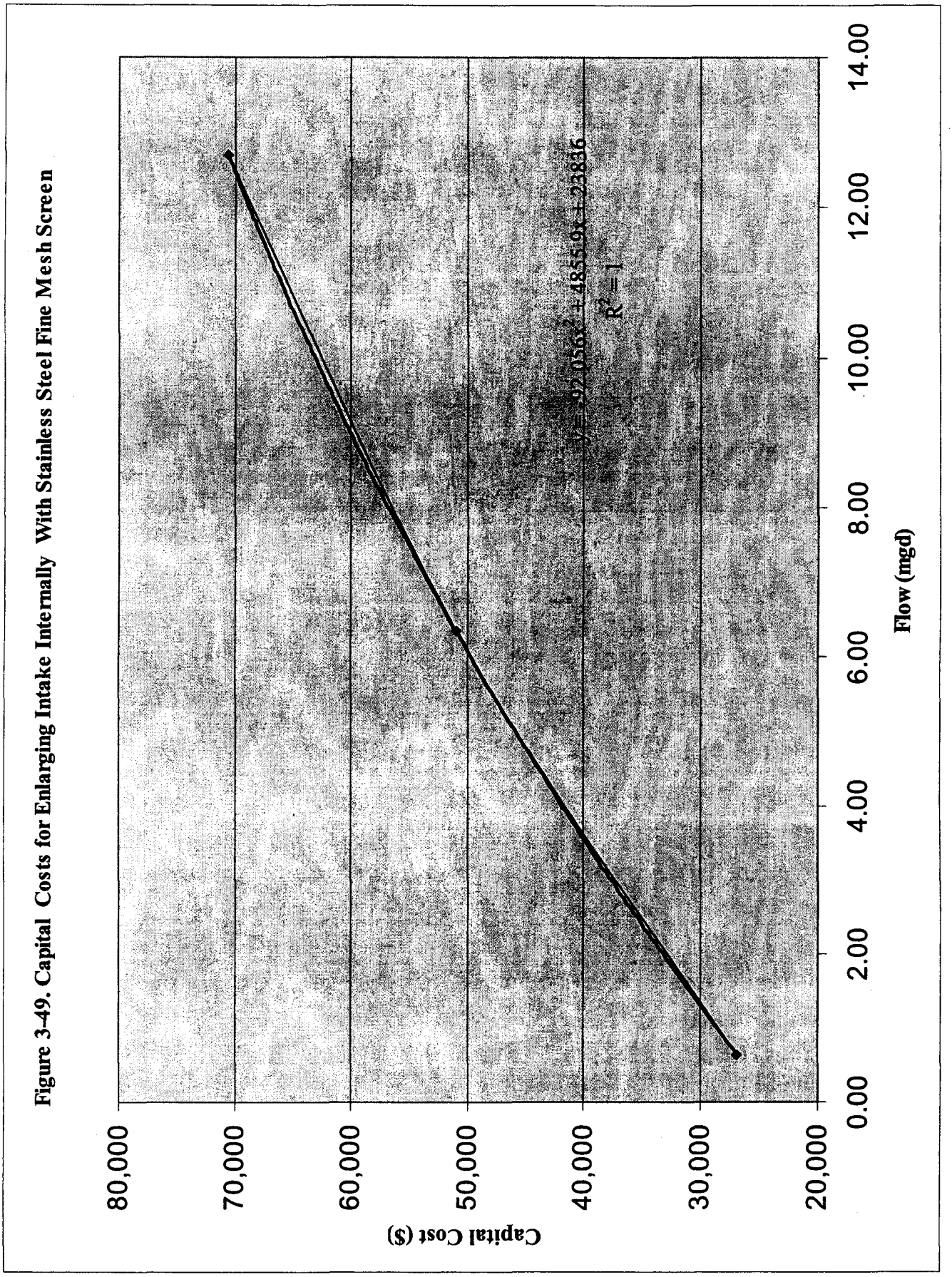


Figure 3-49. Capital Costs for Enlarging Intake Internally With Stainless Steel Fine Mesh Screen

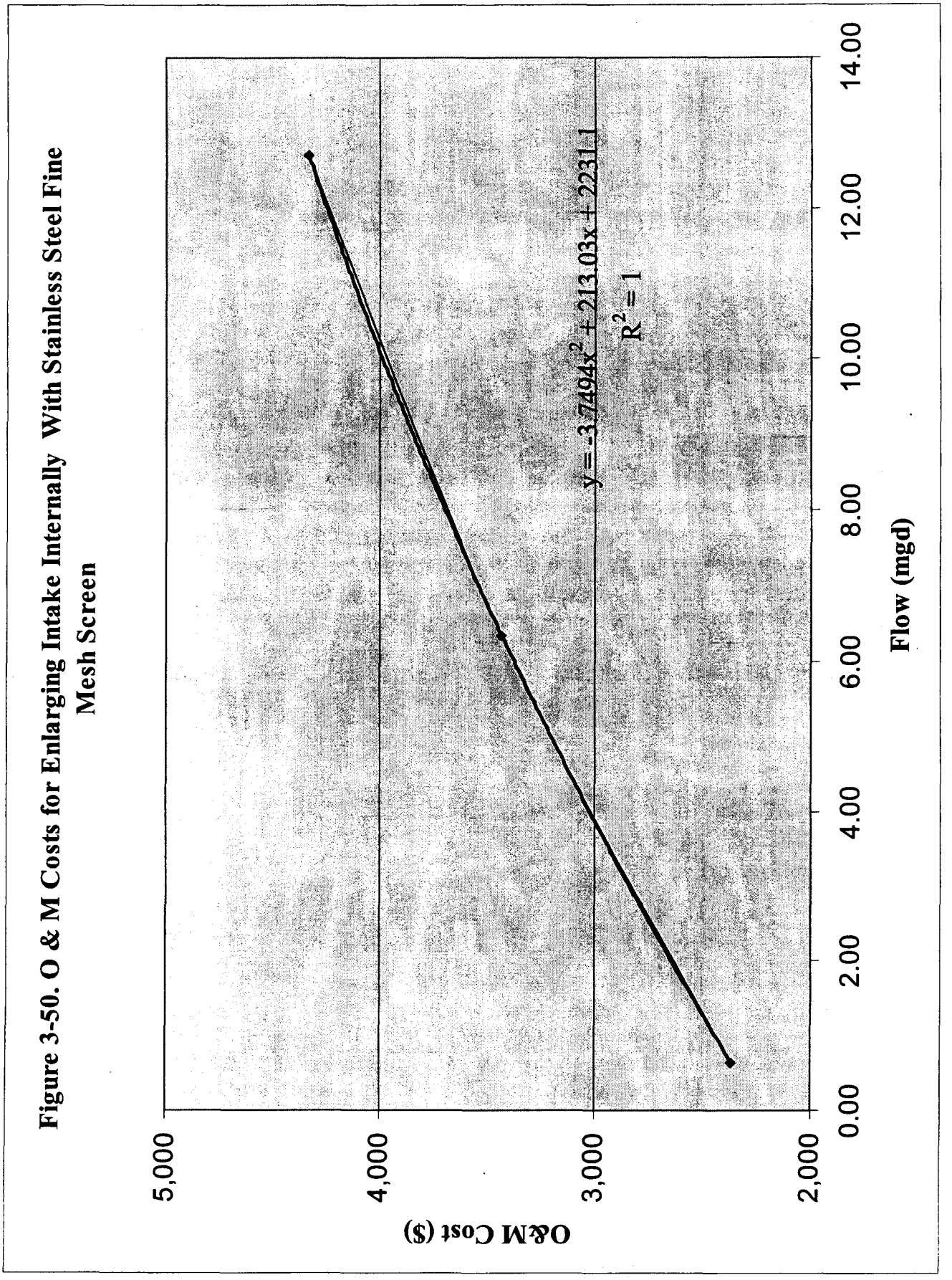


Figure 3-50. O & M Costs for Enlarging Intake Internally With Stainless Steel Fine Mesh Screen
O&M Cost ($)
5,000
4,000
3,000
2,000
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Flow (mgd)
y = -3.7494x^2 + 213.03x + 2231.1
R^2 = 1

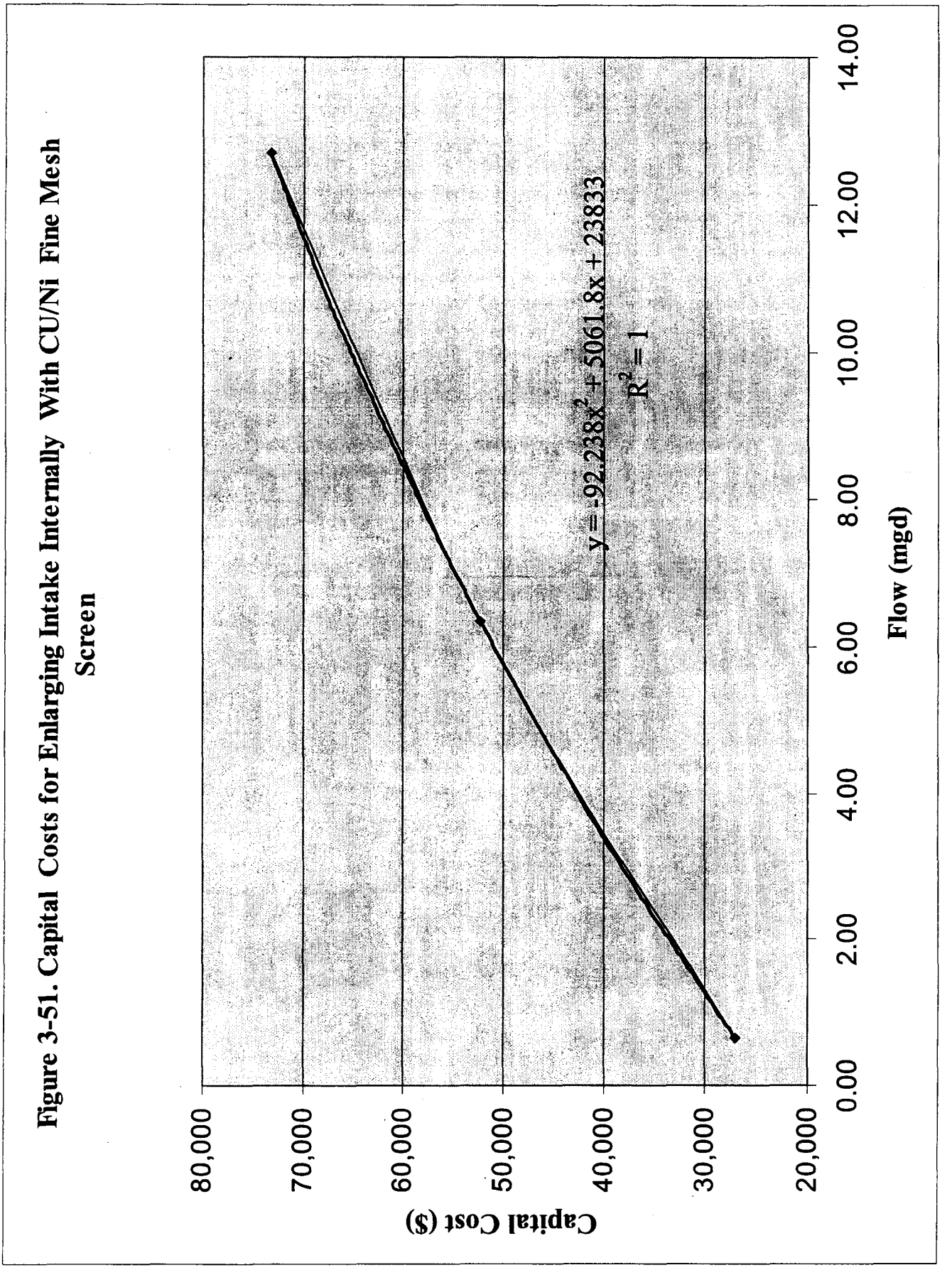


Figure 3-51. Capital Costs for Enlarging Intake Internally With CU/Ni Fine Mesh Screen
Capital Cost ($)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Flow (mgd)
y = -92.238x2 + 5061.8x + 23833
R2 = 1

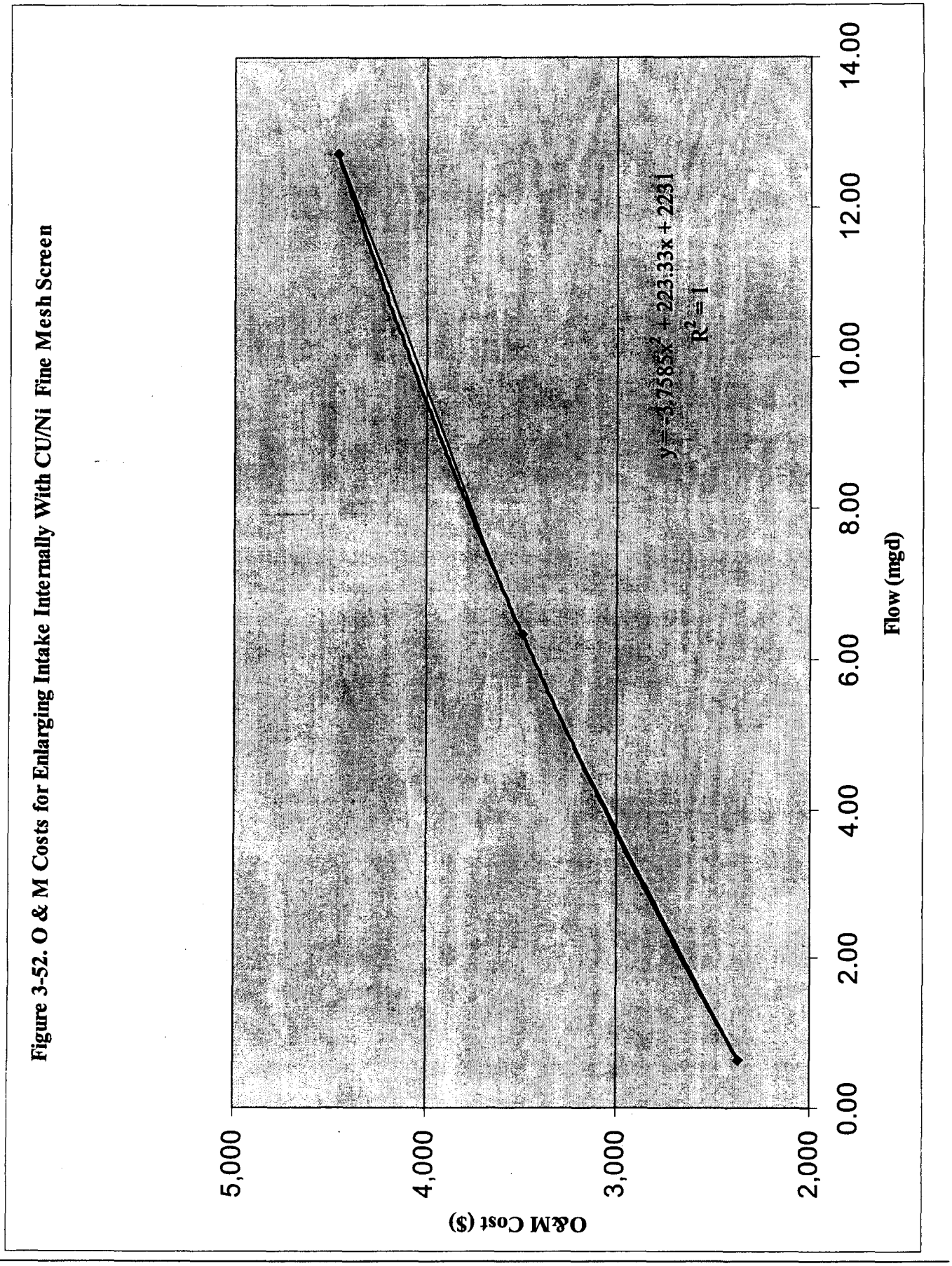


Figure 3-52. O & M Costs for Enlarging Intake Internally With CU/Ni Fine Mesh Screen

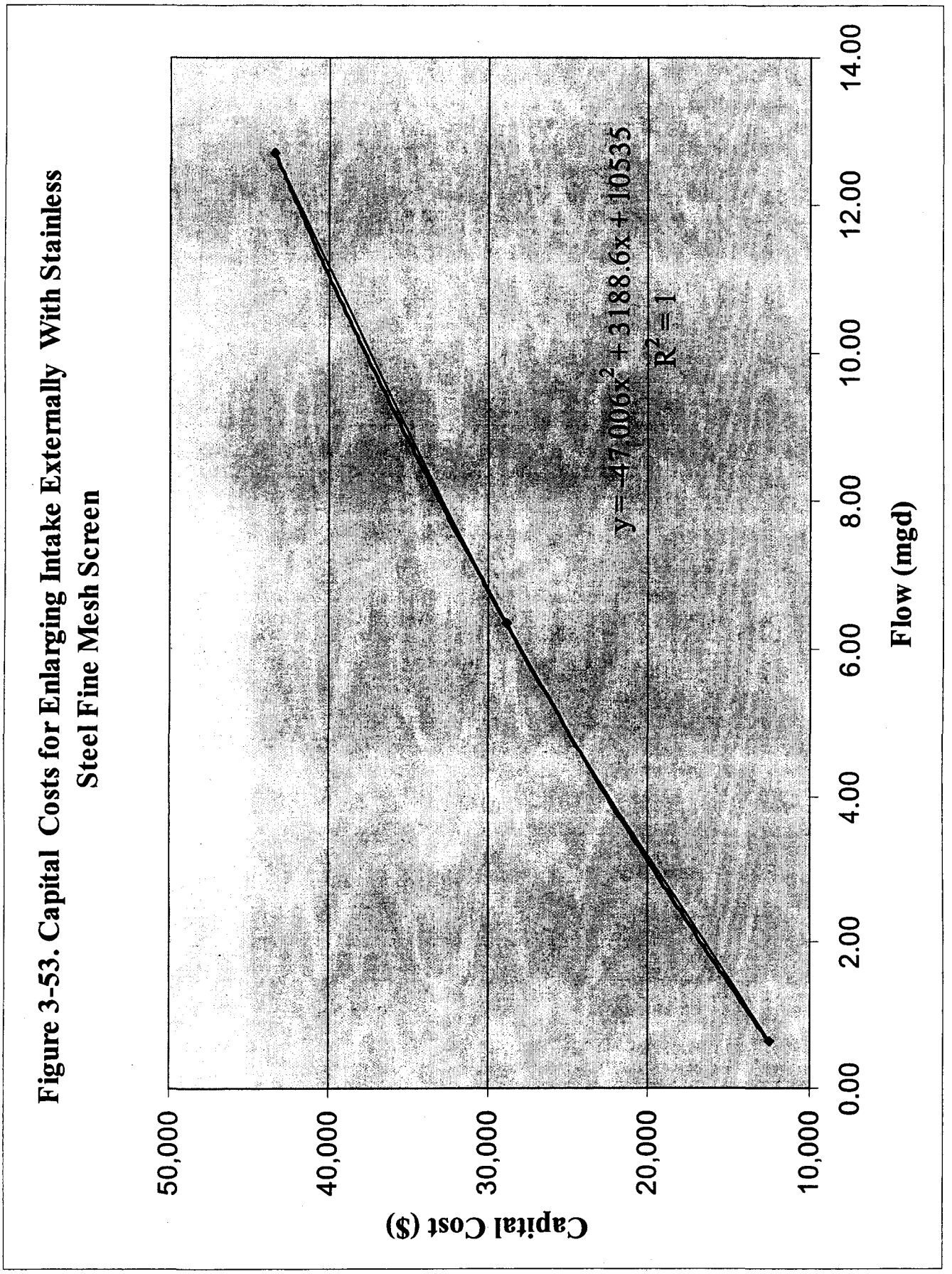


Figure 3-53. Capital Costs for Enlarging Intake Externally With Stainless Steel Fine Mesh Screen

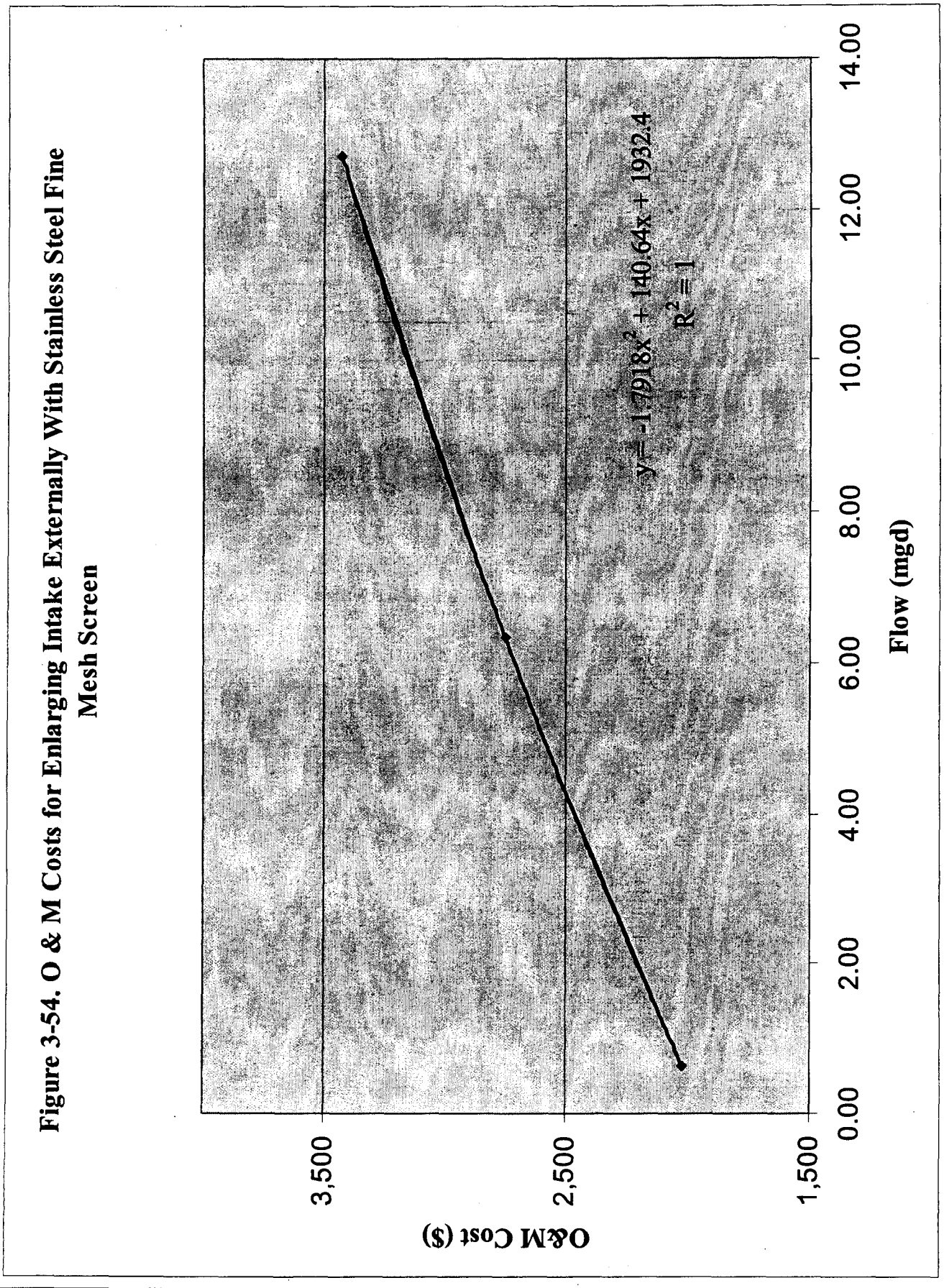


Figure 3-54. O & M Costs for Enlarging Intake Externally With Stainless Steel Fine Mesh Screen

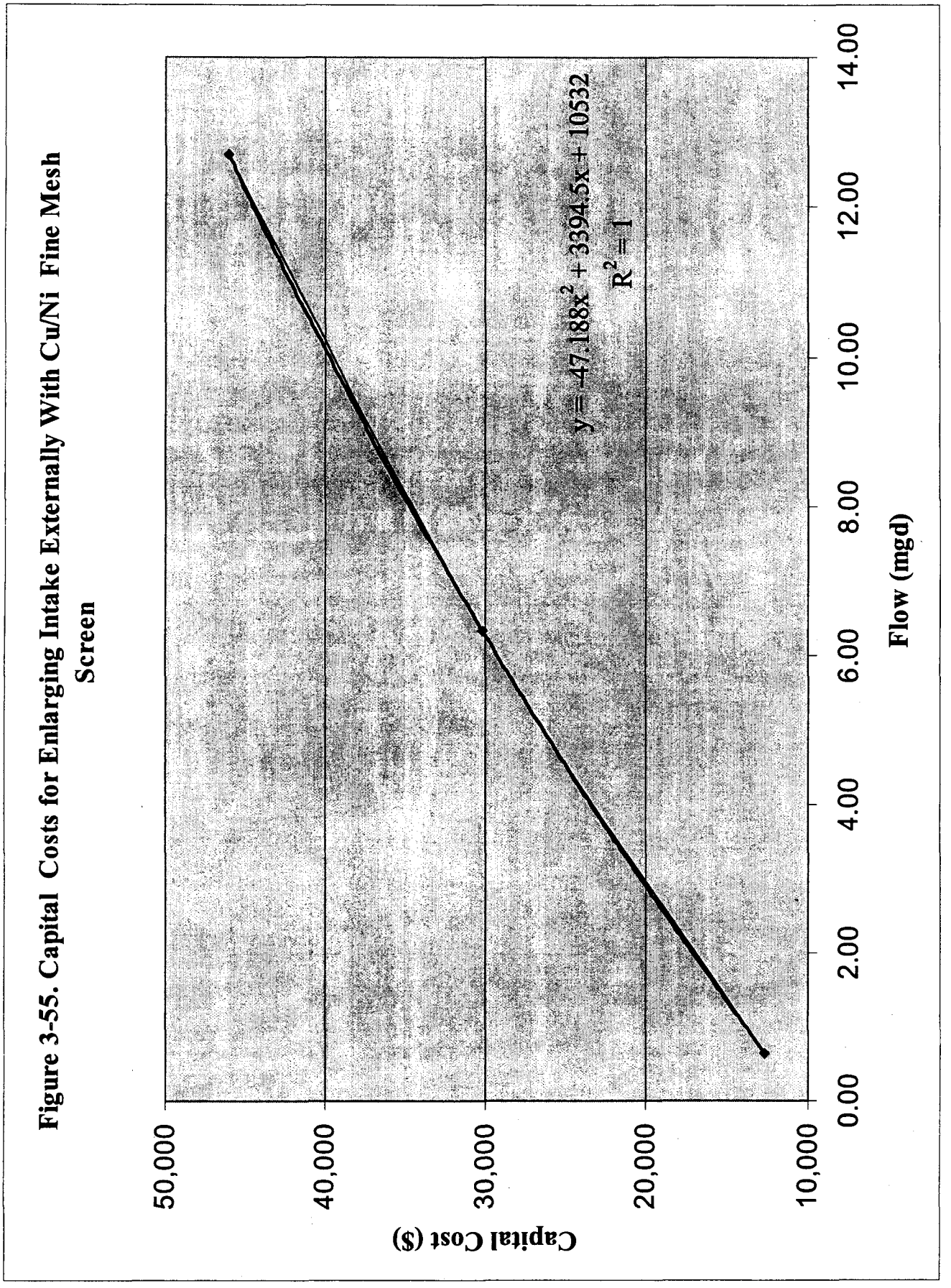


Figure 3-55. Capital Costs for Enlarging Intake Externally With Cu/Ni Fine Mesh Screen

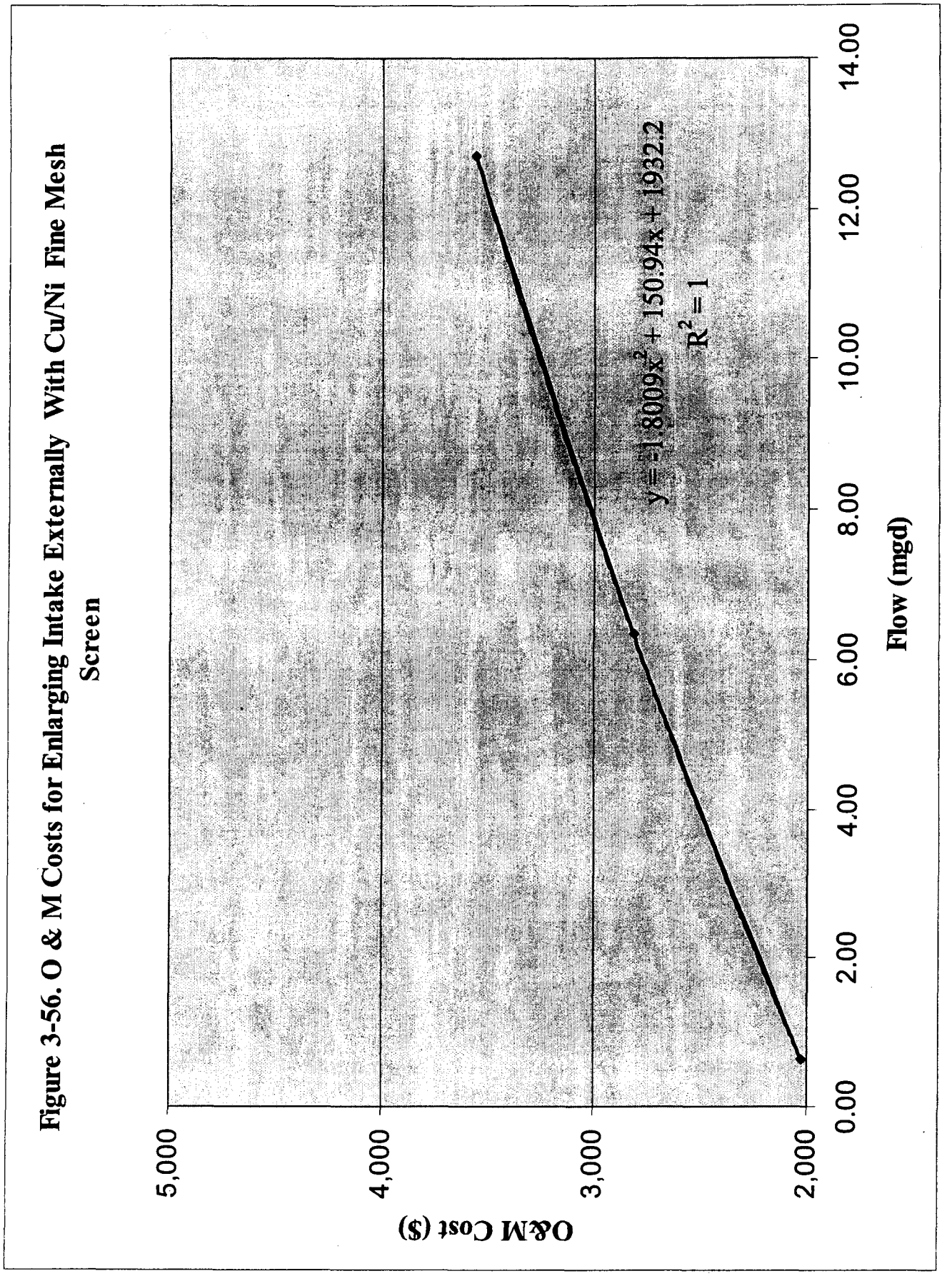


Figure 3-56. O & M Costs for Enlarging Intake Externally With Cu/Ni Fine Mesh Screen

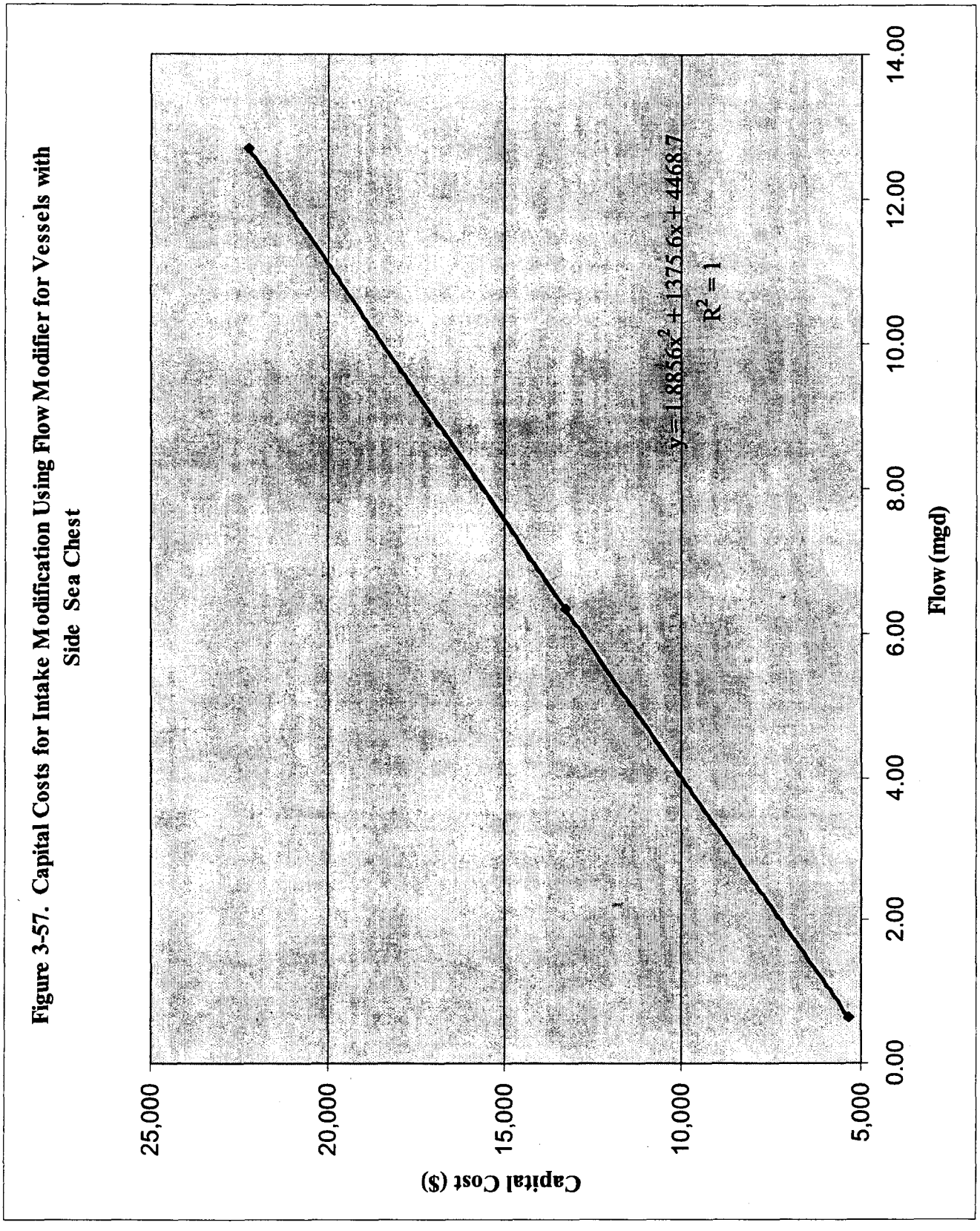
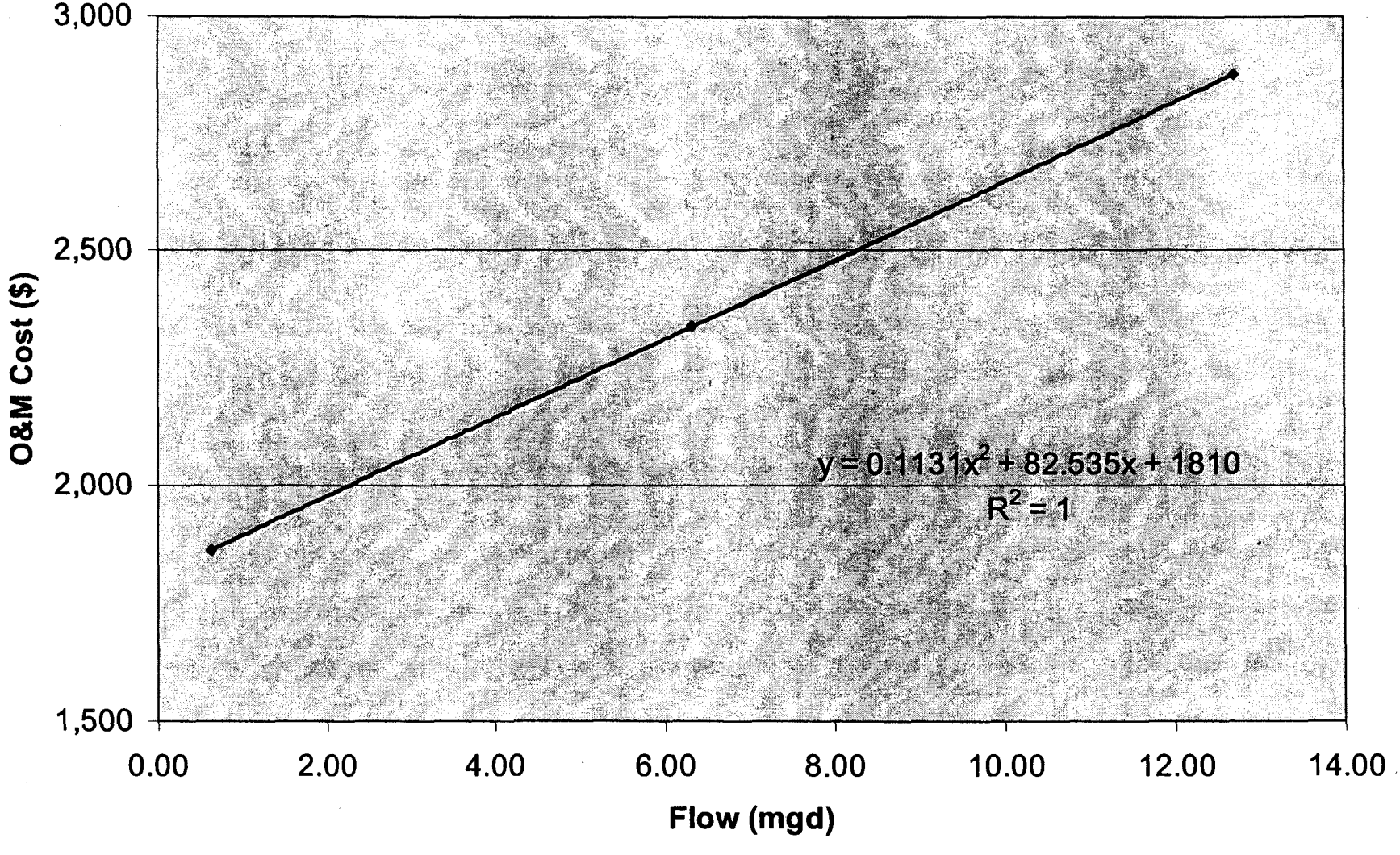


Figure 3-57. Capital Costs for Intake Modification Using Flow Modifier for Vessels with Side Sea Chest

Figure 3-58. O & M Costs for Intake Modification Using Flow Modifier for Vessels with Side Sea Chest



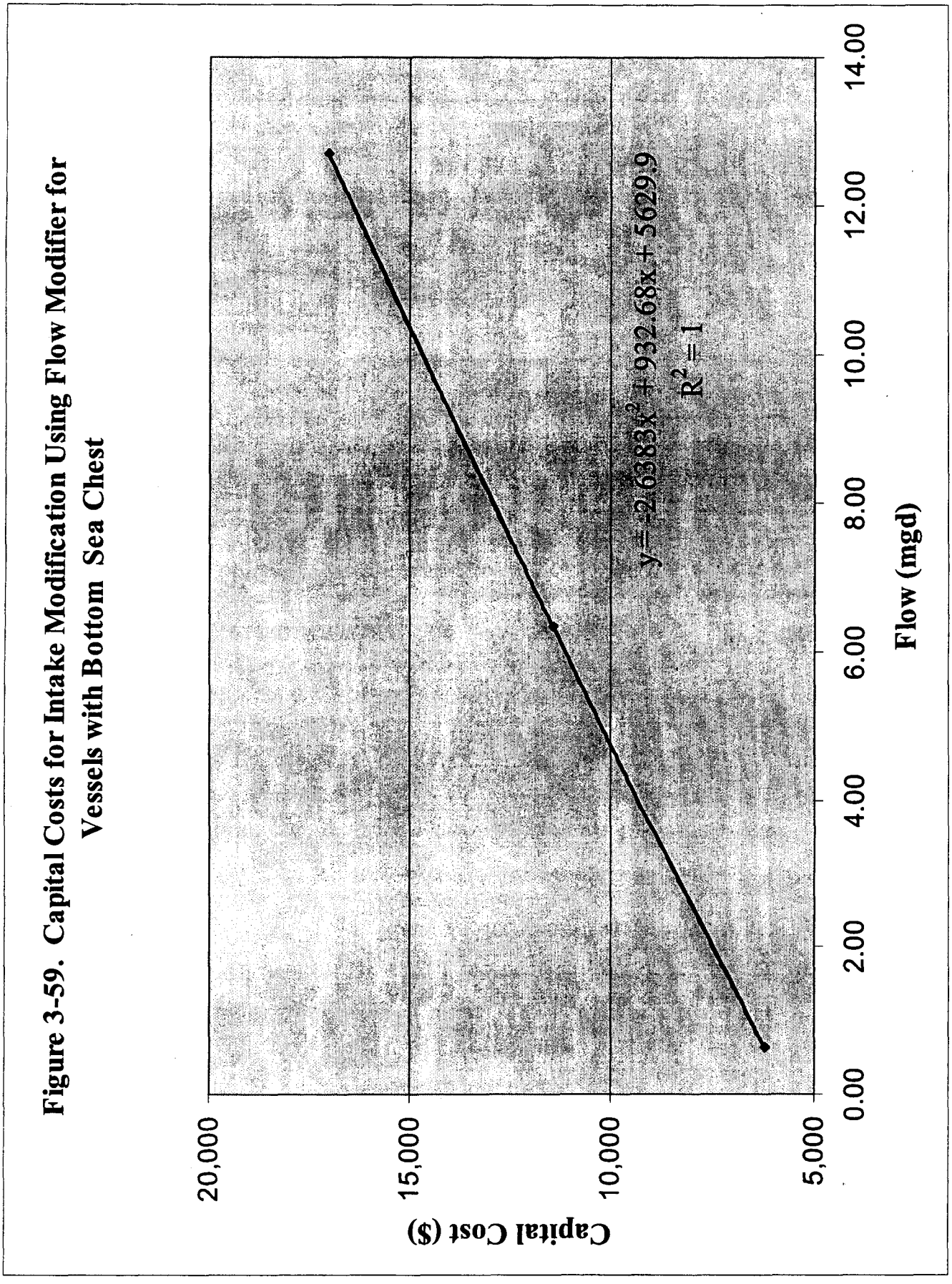


Figure 3-59. Capital Costs for Intake Modification Using Flow Modifier for Vessels with Bottom Sea Chest

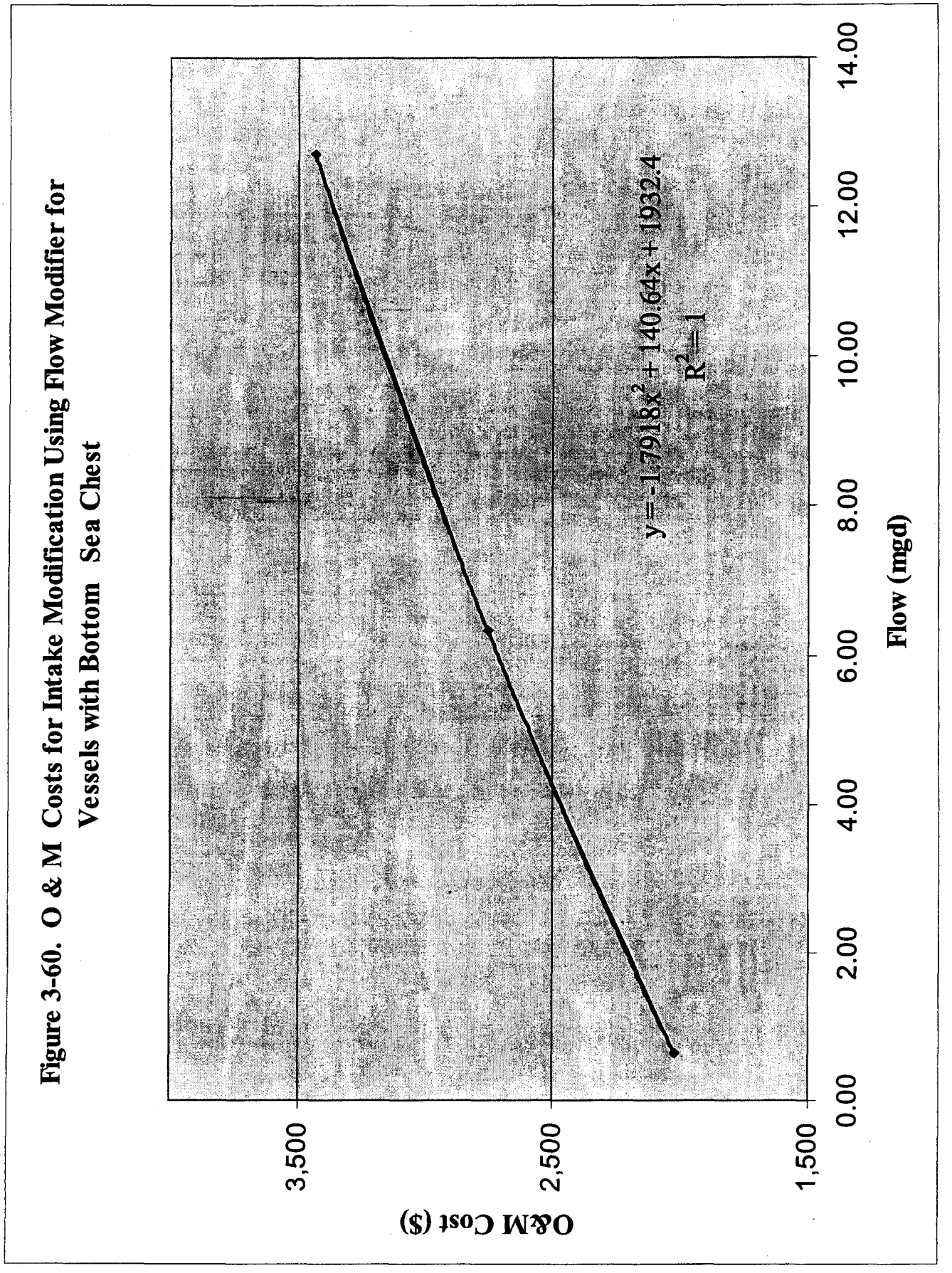


Figure 3-60. O & M Costs for Intake Modification Using Flow Modifier for Vessels with Bottom Sea Chest

III. TECHNOLOGY COST MODULES FOR OFFSHORE OIL AND GAS EXTRACTION FACILITIES

APPLICATION OF THE PROPOSED RULE

Under each of the co-proposed options, no existing oil and gas extraction facilities would be subject to national performance standards. New oil and gas extraction facilities would be subject to the proposed rule, as described in the preamble to today's rule.

INTRODUCTION

EPA did not consider new offshore oil and gas extraction facilities (the definition of "offshore" includes both coastal and offshore facilities–see the preamble for further details) in the 316(b) Phase I - New Sources rulemaking. Non-contact, once-through water is used to cool crude oil, produced water, power generators, and various other pieces of machinery at oil and gas extraction facilities.[1] The Phase I proposal and its record included no analysis of issues associated with offshore oil and gas extraction facilities (such as significant space limitations on mobile drilling platforms and ships) that could significantly increase the costs and economic impacts and affect the technical feasibility of complying with the proposed requirements for land-based industrial operations. Consequently, EPA exempted these facilities from the Phase I rule (see December 18, 2001; 66 FR 65311). As part of the Phase III rulemaking, EPA also evaluated potential 316(b) technology options for existing offshore oil and gas extraction facilities.

Since the Phase I 316(b) rulemaking, EPA collected technical and economic information associated with this industry sector. EPA also received information from industry trade associations to assist its analyses. EPA used this information to assess costs, economic impact and unique technical issues associated with various technology-based options available to control impingement and entrainment of aquatic organisms. This chapter provides an overview of the: (1) industrial sector; (2) information EPA collected and received from industry; (3) facilities in this industrial sector which EPA evaluated for the Phase III rulemaking; (4) technology options available to control impingement and entrainment of aquatic organisms; and (5) proposed technology options identified in the Phase III proposal.

1.0 INDUSTRIAL SECTOR PROFILE: OFFSHORE OIL AND GAS EXTRACTION FACILITIES

The oil and gas extraction industry drills wells at onshore, coastal, and offshore regions for the exploration and development of oil and natural gas. Various engines and brakes are employed which require some type of cooling system. The U.S. oil and gas extraction industry currently produces over 60 billion cubic feet of natural gas and approximately 5.7 million barrels of crude oil per day.[1] The U.S. Outer Continental Shelf (OCS) contributes to this energy production and the largest majority of the OCS oil and gas extraction occurs in the Gulf of Mexico (GOM). The Federal OCS generally starts three miles from shore and extends out to the outer territorial boundary (about 200 miles).[2] The U.S. Department of Interior's Mineral Management Service (MMS) is the Federal agency responsible for managing OCS mineral resources. The following are summary statistics on OCS oil and gas production:[3]

- The OCS accounts for about 25% of the Nation's domestic natural gas production and about 30% of its domestic oil production. On an energy basis (BTU), about 60 percent of the energy currently produced offshore is natural gas.
- The OCS contains about 19% of the Nation's proven natural gas reserves and 18% of its proven oil reserves. The OCS is estimated to contain more than 60% of the Nation's remaining undiscovered natural gas and oil resources.
- Since 1953, the OCS has produced about 141 trillion cubic feet of natural gas and about 13 billion barrels of oil. The Federal OCS provides the bulk—about 89%—of all U.S. offshore production. Five coastal States—Alaska, Alabama, California, Louisiana and Texas—make up the remaining 11%.

Exhibit 3-66 presents the number of wells drilled in three areas (GOM, Offshore California, and Coastal Cook Inlet, Alaska) for 1995 through 1997. The table also separates the wells into four categories: shallow water development, shallow water exploratory, deep water development, and deep water exploratory. Exploratory drilling includes those operations drilling wells to determine potential hydrocarbon reserves. Development drilling includes those operations drilling production wells once a hydrocarbon reserve has been

[1]U.S. DOE, 2004. EIA Quick Stats Pages, http://www.eia.doe.gov/neic/quickstats.html.

[2]The Federal OCS starts approximately 10 miles from the Florida and Texas shores.

[3]E-mail from James Cimato, MMS, to Carey Johnston, EPA, April 9, 2003.

discovered and delineated. Although the rigs used in exploratory and development drilling sometimes differ, the drilling process is generally the same for both types of drilling operations.

The water depth in which either exploratory or development drilling occurs may determine the operator's choice of drill rigs and drilling systems. MMS and the drilling industry classify wells as located in either deep water or shallow water, depending on whether drilling is in water depths greater than 1,000 feet or less than 1,000 feet, respectively.

Exhibit 3-66. Number of Wells Drilled Annually, 1995 - 1997, By Geographic Area

Data Source		Shallow Water (<1,000 ft)		Deep Water (≥ 1,000 ft)		Total Wells
		Development	Exploration	Development	Exploration	
Gulf of Mexico†						
MMS:	1995	557	314	32	52	975
	1996	617	348	42	73	1,080
	1997	726	403	69	104	1,302
	Average Annual	640	355	48	76	1,119
RRC		5	3	NA	NA	8
Total Gulf of Mexico		**645**	**358**	**48**	**76**	**1,127**
Offshore California						
MMS:	1995	4	0	15	0	19
	1996	15	0	16	0	31
	1997	14	0	14	0	28
	Average Annual	**11**	**0**	**15**	**0**	**26**
Coastal Cook Inlet						
AOGC:	1995	12	0	0	0	12
	1996	5	1	0	0	6
	1997	5	2	0	0	7
	Average Annual	**7**	**1**	**0**	**0**	**8**

Source: U.S. EPA, 2000, EPA-821-B-00-013.

† Note: GOM figures do not include wells within State bay and inlet waters (considered "coastal" under 40 CFR 435) and State offshore waters (0-3 miles from shore). In August 2001 there were 1 and 23 drilling rigs in State bay and inlet waters of Texas and Louisiana, respectively. There were also 19 and 112 drilling rigs in State offshore waters (0-3 miles from shore), respectively.

Deepwater oil and gas activity in the Gulf of Mexico has dramatically increased from 1992 to 1999. In fact, in late 1999, oil production from deepwater wells surpassed that produced from shallow water wells for the first time in the history of oil production in the Gulf of Mexico. As shown in Exhibit 3-66, 1,127 wells were drilled in the Gulf of Mexico, on average, from 1995 to 1997, compared to 26 wells in California and 8 wells in Cook Inlet. In the Gulf of Mexico, over the last few years, there has been high growth in the number of wells drilled in deep water, defined as water greater than 1,000 feet deep. For example, in 1995, 84 wells were drilled in deep water, or 8.6 percent of all Gulf of Mexico wells drilled that year. By 1997, that number increased to 173 wells drilled, or over 13 percent of all Gulf of Mexico wells drilled. Nearly all exploration and development activities in the Gulf are taking place in the Western Gulf of Mexico, that is, the regions off the Texas and Louisiana shores.

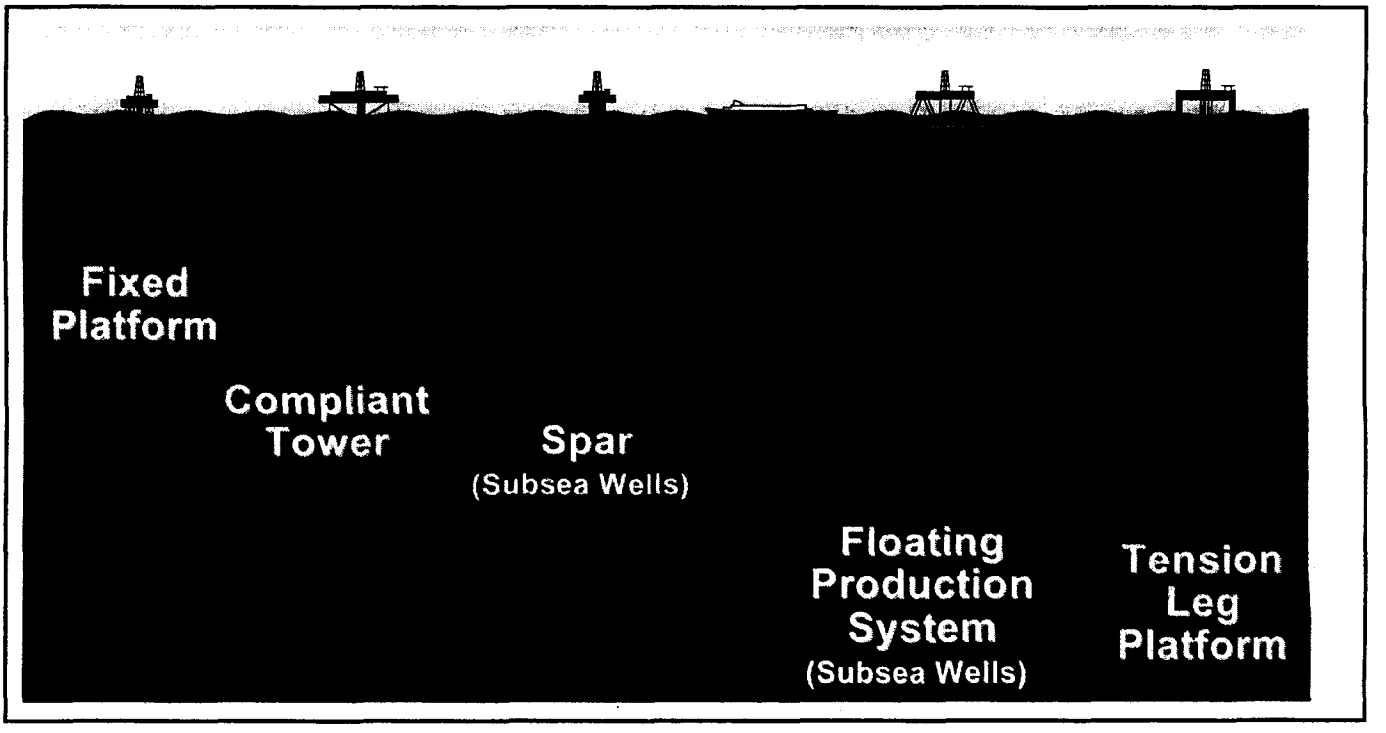
There are numerous different types of offshore oil extraction facilities. Some facilities are fixed for development drilling while other facilities are mobile for both exploration and development drilling. Previous EPA estimates of non-contact cooling water for offshore oil and gas extraction facilities showed a wide range of cooling water demands (294 - 5,208,000 gal/day).[4]

1.1 Fixed Oil and Gas Extraction Facilities

Most of these structures (Figure 3-61) use a pipe with a passive screens (strainers) to convey cooling water. There are a number of cooling water intake structure (CWIS) configurations for fixed facilities including sea chests (Figure 3-62), simple pipe (Figures 3-63 and 3-64), and caisson (Figures 3-66, 3-67, and 3-68). Perforated caissons or simple pipes have been used on some fixed platforms. For example, the Marathon platform at South Ewing Bank (OCS Block 873) has a design intake flow of 4 MGD and uses a 24 inch outer diameter simple pipe with square grid 0.5 inch perforations at the intake which translates to an intake velocity of 1 feet per second. The Aera Energy Ellen (Beta) platform in offshore California withdraws 3.5 MGD and has two cooling water intakes structures each with a through screen of 0.5 feet per second. This platform uses a simple 20 inch pipe with a 2 inch cone screen with approximately 0.5 inch openings. This intake uses a 90/10 Cu/Ni alloy pipe for controlling biofouling.

Non-contact, once-through water is used to cool crude oil, produced water, power generators and various other pieces of machinery (e.g., drawworks brakes). Due to the number of oil and gas extraction facilities in the GOM in relation to other OCS regions, EPA estimated the number of fixed active platforms in the Federal OCS region of the Gulf of Mexico using the MMS 2003 Deepwater Production Summary by Year. Abandoned platforms and platforms without production equipment were eliminated from the platform count. The platforms were then categorized by deepwater and shallow water, and 20+ wells and < 20 wells. The counts are presented in Exhibit 3-66. As the table shows, about 90 percent of platforms in the GOM are small platforms operating in shallow water. Only a limited number of structures (generally not the typical fixed platforms) are found in the deepwater regions of the GOM. Currently (2003 data) only 26 are considered build and operational in the MMS database.

Figure 3-61. Fixed Oil and Gas Extraction Facilities



[4]U.S. EPA, Development Document for Effluent Limitations and Guidelines and New Source Performance Standards for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category, EPA-821-R-93-003, January 1993.

Figure 3-62. Offshore Seachest Cooling Water Intake Structure Design

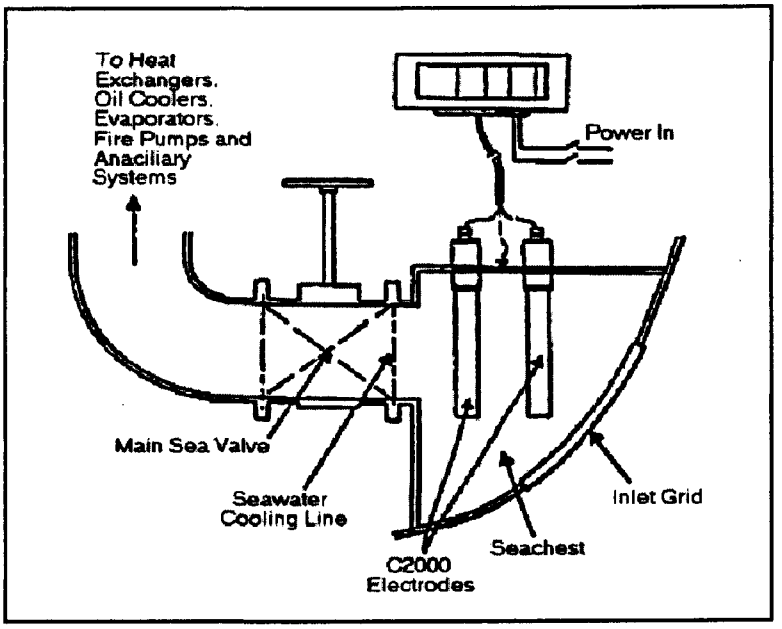


Figure 3-63. Offshore Simple Pipe Cooling Water Intake Structure Design (Schematic)

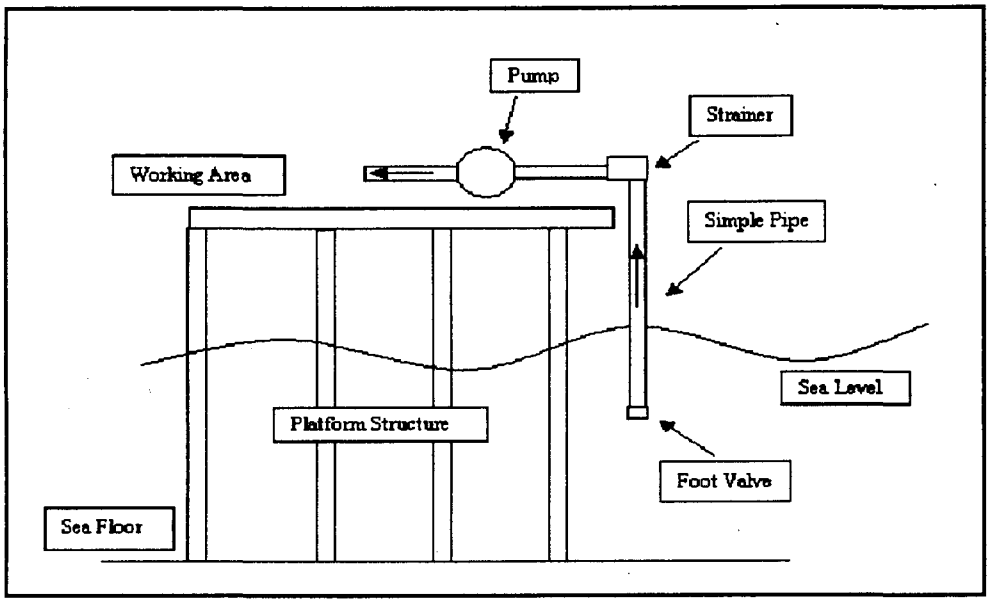
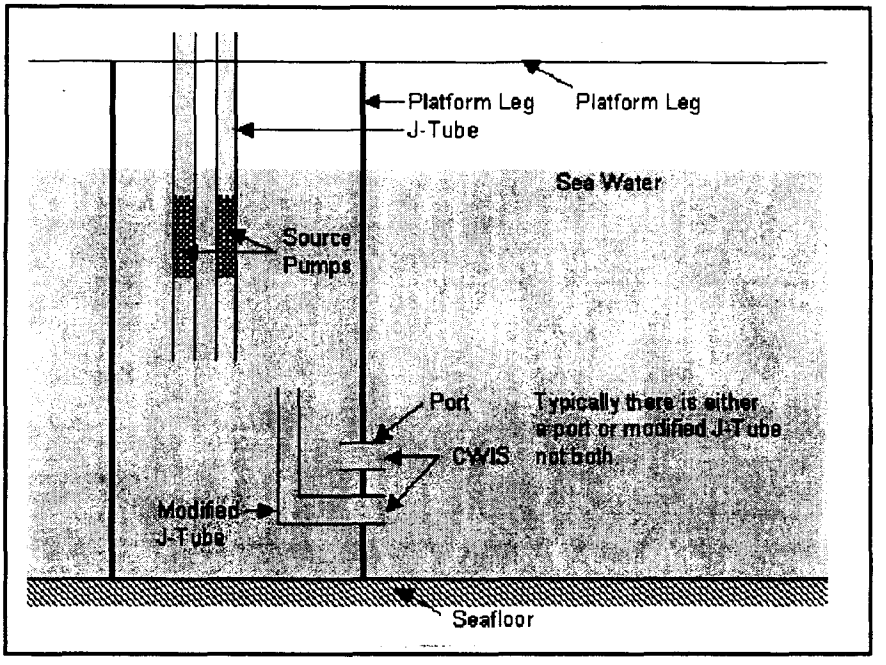


Figure 3-64. Offshore Simple Pipe Cooling Water Intake Structure Design - Wet Leg



Note: Another configuration, the "J" Tube configuration, also uses simple pipes as a cooling water intake structure but with no seawater in the platform leg.

Figure 3-65. Offshore Caisson Cooling Water Intake Structure Design (Thompson Culvert Company)

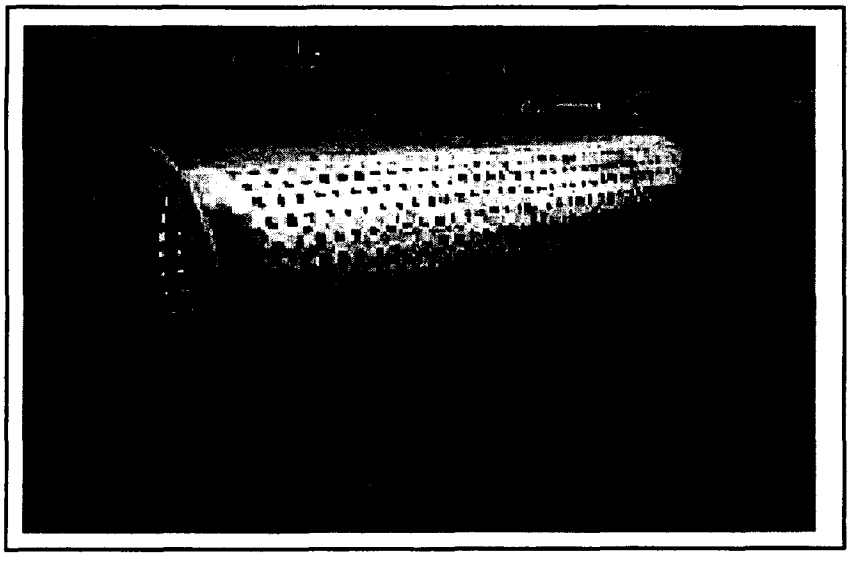


Figure 3-66. Offshore Caisson Cooling Water Intake Structure Design - Leg Mounted Well Tower

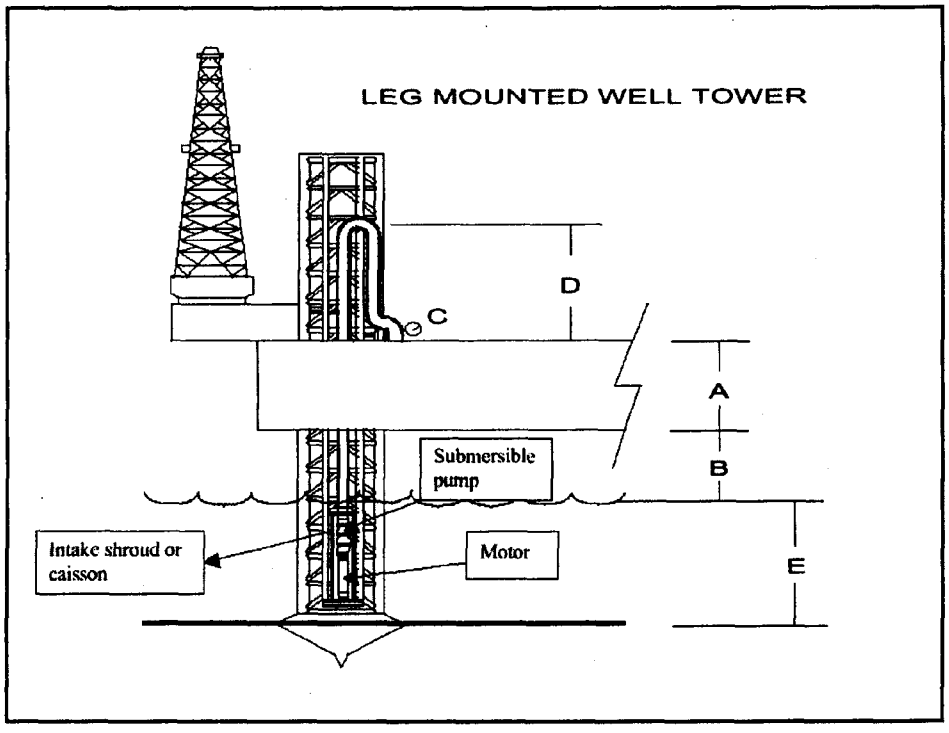


Figure 3-67. Offshore Caisson Cooling Water Intake Structure Design - Conventional Well Tower

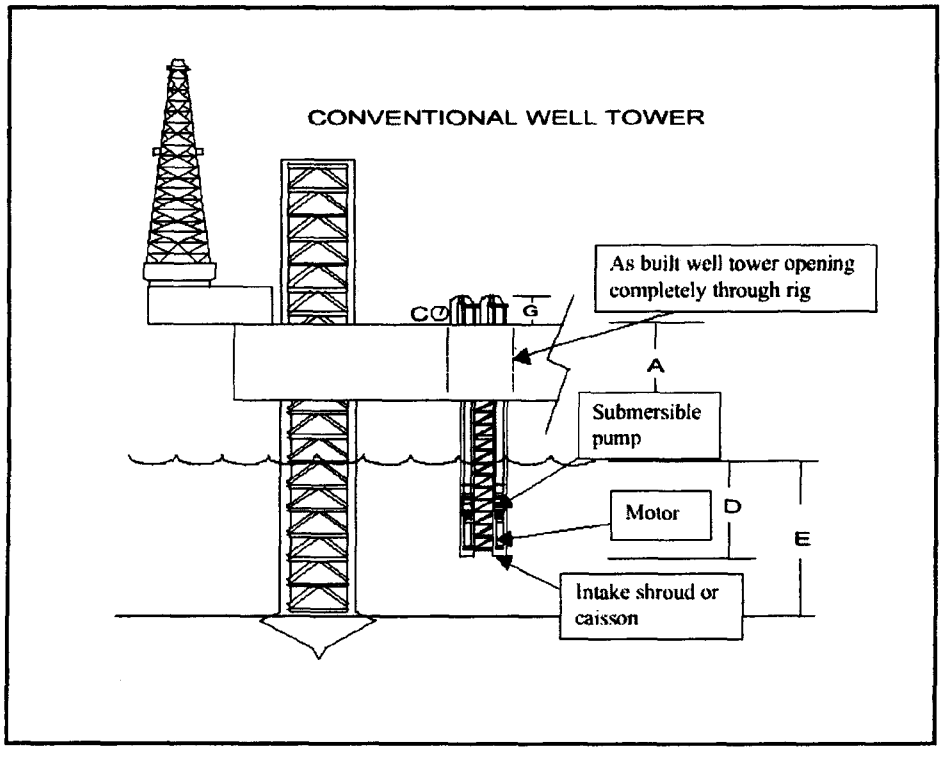


Exhibit 3-67. Identification of Structures in the Gulf of Mexico OCS

Category	Count
Total Number of Platforms	6,266
Removed Platforms	2,229
Abandoned Platforms	21
Platforms without Production Equipment	1,587
Producing Platforms - Deepwater	26
Producing Platforms - Shallow water + 20 slots	209
Producing Platforms - Shallow water < 20 slots	2,194
Total Producing Platforms	2,429

Source: MMS. 2003. Deepwater production summary by year. U.S. Department of the Interior. Mineral Management Service.

The Offshore Operators Committee (OOC) and the National Oceans Industries Association (NOIA) also noted in their comments to the 316(b) Phase I NODA (see May 25, 2001; 66 FR 28853) that a typical platform rig for a Tension Leg Platform[5] will require 10 - 15 MM Btu/hr heat removal for its engines and 3 - 6 MM Btu/hr heat removal for the drawworks brake. The total heat removal (cooling capacity required) is 13 - 21 MM Btu/hr. Assuming continuous once through cooling and a seawater temperature increase of 10 °C between intake and discharge, the volume of seawater required for cooling these engines at a Tension Leg Platform can roughly be estimated between 2.0 to 3.3 MGD (see DCN 7-3645).

OOC/NOIA also estimated that approximately 200 production facilities have seawater intake requirements that exceed 2 MGD. OOC/NOIA estimate that these facilities have seawater intake requirements ranging from 2 - 10 MGD with one-third or more of the volume needed for cooling water. Other seawater intake requirements include firewater and ballasting. The firewater system on offshore platforms must maintain a positive pressure at all times and therefore requires the firewater pumps in the deep well casings to run continuously. Ballasting water for floating facilities may not be a continuous flow but is an essential intake to maintain the stability of the facility.

1.2 Mobile Oil and Gas Extraction Facilities

EPA also estimated the number of mobile offshore drilling units (MODUs) currently in operation (see Figure 3-68 for examples). These numbers change in response to market demands. Over the past five years the total number of mobile offshore drilling units (MODUs) operating at one time in areas under U.S. jurisdiction has ranged from less than 100 to more than 200. There are five main types of MODUs operating in areas under U.S. jurisdiction: drillships, semi-submersibles, jack-ups, submersibles and drilling barges. Exhibit 3-67 gives a brief summary of each MODU. EPA and MMS could not identify any cases where the environmental impacts of a MODU cooling water intake structure were considered.

[5]A Tension Leg Platform (TLP) is a fixed production facilities in deepwater environments (> 1,000 ft).

Figure 3-68. Mobile Oil and Gas Extraction Facilities

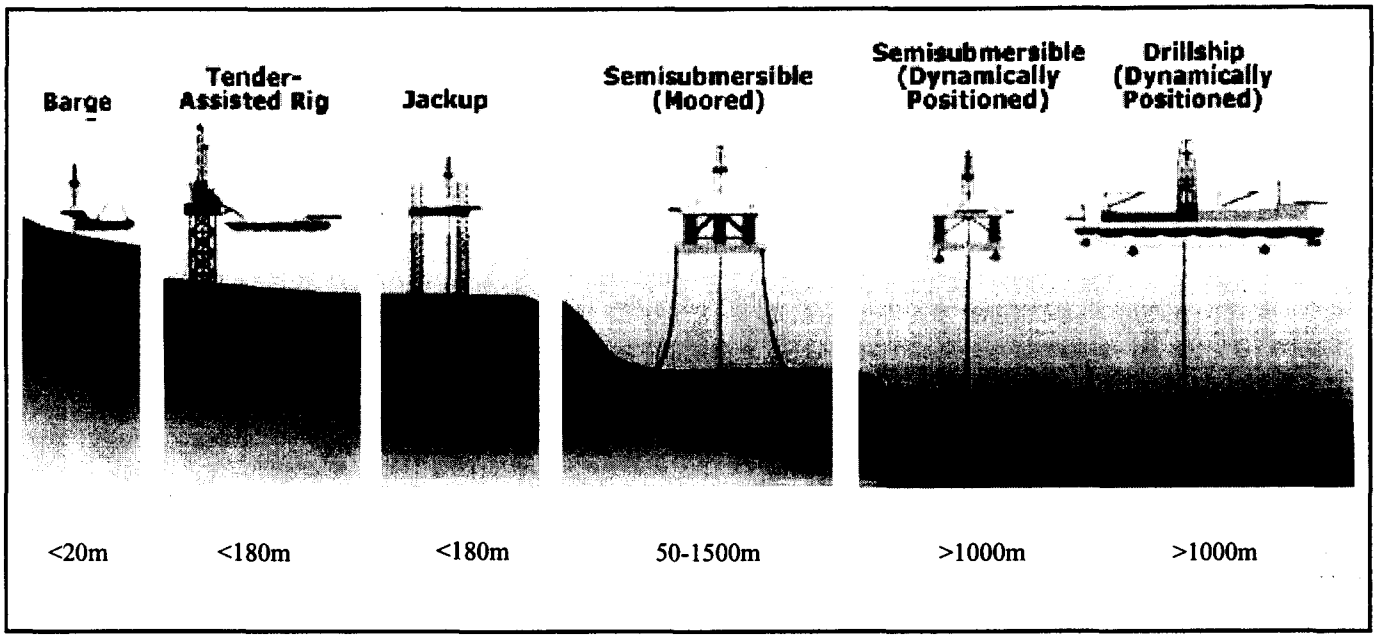


Exhibit 3-68. Description of Mobile Offshore Drilling Units and Their Cooling Water Intake Structures

MODU Type	Water Intake* and Design	Water Depth	Estimate of the Number of Existing MODUs**
Drill Ships	16 - 20 MGD Seachest	Greater than 400 ft	11
Semi-submersibles	2 - 15+ MGD Seachest	Greater than 400 ft	63
Jack-ups	2 - 10+ MGD Intake Pipe	Less than 400 ft	192
Submersibles	< 2 MGD Intake Pipe	Shallow Water (Bays and Inlet Waters)	47
Drill Barges	< 2 MGD Intake Pipe	Shallow Water (Bays and Inlet Waters)	70

Sources: 1) Johnston, Carey A. U.S. EPA, Memo to File, Notes from April 4, 2001 Meeting with US Coast Guard. April 23, 2001, DCN 2–012A. 2) ODS-Petrodata Group, Offshore Rig Locator, Houston, Texas, Vol. 28, No. 4, April 4, 2001. 3) Spackman, Alan, International Association of Drilling Contractors, Comments on Phase I 316(b) Proposed Rule, Comment Number 316bNFR.004.001. 4) Spackman, Alan, International Association of Drilling Contractors, Memo to Carey Johnston, U.S. EPA, 316(b), May 8, 2001.
* Approximately 80% of the water intake is used for cooling water with the remainder being used for hotel loads, fire water testing, cleaning, and ballast water.[6]
** MODU count from DCN 7-3657, Record Section 1.1.3.

[6]Johnston, Carey A. U.S. EPA, Memo to File, Notes from April 4, 2001 Meeting with US Coast Guard. April 23, 2001, DCN 2–012A.

The particular type of MODU selected for operation at a specific location is governed primarily by water depth (which may be controlling), anticipated environmental conditions, and the design (depth, wellbore diameter, and pressure) of the well in relation to the units equipment. In general, deeper water depths or deeper wells demand units with a higher peak power-generation and drawworks brake cooling capacities, and this directly impacts the demand for cooling water.[7]

a. Drillships and Semi-Submersibles MODUs

Drill ships and semi-submersibles use a "sea chest" as a cooling water intake structure.[8] In general there are three pipes for each sea chest (these include cooling water intake structures and fire pumps). One of the three intake pipes is always set aside for use solely for emergency fire fighting operations. These pipes are usually back on the flush line of the sea chest. The sea chest is a cavity in the hull or pontoon of the MODU and is exposed to the ocean with a passive screen (strainer) often set along the flush line of the sea chest. These passive screens or weirs generally have a maximum opening of 1 inch (Comment Number 316bNFR.004.001). There are generally two sea chests for each drill ship or semi-submersible (port and starboard) for redundancy and ship stability considerations. In general, only one seachest is required at any given time for drilling operations (DCN 2–012A).

While engaged in drilling operations most drillships and one-third of semi-submersibles maintain their position over the well by means of "dynamic positioning" thrusters which counter the effects of wind and current. Additional power is required to operate the drilling and associated industrial machinery, which is most often powered electrically from the same diesel generators that supply propulsion power. While the equipment powered by the ship's electrical generating system changes, the total power requirements for drillships are similar to those while in transit. Thus, during drilling operations the total seawater intake on a drillship is approximately the same as while underway. The majority of semi-submersibles are not self- propelled, and thus require the assistance of towing vessels to move from location to location. For example, the Transocean Deepwater Horizon semi-submersible MODU withdraws 16.0 MGD and has eight cooling water intakes structures each with a through screen velocity of 0.5 feet per second. This MODU uses sea chests openings of 24.4 inch by 28.7 inch with single simplex strainers in the sea chest. The sea chest screens are simple passive strainers with a one inch grid opening. The Transocean Cajun Express semi-submersible MODU withdraws 6.1 MGD and has six cooling water intakes structures each with a through screen of 0.23 feet per second. This MODU uses sea chests openings of 32 inches in diameter with 14 inch by 8 inch corrugated basket strainers in the sea chest. The sea chest screens are simple passive strainers with a one inch grid opening.

Information from the U.S. Coast Guard indicates that when semi-submersibles are drilling their sea chests are 80 to 100 feet below the water surface and are less than 20 feet below water when the pontoons are raised for transit or screen cleaning operations (DCN 2–012A). Drill ships have their sea chests on the bottom of their hulls and are typically 20 to 40 feet below water at all times.

The International Association of Drilling Contractors (IADC) notes that one of the earlier semi-submersible designs still in use is the "victory" class unit (Spackman, May 8, 2001). This unit is provided with two seawater-cooling pumps, each with a design capacity of 2.3 MGD with a 300 head. At operating draft the center of the inlet, measuring approximately 4 feet by 6 feet, is located 80 feet below the sea surface and is covered by an inlet screen. In the original design this screen had 3024 holes of 15mm diameter. The approximate inlet velocity is therefore 0.9 feet per second.

The more recent semi-submersible designs typically have higher installed power to meet the challenges of operating in deeper water, harsher environmental conditions, or for propulsion or positioning. IADC notes that a newly-built unit, of a new design, has a seawater intake capacity of 34.8 MGD, which includes salt water service pumps and ballast pumps, and averages 10.7 MGD of seawater intake of which 7.4 MGD is for cooling water.

b. Jack-up MODUs

Jack-up, submersibles, and drill barges use intake pipes for cooling water intake structures. These facilities basically use a pipe with a passive screens (strainers) to convey cooling water. Non-contact, once-through water is used to cool crude oil, produced water, power generators and various other pieces of machinery on these facilities (e.g., drawworks brakes).

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[7]Spackman, Alan, International Association of Drilling Contractors, Memo to Carey Johnston, U.S. EPA, 316(b), May 8, 2001.

[8] A sea chest is an underwater compartment within the vessel's hull through which sea water is drawn in or discharged. A passive screen (strainer) is set along the flush line of the sea chest. Pumps draw seawater from open pipes in the sea chest cavity.

The jack-up is the most numerous type of MODU. These vessels are rarely self- propelled and must be towed from location to location. Once on location, their legs are lowered to the seabed, and the hull is raised (jacked-up) above the sea surface to an elevation that prevents wave impingement with the hull. Although all of these ships do use seawater cooling for some purposes (e.g., desalinators), as with the semi-submersibles a few use air-cooled diesel-electric generators because of the height of the machinery above the sea surface (Comment Number 316bNFR.004.001). Seawater is drawn from deep-well or submersible pumps that are lowered far enough below the sea surface to assure that suction is not lost through wave action. Total seawater intake of these ships varies considerably and ranges from less than 2 MGD to more than 10 MGD. Jack-ups are limited to operating in water depths of less than 500 feet, and may rarely operate in water depths of less than 20 feet.

The most widely used of the jack-up unit designs is the Marathon Letourneau 116-C (Spackman May 8, 2001). For these types of jack-ups typically one pump is used during rig operations with a 6" diameter suction at 20 to 50 feet below water level which delivers cooling water intake rates of 1.73 MGD at an inlet velocity of 13.33 feet per second (Spackman May 8, 2001). Additionally, pre-loading involves the use of two or three pumps in sequence. Pre-loading is not a cooling water procedure, but a ballast water (which is later discharged).[9] Each pump is fitted with its own passive screen (strainer) at the suction point which provides for primary protection against foreign materials entering the system.

In their early configurations, these jack-up MODUs were typically outfitted with either 5 diesel generator units, each rated at about 1,200 horsepower, or three diesel generator units, each rated at about 2,200 horsepower (Spackman May 8, 2001). In subsequent configurations of this design or re-powering of these units, more installed power has generally been provided, as it has in more recent designs. With more installed power, there is a demand for more cooling water. IADC reports that a newly-built jack-up, of a new design, typically requires 3.17 MGD of cooling water for its drawworks brakes and cooling of six diesel generator units, each rated at 1,845 horsepower (Spackman May 8, 2001). In this case one pump is typically used during rig operations with a 10" diameter suction at 20 to 50 feet below water level, delivering the cooling water at 3.2 MGD.

c. Submersibles and Drill Barge MODUs

The submersible MODU is used most often in very shallow waters of bays and inlet waters. These MODUs are not self-propelled. Most are powered by air-cooled diesel-electric generators, but require seawater intake for cooling of other equipment, desalinators, and for other purposes. Total seawater intake varies considerably with most below 2 MGD.

There are approximately 50 drilling barges available for operation in areas under U.S. jurisdiction, although the number currently in operation is less than 20. These ships operate in shallow bays and inlets along the Gulf Coast, and occasionally in shallow offshore areas. Many are powered by air-cooled diesel-electric generators. While they have some water intake for sanitary and some cooling purposes, water intake is generally below 2 MGD.

2.0 PHASE III INFORMATION COLLECTION FOR OIL AND GAS EXTRACTION FACILITIES

Numerous researchers and State and Federal regulatory agencies have studied and controlled the discharges from oil and gas extraction facilities for decades. The technology-based standards for the discharges from these facilities are located in 40 CFR 435. Conversely, there has been little work done to investigate the environmental impacts or evaluation of the location, design, construction, and capacity characteristics of cooling water intake structures for offshore oil and gas extraction facilities.

In developing the Phase III proposal, EPA used a variety of sources to identify data on the current status of the oil and gas extraction industry and the cooling water intake structures associated with these facilities. Sources of data included; consultations with the two main regulatory entities of this industrial sector (i.e., USCG, MMS), an EPA survey of the industry which collected both economic and technical data, technical data submittals from industry which were provided either directly or through various trade associations, and information available from the internet. Each of these sources of information are described in more detail below.

2.1 Consultations with USCG and MMS

The U.S. Coast Guard (USCG) and the Department of Interior's Mineral Management Services (MMS) agency identified no specific regulatory requirements for this industrial sector with respect to potential environmental impacts associated with cooling water intake structures. The USCG does not investigate potential environmental impacts of MODU cooling water intake structures but does require

[9]Vlahos, G., Martin, C.M., Cassidy, M.J., 2001. Experimental Investigation of a Model Jack-Up Unit on Clay, Proceedings of the Eleventh (2001) International Offshore and Polar Engineering Conference, Stavanger; Norway, June 17-22, 2001.

operators to inspect sea chests twice in every five year period and conduct at least one cleaning to prevent blockages of firewater lines. EPA met with Mr. James Magill of USCG, Vessel and Facility Operating Standards Division to collection information on MODU operations and cooling water intake systems.[10]

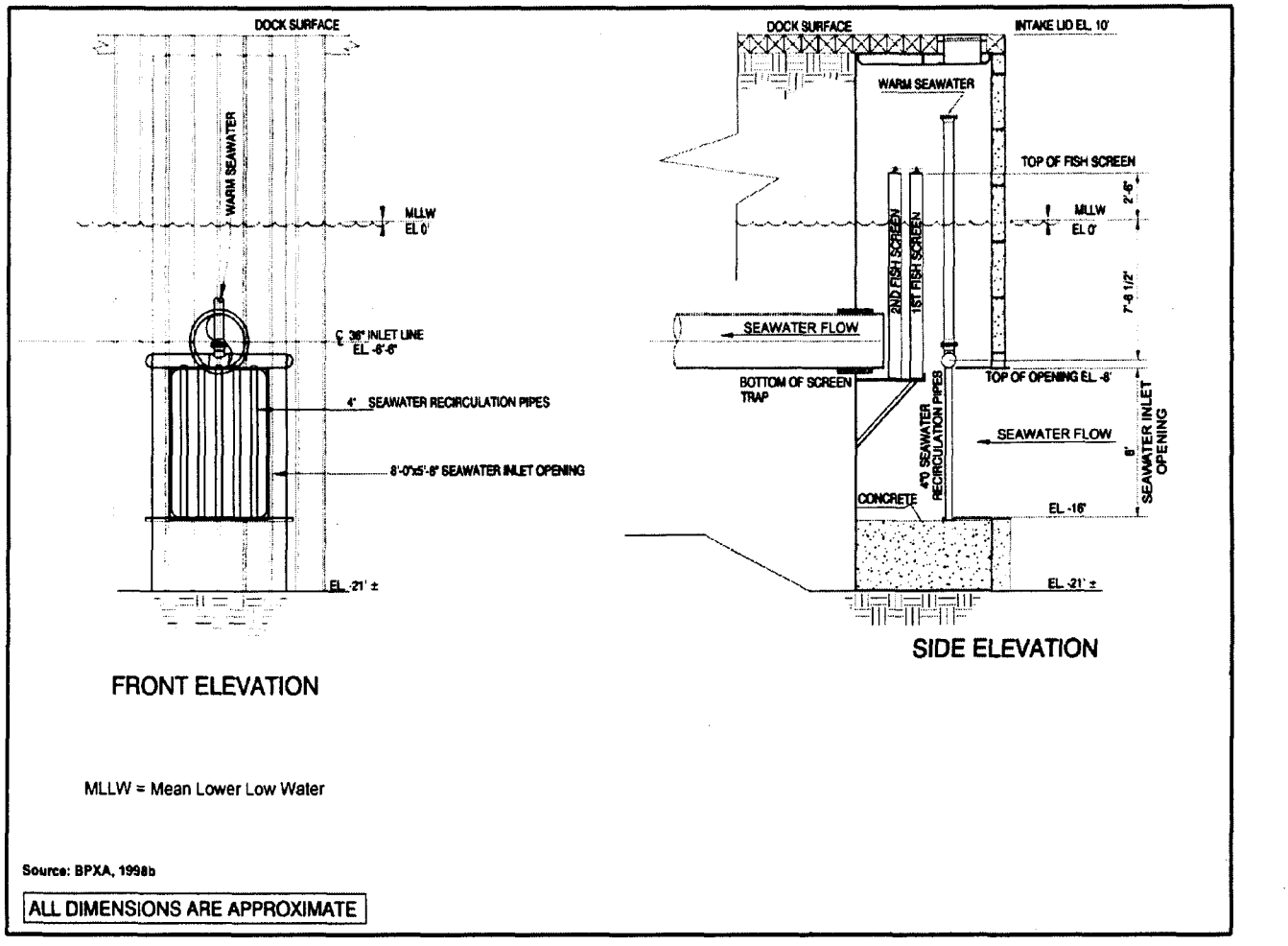
MMS is the Federal agency responsible for managing Outer Continental Shelf (OCS) mineral resources. MMS has authority for leasing in OCS and therefore has current lists of owner-operators and lessees. EPA used the MMS website, MMS Platform Inspection System, Complex/Structure database, Lessees/Operators financial information, MMS's environmental impact statements, environmental assessments, and other MMS sponsored studies to collect information to support the Phase III proposal.

Specifically, EPA used the MMS databases to estimate the number of fixed OCS platforms in the Gulf of Mexico. EPA also used facility information from the Alaska OCS Region office to determine the number of facilities in the OCS. The Pacific OCS Region website provided general information on oil and gas production facilities in the Pacific OCS Region. No information on the number of facilities in State waters and Coastal waters were found. EPA used the MMS environmental impact statements, environmental assessments, and other MMS sponsored studies to evaluate impact on marine organism assemblages from offshore oil and gas exploration and production. In general, MMS did not have information on cooling water intake structures for oil and gas extraction facilities.

EPA identified one case in the MMS files where they evaluated potential environmental impacts from an oil and gas extraction facility cooling water intake structure as part of their NEPA analyses. This analysis was conducted as part of BP Exploration Inc. (BPXA) plans to locate a vertical intake pipe for a seawater-treatment plant on the south side of Liberty Island, Beaufort Sea, Alaska. Figure 3-69 depicts the cooling water intake structure planned for the BPXA sea-water treatment plant. The pipe would have an opening 8 feet by 5.67 feet and would be located approximately 7.5 feet below the mean low-water level. The discharge from the continuous flush system consists of the seawater that would be continuously pumped through the process-water system to prevent ice formation and blockage. Recirculation pipes located just inside the opening would help keep large fish, other animals, and debris out of the intake. Two vertically parallel screens (6 inches apart) would be located in the intake pipe above the intake opening. They would have a mesh size of 1 inch by 1/4 inch. Maximum water velocity would be 0.29 feet per second at the first screen and 0.33 feet per second at the second screen. These velocities typically would occur only for a few hours each week while testing the fire-control water system. At other times, the velocities would be considerably lower. Periodically, the screens would be removed, cleaned, and replaced.

[10]Memorandum: Notes from April 4, 2001 Meeting with U.S. Coast Guard. From: Carey A. Johnston, USEPA/OW/OST, To: File, May 7, 2001.

Figure 3-69. Liberty Island Cooling Water Intake Structure



MMS states in the Liberty Island Draft Environmental Impact Statement that the proposed seawater-intake structure will likely harm or kill some young-of-the-year arctic cisco during the summer migration period and some eggs and fry of other species in the immediate vicinity of the intake. However, MMS estimates that less than 1% of the arctic cisco in the Liberty Island area are likely to be harmed or killed by the intake structure. Further, MMS concludes that: (1) the intake structure is not expected to have a measurable effect on young-of-the-year arctic cisco in the migration corridor; and (2) the intake structure is not expected to have a measurable effect on other fishes populations because of the wide distribution/low density of their eggs and fry. However, essential fish habitat for salmon will be adversely affected according to MMS because it is expected that prey species of zooplankton and fish in their early life stages (juveniles, eggs, and larvae) could be killed in the intake.

More recently, MMS assisted EPA by providing an initial annotated bibliography on all available research reported in marine and coastal waters concerning the impingement and entrainment of estuarine and marine organisms by cooling-water intake systems.[11] Most of the results obtained through this search were references about studies on fish impingement or entrainment by cooling-water intakes of nuclear or thermoelectric power plants located on estuarine or marine environments. MMS did not identify any references specific to fish impingement or entrainment by cooling-water intakes of oil and gas extraction facilities. MMS concluded that studies

[11]MMS, 2003. "Marine and Coastal Fishes Subject to Impingement by Cooling-Water Intake Systems in the Northern Gulf of Mexico: An Annotated Bibliography," MMS 2003-040, August 2003.

of impingement or entrainment by cooling-water intakes of oil and gas extraction facilities are generally unavailable through the searched databases.

2.2 EPA 316(b) Phase III Survey

In September 2003, EPA sent out a 316(b) Phase III survey to oil and gas extraction facilities to collect technical and economic data related to these types of facilities and their cooling water intake structures. EPA surveyed 90 facilities as part of this effort and received responses from 78 facilities. Exhibit 3-69 presents a breakout of the number of surveys mailed and responses by type of survey.

Exhibit 3-69. 316(b) Phase III Survey Statistics

Industry/Type of Survey	No. of Surveys Mailed	No. of Survey Responses
Oil & Gas Platforms (Technical and Economic Survey)	55	52
Oil & Gas Platforms (Economic Survey only)	5	3
MODU's (Economic Survey only)	30	23
Total	90	78

Source: Phase III Technical Questionnaire Tracking Report, From: Kelly Meadows, TetraTech, Date: 3/12/2004 (revised 3/23/2004).

EPA identified companies to survey based on a sampling frame of facilities expected to be in-scope. When a facility's eligibility was unknown, it was retained in the sampling frame. The sampling design selected by EPA included stratification of facilities based on the type of structure and its location. The stratification categories used in the survey included:

1. Gulf of Mexico Platforms - Deep Water
2. Gulf of Mexico Platforms - More than 20 Slots
3. Gulf of Mexico Platforms - Shallow Waters
4. California Platforms
5. Alaska Platforms
6. MODUs

These strata were chosen because they were expected to correspond to major differences in economic variables and also in the technology costs of implementing controls on impingement and entrainment. The survey samples were selected from lists for each of the subpopulations. A systematic sample with a random start was taken.

Exhibit 3-70 presents the number of facilities estimated to be in-scope in each of these strata and the number that were sampled in the survey.

Exhibit 3-70. Number of In-Scope Facilities and Number Sampled by Frame

Sampling Stratification Frame	Number of Facilities Estimated to be In-Scope	Number of Facilities Sampled
Gulf of Mexico Platforms - Deep Water	24	4
Gulf of Mexico Platforms - More than 20 Slots	206	33
Gulf of Mexico Platforms - Shallow Waters	2,194	18
California Platforms	20	3
Alaska Platforms	19	2
MODUs	404	30
All Frames	2,867	90

Source: Memorandum: Sampling Selection for Offshore Oil & Gas - TD#W040917a dated September 17, 2003, From: G. Hussain Choudhry and Inho Park, Westat, To: John Fox, EPA, Date: October 7, 2003.

Economic and technical data submitted as part of the responses were used by EPA in the economic and costing analyses conducted as part of the Phase III proposal.

2.3 Technical Data Submittals from Industry

EPA received the majority of its technical cooling water intake structure data from industry either directly or through industry trade associations. The trade associations supporting and providing data submittals included the:

- International Association of Drilling Contractors (IADC)
- Offshore Operators Committee (OOC)
- Western States Petroleum Association (WSPA)
- Louisiana Mid-Continent Oil and Gas Association (LMOGA)

IADC provided cooling water intake structures information, solicited from its members, for over 140 mobile offshore drilling units operating in or marketed for operations in areas under the jurisdiction of the U.S. In addition, the 2002 IADC membership directory listed companies that represent a significant portion of the world's exploration and production activity. The directory information included, names of key personnel, addresses of both headquarter and branch locations, telephone and fax numbers, and internet addresses. The contractor directory also provided an alphabetical listing of drilling contractors who own and operate the vast majority of the world's land and offshore drilling units. That listing included the names of key personnel, addresses of both headquarter and branch locations, telephone and fax numbers, internet addresses, the size of each firm's rig fleet and operating theaters, and for offshore units, the rig type. The IADC submittals and directories did not include any economic information.

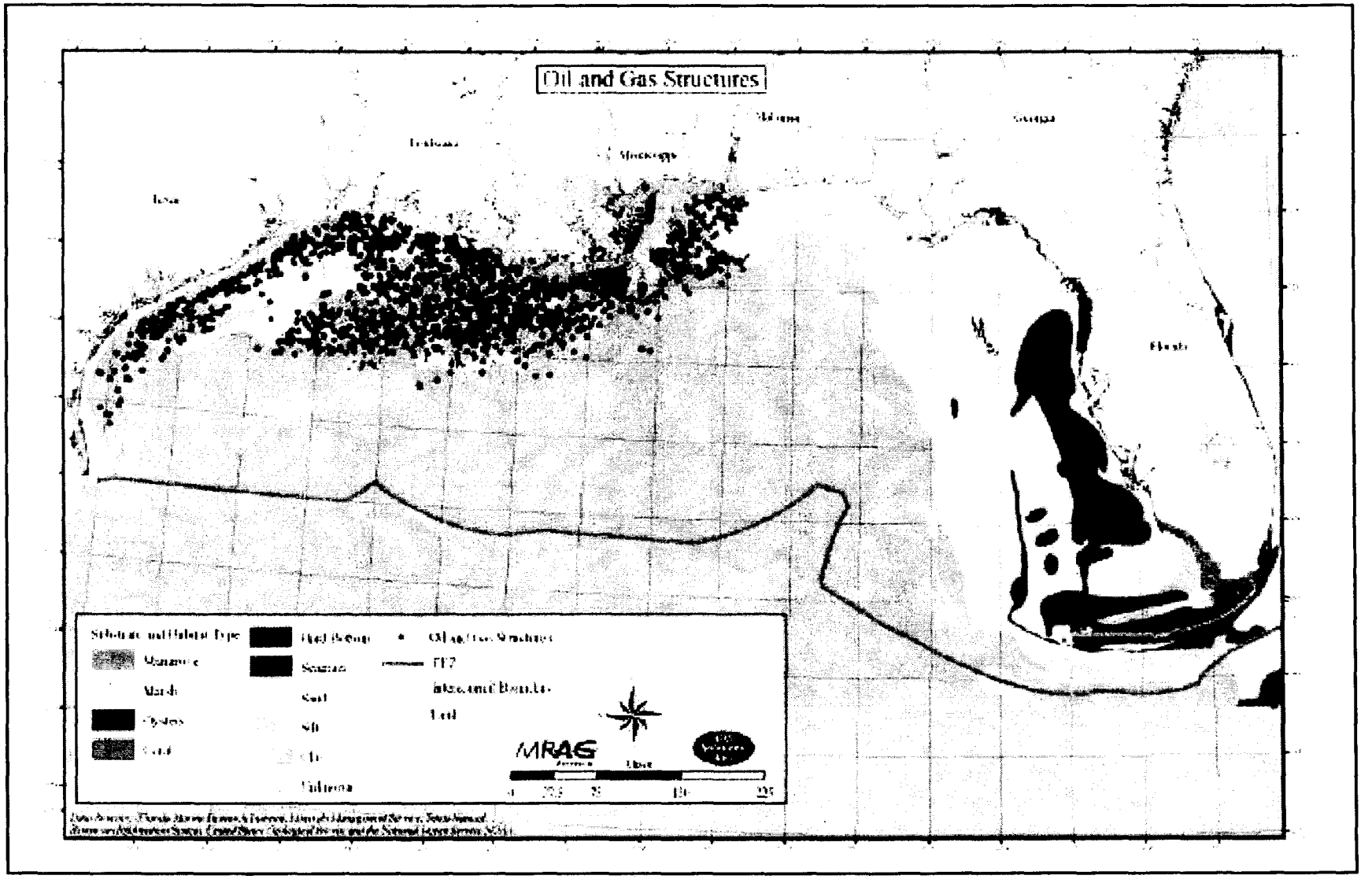
The OOC provided information, compiled on behalf of its members, on cooling water intake structures for offshore oil and gas extraction facilities in the Gulf of Mexico. Cooling water intake structure data were provided for 21 fixed platforms and no economic information were included. EPA was able to identify that 16 of the 2,429 fixed facilities and 87 of the 383 MODUs in the GOM withdrew more than 2 MGD of seawater with more than 25% used for cooling (see Figures 3-70 and 3-71 for display of fixed facilities).

Operators in Cook Inlet, Alaska, also provided information to EPA on cooling water intake structures for Cook Inlet platforms. The oil and gas fields in Cook Inlet are considered mature and since 1995 production in the Trading Bay Field, Granite Point Field, Middle Ground Field, and Tyonek platform declined from 17 to 92 percent. Consequently, fewer wells are being drilled in Cook Inlet and this means less equipment requires cooling. For example, the Spark and Spurr platforms have not operated their cooling water systems in over 7 years. These two cooling water system were decommissioned by their operator. Currently these two platforms are unmanned, remotely operated, gas production facilities without drilling, compression, or fire water suppression systems. Using industry data EPA

was able to identify that five of the 16 fixed platforms in Cook Inlet withdrew more than 2 MGD of seawater with more than 25% used for cooling (see Figure 3-72).

The WSPA provided information, compiled on behalf of its members, on cooling water intake structures for offshore oil and gas extraction facilities off the coast of California. Cooling water intake structure data were provided for 18 fixed platforms and no economic information were included. Using this data EPA was able to identify that six of the 32 fixed platforms withdrew more than 2 MGD of seawater with more than 25% used for cooling (see Figure 3-72).

Figure 3-70. Gulf of Mexico Oil and Gas Extraction Facilities



Source:

Final Environmental Impact Statement for the Generic Essential Fish Habitat, Gulf of Mexico Fishery Management Council, March 2004.

Figure 3-71. Gulf of Mexico Oil and Gas Extraction Facilities That Withdraw More than 2 MGD of Seawater with More than 25% of the Intake Is Used for Cooling

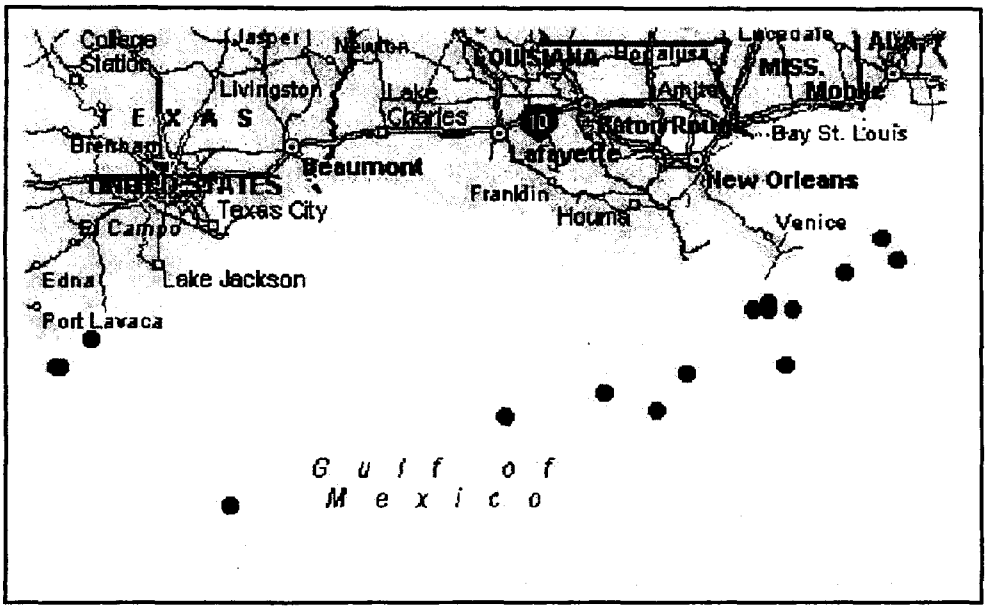
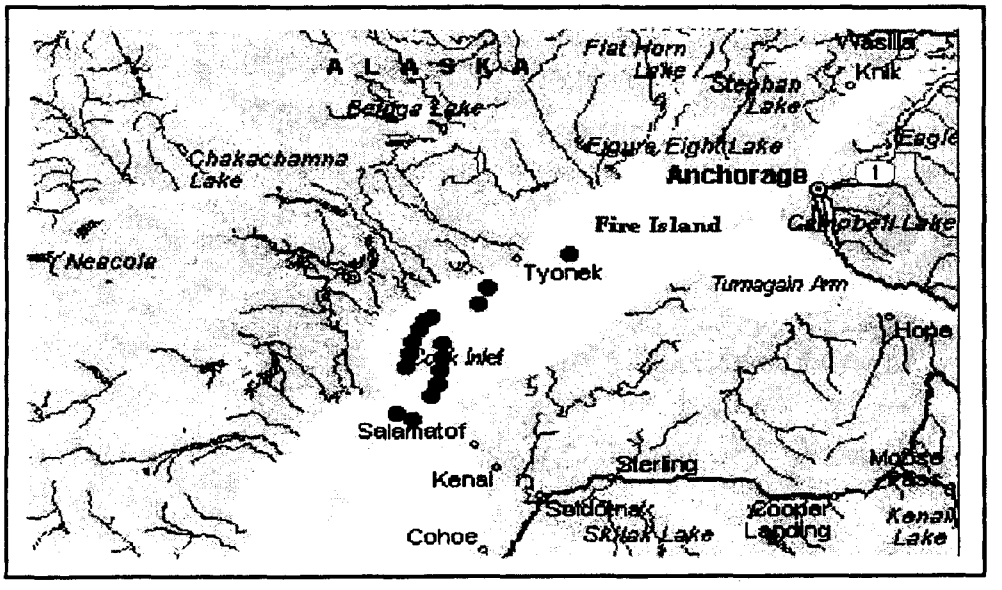
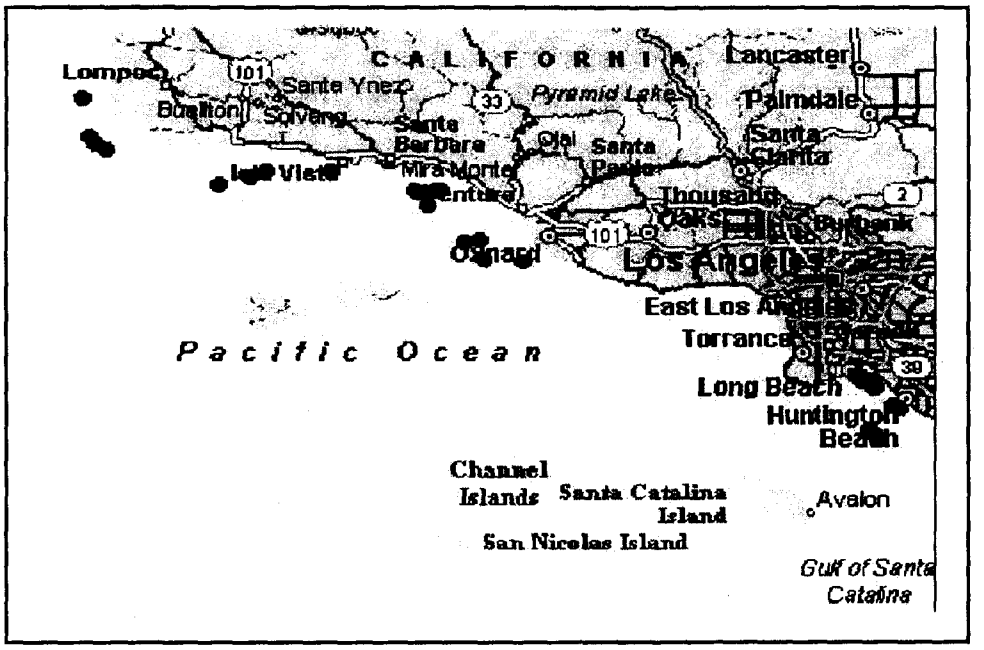


Figure 3-72. Cook Inlet, Alaska, Oil and Gas Extraction Facilities



Note: Platforms marked in red withdraw more than 2 MGD of seawater with more than 25% of the intake used for cooling.

Figure 3-72. California Oil and Gas Extraction Facilities



Note: Platforms marked in red withdraw more than 2 MGD of seawater with more than 25% of the intake used for cooling.

The LMOGA represents facilities located in the state and includes those facilities located in state-waters of the Gulf of Mexico. LMOGA contacted its trade association members asking for information on water withdrawal rates. All respondents to the LMOGA data request indicated that they use less than 2 MGD of surface water. Again, no economic information was provided.

All technical information provided by industry and collected as part of the EPA Phase III survey for oil and gas exploration facilities was compiled into an Excel datasheet for use in costing existing in-scope facilities for cooling water intake structure control. That database is located in the rulemaking record (see DCN 7-3505, section 8.0).

2.4 Internet Sources

EPA collected pertinent information on the identity, number, and location of oil and gas extraction facilities from five websites:

The California Environmental Resources Evaluation System (http://www.ceres.ca.gov),
The Alabama State Oil and Gas Board (http://www.ogb.state.al.us),
The Texas Railroad Commission (http://www.rrc.state.tx.us/),
World Oil (http://www.worldoil.com/),
Rig Zone (http://www.rigzone.com), and
Drilling Contractor websites.

None of these websites provided technical information on cooling water intake structures or facility economic data. Exhibit 3-72 presents a description of the type of information that was collected from each site.

Exhibit 3-72. Oil & Gas Extraction Facilities - Information Collected from Internet Sources

Source	Information Collected
California Environmental Resources Evaluation System Website	This site contained an Oil, Gas, and Mineral Resources Background article. The article states there are twenty-six production platforms, one processing platform and six artificial oil and gas production islands located in the waters offshore California. Of the twenty-seven platforms, four are located in State waters offshore Santa Barbara and Orange Counties, and twenty-three are located in Federal waters offshore Santa Barbara, Ventura and Los Angeles Counties. Four platforms in State waters off Santa Barbara County were abandoned and removed in 1966. The site did not include cooling water intake structure or economic information.
Alabama State Oil and Gas Board Website	According to the Alabama State Oil and Gas Board website, there are 44 total structures in the state waters: 14 single well caissons; 11 well platforms; 4 well/production platforms; 4 bridge-connected well platforms; 1 bridge-connected well/production platform; 8 production platforms; 1 bridge-connected living quarters platform; and 1 gathering platform. The site does not contain any technical information on cooling water intake structure or economic information. The Alabama Offshore Fields database provides field name, county name, operator of the field, producing formation, date established, total wells, producing wells, monthly production, and cumulative production. The list of oil and gas operators in Alabama provides operator name, address, telephone and fax number.
Texas Railroad Commission Website	The Texas Crude Oil Production - Offshore State Waters database contains Railroad Commission district number, field name, county, gas well, condensate, and cumulative gas production. The Texas Gas Well Production - Offshore State Waters contains Railroad Commission district number, field name, county, monthly production for December 2002, year-to-date production January to December 2002, and cumulative oil production. This site does not have information on the number of facilities in State waters or cooling water intake structures.
World Oil Website	This site includes the World Oil's Marine Drilling Rigs 2002/2003 Directory which lists performance data for 635 mobile offshore drilling units. Listings are separated into four categories, including jackups, semisubmersibles, drillships and barges, excluding inland barges, submersibles. Owners and rigs are listed alphabetically, with rigs grouped by class under a typical photograph. The directory provided EPA with a list of mobile offshore drilling units in US water. This site did not contain information on cooling water intake structures for mobile offshore drilling units.
Rig Zone Website	This site includes a search engine which provided the location of drill barges, drillships, inland barges, jackups, semisubmersibles, and submersibles worldwide. The site provided a list of mobile offshore drilling units currently in U.S. waters.
Drilling Contractor Websites	These sites provide information on offshore oil and gas drilling contractors. These sites include: - ENSCO Website (http://www.enscous.com/RigStatus.asp?Content=All), - Noble website (http://www.noblecorp.com/rig/foverviewfrX.html), and - Rowan Website (http://www.rowancompanies.com/) - Transocean (http://www.deepwater.com/StatusandSpecs.cfm) - Nabors (http://www.nabors.com/offshore/default.asp) ENSCO has 53 offshore rigs servicing domestic and international markets and two rigs under construction. Its website includes a listing of ENSCO rigs with drilling equipment specifications (e.g., power plant and drawwork brake specifics) including information on available horsepower. Noble has 59 offshore rigs servicing domestic and international markets. Its website includes a listing of Noble rigs with drilling equipment specifications including information on available horsepower. Rowan has 25 offshore rigs servicing domestic and international markets. Its website identifies the companies rig utilization rate. Transocean has 95 offshore rigs and 70 shallow and inland water mobile drilling units servicing domestic and international markets. Its website includes a listing of Transocean rigs with drilling equipment specifications including information on available horsepower. Nabors markets 26 platform, nine jackup and three barge rigs in the Gulf of Mexico market. These rigs provide well-servicing, workover and drilling services. Its website identifies the companies rig utilization rate.

2.5 Regulatory Agencies

EPA also contacted State regulatory agencies in Alaska, Florida, Alabama, Mississippi, Louisiana, and Texas to determine if they had any specific regulatory requirements for this industrial sector with respect to potential environmental impacts associated with cooling water intake structures. Only Alaska and Alabama provided information to EPA.

The State of Alaska has a standard clause in their oil and gas leasing agreements which controls potential impingement and entrainment impacts from oil and gas extraction facilities. EPA contacted Alaska Department of Natural Resources (AKDNR) to confirm that this clause (see below) is standard for all Alaska leasing statements and how the State ensures compliance with this mitigation measure throughout the duration of the lease.[12]

> Water intake pipes used to remove water from fishbearing waterbodies must be surrounded by a screened enclosure to prevent fish entrainment and impingement. Screen mesh size shall not exceed 0.04 inches unless another size has been approved by Alaska Department of Fish and Game. The maximum water velocity at the surface of the screen enclosure may be no greater than 0.1 foot per second.

AKDNR confirmed that this clause is standard in all Alaska leasing statements in order to control impingement and entrainment impacts from oil and gas extraction facilities in Alaska state waters. This clause was developed by the Alaska Department of Fish and Game (AKDFG). Most water withdrawals occur on the North Slope for building ice roads and ice pads.

AKDNR also stated that the impingement and entrainment mitigation measures are first enforced when they review the oil and gas extraction plan of operations. A facility seeking approval from the State to begin operations must identify in their plans whether it is proposing any surface water withdrawals. They must also identify the source of the surface water, re-state compliance with the standard clause, or the need for a variance. The withdrawal will also require water withdrawal permits from AKDNR. As a matter of practice, unless there was some reason to believe the operator was not meeting the standard, the intake would not be inspected by AKDNR or AKDFG (Schmitz e-mail).

Alabama state law requires facilities to register water withdrawals (with capacities in excess of 100,000 gallons per day) with the Office of Water Resources (OWR) within the Alabama Department of Economic and Community Affairs (ADECA). However, OWR does not track water withdrawal facilities in Alabama by industry specific codes (i.e. SIC).[13] They register facilities under one of three categories: public, non-public and irrigation. Consequently, OWR does not have any useful records on whether oil and gas extraction facilities in Alabama state waters withdraw more than 100,000 gallons per day. Additionally, the Alabama State Oil and Gas Board and the Alabama Petroleum Council were contacted by the Alabama Department of Environmental Management on behalf of EPA. Both Alabama State Oil and Gas Board and the Alabama Petroleum Council estimate that cooling water withdrawals for the oil and gas extraction industry in Alabama waters should be considered *de minus*.[14] This estimate is also consistent with data provided by LMOGA.

EPA also contacted a few foreign regulatory agencies who control environmental impacts from oil and gas extraction facilities in their country's waters. Responses from these foreign regulatory agencies confirm that they have not: (1) investigated any potential impingement or entrainment impacts of surface water intakes at oil and gas extraction facilities; or (2) established any standards for controlling impingement or entrainment impacts for the oil and gas extraction industry.[15]

[12]E-mail communication between Steve Schmitz, AKDNR, and Carey A. Johnston, EPA, August 21, 2003.

[13]E-mail communication between Tom Littlepage, ADECA, and Carey A. Johnston, EPA, April 21, 2004.

[14]Letter from Glenda L. Dean, ADEM, to Mary T. Smith, EPA, March 30, 2004.

[15]Memo to record, C. Johnston, August 17, 2004

3.0 FACILITIES IN THIS INDUSTRIAL SECTOR WHICH EPA EVALUATED FOR THE PHASE III RULEMAKING

As previously mentioned, EPA did not consider new offshore oil and gas extraction facilities in the 316(b) Phase I - New Sources rulemaking. Consequently, EPA evaluated as part of the Phase III proposed rule the technology options available to control impingement and entrainment of aquatic organisms for both existing and new offshore oil and gas extraction facilities.

4.0 TECHNOLOGY OPTIONS AVAILABLE TO CONTROL IMPINGEMENT AND ENTRAINMENT OF AQUATIC ORGANISMS

4.1 Summary of Technology Options to Control Impingement and Entrainment of Aquatic Organisms

There are three main technologies applicable to the control of impingement and entrainment of aquatic organisms for cooling water intakes: passive intake screens, velocity caps, and modification of an intake location. Passive intake screens cover a whole range of static screens that act as a physical barrier to fish entrainment. These barriers include simple mesh over an open pipe end with a suitably low face velocity to prevent impingement, grille or mesh spanning an opening with a suitably low face velocity to impingement, and cylindrical and tee wedgewire screens designed for protecting fish stocks (Figure 3-74). A velocity cap is a device that is placed over vertical inlets at offshore intakes (Figure 3-75). This cover converts vertical flow into horizontal flow at the entrance of the intake. The device works on the premise that fish will avoid rapid changes in horizontal flow. Beyond design alternatives, a facility may also be able to locate their cooling water intake structures in areas that minimize entrainment and impingement. Near shore coastal waters are generally the most biologically productive areas. The zone of photosynthetic available light typically does not extend beyond the first 328 feet of depth. Modification of an intake location may therefore be implemented by adding an extension to the bottom of an existing intake to relocate the opening to a low impact area. To identify low impact areas, an environmental study or assessment is required.

EPA believes that the cost of modifying existing structures with deeper intakes will be significantly greater than the equipment costs associated with screens and velocity caps. In addition, the need for an environmental assessment to identify a lower impact zone for modified intakes would result in additional cost and time constraints. Therefore, EPA did not include modification of an intake location as part of their proposed technology options.

The following items are typically direct air cooled: gas coolers on compressors, lubrication oil coolers on compressors and generators, and hydraulic oil coolers on pumps. However, seawater cooling is necessary in many cases because space and weight limitations render air cooling infeasible. This is particularly true for floating production systems which have strict payload limitations. See Chapter 6 of the Phase I TDD for additional information.

EPA also considered but did not estimate costs associated with dry cooling options for oil and gas extraction facilities. The following items are typically direct air cooled at oil and gas extraction facilities: gas coolers on compressors, lubrication oil coolers on compressors and generators, and hydraulic oil coolers on pumps. However, seawater cooling is necessary in many cases because space and weight limitations render air cooling for all oil and gas extraction equipment infeasible. This is particularly true for floating production systems which have strict payload limitations. EPA agrees with industry that dry cooling systems are most easily installed during planning and construction, but some can be retrofitted with additional costs. IADC believes that it is already difficult to justify such conversions of jack-ups and that it would be far more difficult to justify conversion of drillships or semi-submersibles. See Chapter 6 of the Phase I TDD for additional information.

The technologies EPA evaluated for cooling water intake structures at offshore oil and gas extraction facilities depend on the type of cooling water intake structure and the rig type (rig types are described in section 1.0). The cooling water intake structure types include simple pipes, caissons, and submerged pump intakes, and sea chests. The impingement and entrainment control technologies EPA identified for this sector (passive intake screens, velocity caps, and modification of an intake location) are being used at other industries with marine intakes and are also being proposed for new LNG import terminals. In particular, the Main Pass Energy Hub LNG import terminal is converting an existing offshore platform to an LNG import terminal and installing technology (cynlindrical wedgewire screens) that would meet the proposed impingement and entrainment standards for new oil and gas extraction facilities. Based on similarities in intake structures, EPA is transferring these impingement and entrainment control technologies to this industrial sector.

A simple intake pipe, as the name suggests, is a pipe that is open ended in the water. A pump will draw water up through the pipe for distribution as required by the process. These systems generally include a strainer to protect the pump and, if the pump is above water level, a non-return valve to help keep the system primed. A caisson is a steel pipe attached to a fixed structure that extends from an operating area down some distance into the water. It is used to provide a protective shroud around another process pipe or pump that

is lowered into the caisson from the operating area. A caisson to house seawater intake equipment is a very common arrangement for offshore oil and gas extraction facilities. Typical equipment installed in the caisson may be a simple suction pipe, submersible pump and discharge pipe or a shaft driven borehole/vertical turbine pump. All caisson arrangements have the similarity that seawater is drawn into a single opening at the bottom of the caisson. Submersible pumps are simply lowered off the deck of a unit into the water without caissons or shrouds and pump water up through an intake pipe.

A sea chest is a cavity in the hull or pontoon of a MODU and is exposed to the ocean with a passive screen (strainer) often set along the flush line of the sea chest. In general there are three pipes for each sea chest (these include cooling water intakes and fire pumps). One of the three intake pipes is used for emergency fire fighting operations and the other pipes for cooling water. These pipes are usually back on the flush line of the sea chest.

For simple pipes, caissons and submerged pump intakes, cooling water intake structure control technologies include velocity caps or cylindrical wedgewire screens. Velocity caps result in impingement control and cylindrical wedgewire screens result in both impingement and entrainment control and are designed to create an intake velocity of equal to or less than 0.5 feet per second. Additionally, cylindrical wedgewire screens can be fitted with air sparges to physically remove bio matter from a screen face. This is a suitable technology in most marine environments and is useful for intakes above about 50 foot depth. In situations where there are prolific marine organisms that may grow on the screen surface (such as mussels, corral, or seaweed growth), alternative materials of construction may be needed to protect the screen. Alloys of copper and nickel have been found to limit marine growth on a submerged surface. These alloys are used in the manufacture of screen surfaces to prevent problems with invasive marine growth and cylindrical wedgewire screens can be costed using this material of construction.

For sea chests, cooling water intake structure control technologies include horizontal flow diverters and/or flat panel wedgewire screens. Horizontal flow diverters result in impingement control while flat panel wedgewire screens result in entrainment control. To achieve both impingement and entrainment control on a sea chest, both the flat panel wedgewire screen and a horizontal flow diverter are required. As in the case with cylindrical wedgewire screens, flat panel screens can also be manufactured using copper-nickel alloy material.

Exhibit 3-72 presents the Phase III cooling water intake structure control regulatory options and the technologies applicable to each option. The appropriate control technologies are a function of the cooling water intake structure and rig type.

Figure 3-74. Cylindrical Wedgewire Screen (Johnson Screens)

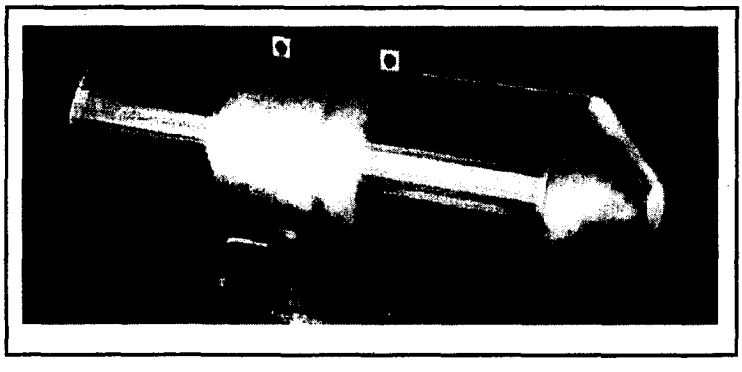


Figure 3-75. Schematic of Seabed Mounted Velocity Cap

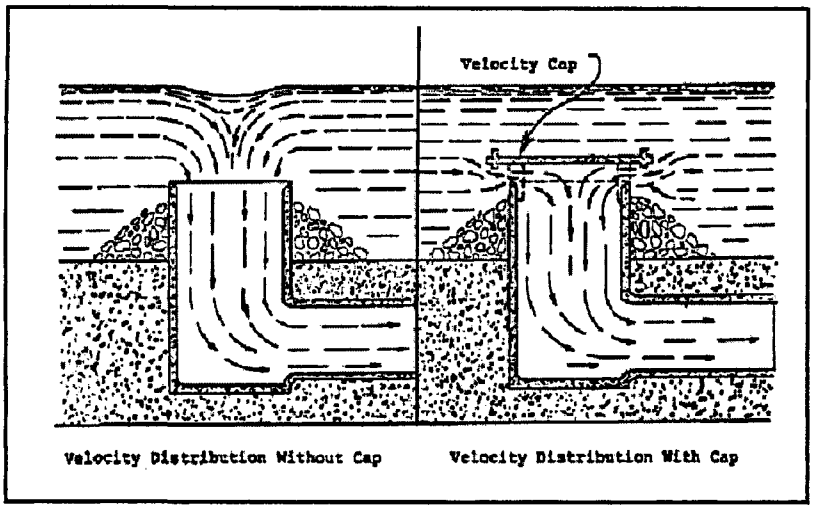


Exhibit 3-72. Regulatory Options and the Technologies Applicable to Each Option

	Option A	Option B	Option C	Option D	Option E
Option Requirements	I&E control for facilities with >2 MGD	I control for facilities with >2 MGD	I&E control for facilities with > 50 MGD and I control for facilities with 2-50 MGD	I&E control for facilities with > 50 MGD	I control for facilities with > 50 MGD
Type of Rig	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Platforms and Drill Barges which use simple pipes and caissons for cooling water intake	Cylindrical Wedgewire Screens for >2 MGD	Velocity Caps for > 2MGD	Cylindrical Wedgewire Screens for > 50 MGD and Velocity Caps for 2-50 MGD	Cylindrical Wedgewire Screens for >50 MGD	Velocity Caps for >50 MGD
Jack Ups which use sea chests while in transport and simple pipes/ caissons when stationary for cooling water intake	Cylindrical Wedgewire Screens plus Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >2 MGD	Horizontal Flow Diverter and Velocity Caps for > 2 MGD	Cylindrical and Flat Panel Wedgewire Screens plus Horizontal Flow Diverter for pipes and sea chests for >50 MGD and Velocity Caps and Horizontal Flow Diverter for 2-50 MGD	Cylindrical Wedgewire Screens plus Flat Panel Wedgewire Screens and Horizontal Flow Diverter for > 50 MGD	Horizontal Flow Diverter and Velocity Caps for > 50 MGD

Exhibit 3-72. Regulatory Options and the Technologies Applicable to Each Option (continued)

Type of Rig	Option A	Option B	Option C	Option D	Option E
Submersibles, Semi-submersibles and Drill Ships which use sea chests for cooling water intake	Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >2 MGD	Horizontal Flow Diverter for >2 MGD	Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >50 MGD and Horizontal Flow Diverter for 2-50 MGD	Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >50 MGD	Horizontal Flow Diverter for >50 MGD

I = Impingement Control (includes velocity caps and horizontal flow diverters)
I&E = Impingement and Entrainment Control (includes cylindrical wedgewire screens and flat panel wedgewire screens with a horizontal flow diverter)

4.2 Incremental Costs Associated with Technology Options to Control Impingement and Entrainment of Aquatic Organisms

This section documents the costs developed for cooling water intake structure control on existing "in-scope" offshore oil and gas extraction facilities evaluated for the proposed Phase III rulemaking. This section includes a description of:

- In-Scope Facilities for Costing;
- Source of the Costing Equations and Assumptions; and
- Summary of the Capital and Operation and Maintenance (O&M) Costs.

4.2.1 Existing In-Scope Facilities for Costing

EPA developed incremental compliance costs for existing offshore oil and gas extraction facilities if they met two criteria. The first, is that the facility had design or actual water intake flows of greater than 2 MGD and the second is that there were data (or a documented assumption) to support a determination that 25 percent or greater of the intake water (on an intake flow weighted basis) is used for cooling purposes.

Using the Excel datasheet which included all technical information collected on existing oil and gas extraction facilities and their cooling water intake structures, EPA assessed which facilities had data supporting an "in-scope" determination and sufficient information to assess costs. In this datasheet, some MODUs did not have cooling water flow data for the 25 percent or greater cooling water criteria assessment. Based on EPA's data from the USCG, it was assumed that most MODUs use approximately 80% of their intake water for cooling purposes and therefore meet the second "in-scope" criteria. The facilities identified as "in-scope" for costing are presented in the proposal record (see DCN 7-3505, section 8.0).

4.2.2 Source of Costing Equations and Assumptions

EPA developed costs for screens, velocity caps, and horizontal flow diverters using capital and operating and maintenance (O&M) cost data from vendors and the following assumptions: (1) 10% engineering factor; (2) 10% contingency factor; and (3) an allowance of 6% of the capital cost for annual parts replacement. The capital and O&M equipment costs are summarized by pipe diameter (or by sea chest flow rate) in the Hatch Report[16] which is located in the proposal record (see DCN 7-0010). Using these costs per pipe diameter (or costs per sea chest flow rate), EPA developed linear costing equations which were then used to develop facility specific costs.

Exhibits 3-74 through 3-77 present the costing equations and their source for each technology costed. Costs were prepared for both stainless steel flat panel and cylindrical wedgewire screens and also for copper-nickel (Cu-Ni) flat panel and cylindrical wedgewire

[16]Hatch Report, "Offshore and Coastal Oil and Gas Extraction Facilities Seawater Intake Structure Modification Cost Estimate: Mobile Offshore Drilling Units (MODUs)" and "Offshore and Coastal Oil and Gas Extraction Facilities Seawater Intake Structure Modification Cost Estimate: Caisson and Simple Pipe Intakes", March 12, 2004.

screens. Costs were also developed for cylindrical wedgewire systems with air sparging and without. Air sparging is used for cylindrical wedgewire screens installed in waters of shallow to medium depth (pipe depth less than 200 feet) to help prevent biofouling of the wedgewire screen. Copper-nickel screen material is more expensive than stainless steel but has also been shown to have a greater resistance to biofouling. In addition, costs were developed for both side and bottom horizontal flow diverters as well as velocity caps.

Exhibit 3-73. Installed Capital Cost Equations and Variables for Stationary Platforms

Category	CWIS Type	Description	Cost Equations	Variable	Ref.
Platform	Simple Pipe or Caisson	Stainless steel wedgewire screen - no air sparge cleaning	$ = 585.1 x dia +113,231 Single CWIS <60' $ = (417.8 x dia + 15,993) x (No. CWIS - 1) Additional CWIS <60' $ = 585.1 x dia + 161,981 Single CWIS 60-200' $ = (417.8 x dia + 24,493) x (No. CWIS - 1) Additional CWIS 60-200' $ = 585.1 x dia + 265,481 Single CWIS 200-350' $ = (417.8 x dia + 27,993) x (No. CWIS - 1) Additional CWIS 200-350' $ = 585.1 x dia + 326,981 Single CWIS >350' $ = (417.8 x dia + 38,493) x (No. CWIS - 1) Additional CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1
Platform	Simple Pipe or Caisson	Stainless steel wedgewire screen - with air sparge cleaning	$ = 1100.1 x dia +122,921 Single CWIS <60' $ = (623.4 x dia + 12,841) x (No. CWIS - 1) Additional CWIS <60' $ = 1100.1 x dia + 171,671 Single CWIS 60-200' $ = (623.4 x dia + 21,341) x (No. CWIS - 1) Additional CWIS 60-200' $ = 1100.1 x dia + 275,171 Single CWIS 200-350' $ = (623.4 x dia + 24,841) x (No. CWIS - 1) Additional CWIS 200-350' $ = 1100.1 x dia + 336,671 Single CWIS >350' $ = (623.4 x dia + 35,341) x (No. CWIS - 1) Additional CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1
Platform	Simple Pipe or Caisson	CuNi wedgewire screen - no air sparge cleaning	$ = 1036.8 x dia +113,231 Single CWIS <60' $ = (1036.8 x dia + 15,993) x (No. CWIS - 1) Additional CWIS <60' $ = 1036.8 x dia + 161,981 Single CWIS 60-200' $ = (1036.8 x dia + 24,493) x (No. CWIS - 1) Additional CWIS 60-200' $ = 1036.8 x dia + 265,481 Single CWIS 200-350' $ = (1036.8 x dia + 27,993) x (No. CWIS - 1) Additional CWIS 200-350' $ = 1036.8 x dia + 326,981 Single CWIS >350' $ = (1036.8 x dia + 38,493) x (No. CWIS - 1) Additional CWIS >350	CWIS Pipe Diameter (inches) and depth of CWIS opening	1*

Exhibit 3-73. Installed Capital Cost Equations and Variables for Stationary Platforms (continued)

Category	CWIS Type	Description	Cost Equations	Variable	
Platform	Simple Pipe or Caisson	CuNi wedgewire screen - with air sparge cleaning	$ = 1551.8 x dia +122,921 Single CWIS <60' $ = (1075.1 x dia + 12,841) x (No. CWIS - 1) Additional CWIS <60' $ = 1551.8 x dia + 171,671 Single CWIS 60-200' $ = (1075.1 x dia + 21,341) x (No. CWIS - 1) Additional CWIS 60-200' $ = 1551.8 x dia + 275,171 Single CWIS 200-350' $ = (1075.1 x dia + 24,841) x (No. CWIS - 1) Additional CWIS 200-350' $ = 1551.8 x dia + 336,671 Single CWIS >350' $ = (1075.1 x dia + 35,341) x (No. CWIS - 1) Additional CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1*
Platform	Simple Pipe or Caisson	Stainless steel and CuNi velocity caps	$ = 482.8 x dia +135,863 Single CWIS <60' $ = (482.8 x dia + 35,613) x (No. CWIS - 1) Additional CWIS <60' $ = 482.8 x dia + 184,613 Single CWIS 60-200' $ = (482.8 x dia + 44,113) x (No. CWIS - 1) Additional CWIS 60-200' $ = 482.8 x dia + 288,113 Single CWIS 200-350' $ = (482.8 x dia + 47,613) x (No. CWIS - 1) Additional CWIS 200-350' $ = 482.8 x dia + 349,613 Single CWIS >350' $ = (482.8 x dia + 58,113) x (No. CWIS - 1) Additional CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1

References

1. Hatch Report "Off Shore and Coastal Oil and Gas Extraction Facilities Sea Water Intake Structure Modification Cost Estimate: Caisson and Simple Pipe", March 12, 2004.

* Note: Hatch Cu-Ni costs were < Stainless Steel costs. Since the CuNi screen material is expected to be more expensive than stainless steel, EPA used the Hatch slope for Cu-Ni + the Stainless Steel intercept to develop the CuNi wedgewire screen cost equations.

Exhibit 3-74. Operating and Maintenance (O&M) Cost Equations and Variables Used for Stationary Platforms

Category	CWIS Type	Description	Cost Equations	Variable	Ref.
Platform	Simple Pipe or Caisson	Inspection and cleaning of stainless steel wedgewire screens using commercial divers - no air sparge system	$ = (45.77 x dia +16,180) x No. CWIS <60' $ = (45.77 x dia + 19,180) x No. CWIS 60-200' $ = (45.77 x dia + 24,680) x No. CWIS 200-350' $ = (45.77 x dia + 28,180) x No. CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1
Platform	Simple Pipe or Caisson	Inspection and cleaning of stainless steel wedgewire screens using commercial divers - with air sparge system	Add $ = (50.5 x dia + 9888.8) + ((21.9 x dia + 9229) x No. CWIS - 1) to each stainless steel screen inspection equation above	CWIS Pipe Diameter (inches) and depth of CWIS opening	1
Platform	Simple Pipe or Caisson	Inspection and cleaning of CuNi wedgewire screens using commercial divers - no air sparge system	$ = (18.63 x dia +16,444) x No. CWIS <60' $ = (18.63 x dia + 19,444) x No. CWIS 60-200' $ = (18.63 x dia + 24,944) x No. CWIS 200-350' $ = (18.63 x dia + 28,444) x No. CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1
Platform	Simple Pipe or Caisson	Inspection and cleaning of CuNi wedgewire screens using commercial divers - with air sparge system	Add $ = (50.5 x dia + 9888.8) + ((21.9 x dia + 9229) x No. CWIS - 1) to each CuNi screen inspection equation above	CWIS Pipe Diameter (inches) and depth of CWIS opening	1
Platform	Simple Pipe or Caisson	Inspection and cleaning of stainless steel or CuNi velocity caps using commercial divers	$ = (12.5 x dia +17,802) x No. CWIS <60' $ = (12.5 x dia + 20,802) x No. CWIS 60-200' $ = (12.5 x dia + 26,302) x No. CWIS 200-350' $ = (12.5 x dia + 29,802) x No. CWIS >350'	CWIS Pipe Diameter (inches) and depth of CWIS opening	1

Exhibit 3-75. Installed Capital Cost Equations and Variables for Jack-Up MODUs

Category	CWIS Type	Description	Cost Equations	Variable	Ref.
Jackup	Simple Pipe or Caisson	Cylindrical wedgewire screen over tower inlet	$ = (684.5 x dia +30,399) x No. CWIS (stainless no air sparge) $ = (1538.8 x dia + 50,540) x No. CWIS (stainless with air sparge) $ = (834.96 x dia + 30,389) x No. CWIS (CuNi no air sparge) $ = (1688.6 x dia + 50,541) x No. CWIS (CuNi with air sparge)	CWIS Tower Assembly Diameter (inches)	2
Jackup	Simple Pipe or Caisson	Horizontal Flow Modifier	$ = (1106.1 x dia + 30,400 x No. CWIS)	CWIS Tower Assembly Diameter (inches)	2
Jackup	Sea Chest	Flat panel wedgewire screen over sea chest opening	$ = (4.74 x flow (gpm) +29,700) x No. sea chests (stainless steel) $ = (5.05 x flow (gpm) + 29,700) x No. sea chests (CuNi)	Flow through sea chest (gpm)	2
Jackup	Sea Chest	Horizontal Flow Diverter for Side Sea Chests	$ = (2.93 x flow (gpm) + 20,520) x No. sea chests	Flow through sea chest (gpm)	2
Jackup	Submersible Pumps	Cylindrical wedgewire screen over suction pipe inlet	$ = (349.1 x dia - 1,030) x No. suction pumps (stainless steel) $ = (564.7 x dia - 1,389) x No. suction pumps (CuNi)	Pump suction diameter (inches)	2

Exhibit 3-76. Installed Capital Cost Equations and Variables for Submersibles, Semi-Submersibles, Drill Ships, and Drill Barge MODUs

Category	CWIS Type	Description	Cost Equations	Variable	Ref.
Submersibles, Semi-Submersibles and Drill Ships	Sea Chests	Flat panel wedgewire screen over sea chest	$ = (6.4621 x flow (gpm) +0.287) x No. CWIS (stainless steel) $ = (6.773 x flow (gpm) - 0.273) x No. CWIS (CuNi)	Flow through sea chest (gpm)	2
Submersibles, Semi-submersibles and Drill Ships	Sea Chests	Horizontal flow diverter over side sea chest	$ = (3.4995 x flow (gpm) + 0.014) x No. CWIS	Flow through sea chest (gpm)	2
Drill Barges	Simple Pipes	Cylindrical wedgewire screen over simple pipes	$ = (393.67 x dia - 1208) x No. CWIS (stainless steel - no air sparge) $ = (908.67 x dia + 8481) x No. CWIS (stainless steel - air sparge) $ = (845.33 x dia - 5603) x No. CWIS (CuNi - no air sparge) $ = (1360.3 x dia + 4087) x No. CWIS (CuNi - air sparge)	Diameter of CWIS opening (inches)	2
Drill Barges	Simple Pipes	Velocity Cap on the CWIS	$ = (291.33 x dia + 21423) x No. CWIS (stainless steel or CuNi)	Diameter of CWIS opening (inches)	2

References

1. Hatch Report "Off Shore and Coastal Oil and Gas Extraction Facilities Sea Water Intake Structure Modification Cost Estimate: Caisson and Simple Pipe", March 12, 2004.

2. Hatch Report "Off Shore and Coastal Oil and Gas Extraction Facilities Sea Water Intake Structure Modification Cost Estimate: Mobile Off Shore Drilling Units (MODUs)", March 12, 2004.

Operating and maintenance costs are associated with fixed platforms only. Operators are required by the U.S. Coast Guard to inspect sea chests twice in five years with at least one cleaning to prevent blockages of firewater lines. The requirement to drydock MODUs or perform special examination in lieu of drydocking twice in five years and inspect and clean their sea chests and sea valves are found in U.S. Coast Guard regulations (46 CFR 107.261, and 107.265 and 107.267 and 46 CFR 61.20-5). It was therefore assumed that MODU's will undergo cooling water intake structure control maintenance as part of their regularly scheduled dry dock service. Operating and maintenance costs for fixed platform facilities do not include any costs associated with downtime (see section F.3).

For fixed platform facilities using simple pipe and/or caisson intakes, the depth of the water intake is needed to determine maintenance costs for cooling water intake structure control inspection and cleaning. Since intake depth was not available for many of the fixed platform facilities costed, an estimate of the intake pipe depth was developed using available data. Based on an assessment of intake depth performed by Simon, a linear equation was developed to represent intake pipe depth versus total design intake flow. In general, the greater the design intake flow the deeper the intake depth.

The facility-level option costs (summarized below) include air sparging equipment for biofouling control at intake depths less than 200 feet for both stainless steel and Cu-Ni cylindrical wedgewire screens. According to Linda Cook at Johnson Screens (email correspondance dated May 20, 2004), the water is typically clean at depths below 40 to 50 feet and biofouling is typically not a concern, however it depends on the water quality at the actual location. As a conservative estimate, EPA assumed air sparging systems may be needed at depths up to 200 feet. In addition, for sea chests, costs were developed for both bottom and side horizontal flow diverters. Since it was unknown in most cases whether specific facilities had bottom or side sea chests, the costs included in the facility-level option costs used the more expensive option (i.e., assumed side sea chests).

4.2.3 Summary of Technology Option Costs for Existing Oil and Gas Extraction Facilities

Exhibit 3-78 presents a summary of the cooling water intake control costs developed for existing "in-scope" O&G extraction facilities for cooling water intake structure control options A through E. These costs are broken out by platforms versus MODUs and by location. These costs do not represent scaled-up costs.

Exhibit 3-77. Summary of Technology Option Costs for Existing Oil and Gas Extraction Facilities

	No. of Facilities Included in Costs	Option A	Option B	Option C	Option D	Option E
Capital Costs Platforms, GOM	16	4,047,201	4,187,716	4,187,716	0	0
Capital Costs Platforms, California	6	2,546,486	2,598,198	2,598,198	0	0
Capital Costs Platforms, Alaska	5	1,543,426	0	0	0	0
Capital Costs MODUs	87	21,653,766	11,440,066	14,408,685	4,502,389	1,533,770
Total Capital Costs ($)	114	29,790,879	18,225,980	21,194,599	4,502,389	1,533,770
O&M Costs Platforms, GOM	16	905,315	675,924	675,924	0	0
O&M Costs Platforms, California	6	576,504	539,340	539,340	0	0
O&M Costs Platforms, Alaska	5	573,804	0	0	0	0
O&M Costs MODUs	87	0	0	0	0	0
Total O&M Costs ($)	114	2,055,623	1,215,264	1,215,264	0	0

Option A = I & E control for facilities with > 2 MGD
Option B = I control for facilities with > 2 MGD
Option C = I & E control for facilities with > 50 MGD and I control for facilities with 2-50 MGD
Option D = I & E control for facilities with > 50 MGD
Option E = I control for facilities with >50 MGD

When these costs are scaled-up to include additional facilities believed to be "in-scope" and not costed, the total capital and O&M costs become:

	Option A	Option B	Option C	Option D	Option E
Total Capital Costs ($)	48,354,142	27,766,279	30,734,897	4,502,389	1,533,770
Total O&M Costs ($)	3,054,978	1,257,368	1,257,368	0	0

EPA used these costs for existing facilities to estimate the incremental compliance costs for new facilities. This is a conservative approach to estimate potential economic impacts as incremental compliance costs for new facilities will be lower than incremental compliance costs for existing facilities since new facilities will not need to retrofit existing equipment. Economic impacts on new MODUs and platforms and their associated firms from these incremental compliance costs are expected to be minimal (see DCN 7-0002). EPA estimates that the costs of the Phase III proposed rule are highly unlikely to have any production effects on new deepwater platforms, nor are these costs expected to pose a barrier to entry to new oil and gas development. The economic modeling does not indicate that production is very sensitive to costs estimated at the current order of magnitude.

5.0 PROPOSED TECHNOLOGY OPTIONS IDENTIFIED IN THE PHASE III PROPOSAL

EPA is proposing to require impingement and entrainment control requirements for new offshore oil and gas extraction facilities in the Phase III 316(b) rulemaking. EPA finds the technology available and affordable. Moreover, the importance of controlling impingement and entrainment at oil and gas extraction facilities is highlighted by the fact that these structures provide an important fish habitat. A variety of fish species are known to be attracted to and to aggregate around and directly under offshore oil and gas extraction facilities, often resulting in densities of fish of that are higher than the densities found in adjacent open waters. Both adult fish and young fish gather around these structures. Young fish may be more susceptible to impingement and entrainment than adult fish. For example, oil and gas platforms and artificial reefs undoubtedly serve as red snapper habitat, and they may serve as an important (but not obligate) link in the life history of both juvenile and adult red snapper.[17] In general, five to 100 times more fish can be concentrated near offshore platforms than in the soft mud and clay habitats elsewhere in the Gulf of Mexico.[18] As a result, 70 percent of all fishing trips in the Gulf of Mexico head for oil and natural gas platforms. Likewise, 30 percent of the 15 million fish caught by recreational fishermen every year off the coasts of Texas and Louisiana come from the waters around platforms. The offshore marine areas in which oil and gas extraction facilities are located contain large numbers of fish and shellfish eggs and larvae that drift with ambient currents and have minimal swimming ability. These organisms are vulnerable to entrainment by oil and gas facility cooling water intake structures. Densities of these organisms are variable across offshore marine areas, but they can be as great as the densities found in estuarine environments. EPA will address potential impingement and entrainment impacts at existing facilities through NPDES permits on a case-by-case basis, using best professional judgment (see 40 CFR 125.80(c)).

EPA applied different regulatory requirements for new oil and gas extraction facilities depending on whether they are projecting to use sea chest as their cooling water intake structure. New oil and gas extraction facilities without sea chests as cooling water intake structures are required to meeting impingement and entrainment requirements while those with are only required to meet impingement requirements. EPA made this distinction based on the potential lack of technologies to control entrainment impacts for sea chest cooling water intake structures. Simple pipes, caissons and submersible pumps used for cooling water extraction can be fitted with pre-manufactured cylindrical wedgewire screens to prevent entrainment and impingement of marine life. Consequently, control technologies are available for these cooling water intake structures and EPA is proposing impingement and entrainment control requirements for new offshore oil and gas extraction facilities that do not use sea chests.

[17] Reef Fish Stock Assessment Panel, Gulf of Mexico Fishery Management Council, 1996. "Review of 1996 Analysis by Gallaway and Gazey, http://www.gulfcouncil.org/downloads/RFSAP-GG-1996.pdf, August 1996.

[18] Sandra Fury, ChevronTexaco, statements before U.S. Commission on Ocean Policy, http://oceancommission.gov/meetings/mar7_8_02/fury_statement.pdf, March 8, 2002.

EPA had limited information on the effectiveness of flat-paneled wedgewire screens in controlling entrainment impacts. However, in order to estimate compliance costs associated with this technology, EPA costed flat paneled wedgewire screens for sea chest cooling water intake structures. EPA solicits data and information on whether this technology can be used to controlling entrainment impacts.

EPA identified in its record that only 'jack up' type oil and gas extraction facilities use both sea chests and non-sea chest cooling water intake structures. EPA estimates that the design of the cooling water intake structures for jack up oil and gas extraction facilities will primarily depend on the operation needs of the facility and will not be influence by reduced regulatory requirements. However, EPA solicits comment on the major factors influencing the design of cooling water intake structures for 'jack up' oil and gas extraction facilities and whether reduced regulatory requirements might lead industry to select sea chests to reduce their potential compliance costs.

6.0 316(b) ISSUES RELATED TO OFFSHORE OIL AND GAS EXTRACTION FACILITIES

EPA investigated several issues related to 316(b) technology options for this industrial sector. These issues included: biofouling; the definition of new source; potential lost production and downtime associated with proposed technology option impacts; drilling equipment at production platforms; and current regulatory requirements.

6.1 Biofouling

Industry comments to the 316(b) Phase I proposal assert that operators must maintain a minimum intake velocity of 2 to 5 feet per second in order to prevent biofouling of the offshore oil and gas extraction facility cooling water intake structure. EPA requested documentation from industry regarding the relationship between marine growth (biofouling) and intake velocities (Johnston - March 21, 2001). Industry was unable to provide any authoritative information to support the assertion that a minimum intake velocity of 2 to 5 feet per second is required in order to prevent biofouling of the facility's cooling water intake structure. IADC asserts that it is common marine engineering practice to maintain high velocities in the seachest to inhibit attachment of marine biofouling organisms (Spackman, May 8, 2001).

The Offshore Operators Committee (OOC) and the National Oceans Industries Association (NOIA) also noted in their comments to the May 25, 2001 316(b) Federal Register Notice that the ASCE "Design of Water Intake Structures for Fish Protection" recommends an approach velocity in the range of 0.5 to 1 feet per second for fish protection and 1 feet per second for debris management but does not address biofouling specifically. OOC/NOIA were unable to find technical papers to support a higher intake velocity. The U.S. Coast Guard and MMS were also unable to provide EPA with any information on velocity requirements or preventative measures regarding marine growth inhibition or has a history of excessive marine growth at the sea chest.

EPA was able to identify some of the major factors affecting marine growth on offshore structures. These factors include temperature, oxygen content, pH, current, turbidity, and light (Johnston - March 26, 2001) & (Johnston - October 9, 2001). Fouling is particularly troublesome in the more fertile coastal waters, and although it diminishes with distance from the shoreline, it does not disappear in midoceanic and in the abyssal depths (Johnston - October 9, 2001). Moreover, as detailed above, operators are required to perform regular inspection and cleaning of these cooling water intake structures in accordance with USCG regulations.

EPA and industry also identified that there are a variety of specialty screens, coatings, or treatments to reduce biofouling. Industry and a technology vendor (Johnson Screens) also identified several technologies currently being used to control biofouling (e.g., air sparging, Ni-Cu alloy materials). See Figure 3-76 for a schematic of air sparging at a cylindrical wedgewire screen. Johnson Screens asserted in May 25, 2001 316(b) Federal Register Notice comments to EPA that their copper based material can reduce biofouling in many applications including coastal and offshore drilling facilities in marine environments.

Figure 3-76. Cylindrical Wedgewire Screen with Air Sparging (Johnson Screens)

Biocide treatment can also be used to minimize biofouling. IADC reports that one of their members uses Chloropac systems to reduce biofouling (www.elcat.co.uk/chloro_anti_mar.htm). The Liberty Project plans to use chlorine, in the form of calcium hypochlorite, to reduce biofouling. The operator (BPXA) will reduce the total residual chlorine concentration in the discharged cooling water by adding sodium metabisulfate in order to comply with limits of the National Pollution Discharge Elimination System Permit. MMS estimates that the effluent pH will vary slightly from the intake seawater because of the chlorination/dechlorination processes, but this variation is not expected to be more than 0.1 pH units.

In another offshore industrial sector, LNG import terminals, industry is proposing intake velocities of 0.5 feet per second. In their proposals, industry identified the use of sodium hypochlorite to control biofouling and did not identify any concerns over the proposed intake velocity (0.5 feet per second) and biofouling. Moreover, some of these proposed facilities include in their designs cylindrical wedgewire screens with air sparging to remove biofouling and clear water intake structures.

In summary, EPA did not identify any relationship between the intake velocity and biofouling of an offshore oil and gas extraction facility cooling water intake structure. EPA finds that operators can reasonably control biofouling associated with cooling water intake structures. As previously mentioned, EPA included the costs of controlling biofouling for intakes at depths less than 200 feet as part of the incremental compliance costs.

6.2 Definition of New Source

Industry claimed in comments to the Phase I 316(b) proposal and the May 25, 2001 316(b) Federal Register Notice that existing MODUs could be considered "new sources" when they drill new development wells under 40 CFR 435.11 (exploration facilities are excluded from the definition of new sources). EPA excluded existing facilities from the Phase III proposed rule and clarified the regulatory language.

6.3 Potential Lost Production and Downtime Associated with Proposed Technology Option Impacts

6.3.1 Potential Lost Production

EPA estimates that there will be no lost production for new oil and gas extraction fixed platform facilities due to incremental 316(b) Phase III compliance costs.

Lost production for an oil and gas extraction facility could occur if the operator made a decision to shut in a facility early due to the incremental costs associated with cooling water intake structure operation and maintenance (O&M.) The decision to shut in a facility is generally made on an annual, semi-annual, or at most quarterly basis. At the end of a fixed facility production life, the costs of production would be in the $3.7 million/year range and the incremental cooling water intake structure O&M costs are estimated to be in the $37,000/year range. Therefore, the incremental cooling water intake structure O&M costs are approximately 0.1 % of the

production costs and would not impact a quarterly, semi-annual or annual shut in decision. Well shut in decisions will be much more sensitive to the price of oil and gas.

Preliminary economic analysis shows that the costs of the Phase III rule are highly unlikely to have any production effects on new deepwater platforms, nor are these costs expected to pose a barrier to entry to new oil and gas development. The economic modeling does not indicate that production is very sensitive to costs estimated at the current order of magnitude.

6.3.2 Potential Downtime

EPA evaluated the potential for downtime at existing oil and gas extraction facilities to allow for cooling water intake structure control maintenance. This issue was evaluated for both mobile and fixed oil and gas extraction facilities. EPA gathered information from the following experts on the topic of maintenance practices for mobile and fixed oil and gas extraction facilities:

- April 4, 2001 Meeting with Mr. James M. Magill, U.S. Coast Guard, Vessel and Facility Operating Standards Division.
- June 8, 2004 Email Correspondence with Mr. Elmer Danenberger, Mineral Management Service (MMS).
- June 9, 2004 Email Correspondence with Mr. Kent Satterlee, Shell Oil Company.

Mobile Oil and Gas Extraction Facilities

Mr. Magill of the U.S. Coast Guard provided information related to cooling water intake structures for MODUs. MODUs typically draw in intake water through a sea chest. The sea chest is a cavity in the hull or pontoon of the MODU and is exposed to the ocean with a screen often set along the flush line of the sea chest. There are generally two sea chests for each drill ship or semi-submersible (port and starboard) for redundancy and ship stability. In general, only one sea chest is required at any given time for drilling operations. Mr. Magill indicated that there are generally three pipes for each sea chest (including cooling water intakes and fire pumps). One of the intake pipes is always set aside for use solely for emergency fire fighting operations. Regarding maintenance downtime, Mr. Magill stated that current Coast Guard requirements are that operators must inspect sea chests twice in five years with at least one cleaning. These requirements are particularly important to ensure that the separate intake for the fire pump is clear. The requirement to drydock MODUs or perform special examination in lieu of drydocking twice in five years and inspect and clean their sea chests and sea valves are found in U.S. Coast Guard regulations (46 CFR 107.261, 107.265, and 107.267 and 46 CFR 61.20-5). The U.S. Coast Guard may require the sea chests to be cleaned twice in 5 years at every drydocking or special examination in lieu of drydocking if the unit is in an area of high marine growth or has had history of excessive marine growth at the sea chests. Mr. Magill estimated that the regular cleaning and inspection schedule should be enough to control marine biofouling in the Gulf of Mexico.

Based on this information, EPA assumed that the existing Coast Guard requirements for MODU sea chest maintenance are sufficient and no downtime or additional maintenance costs were developed for MODUs.

Fixed Oil and Gas Extraction Facilities

Fixed Platforms were costed for cooling water intake structure control maintenance (i.e., annual screen inspection and cleaning using divers). EPA requested information from Mr. Danenberger and Mr. Satterlee to determine whether regular downtime is typical for fixed platforms during which cooling water intake structure control maintenance could occur or whether maintenance costs would need to account for potential downtime lost production. Both Mr. Danenberger and Mr. Satterlee indicated that it is usual for fixed platforms to experience periodic shut ins for production maintenance purposes. Mr. Danenberger indicated that the frequency and duration of the production maintenance shut ins is dependent on platform age, complexity, condition of the facility, and company practices and policy. Newer facilities might only shut in once per year for two to three days, other facilities might average two shut ins per year, each for up to a week. Mr. Satterlee indicated that for Shell facilities, on average there are one to two scheduled shut ins per year of varying duration. He estimated that on average a typical shut in would be two to three days depending on the scope of work to be performed. In addition, there can also be unplanned shut ins to address critical maintenance items.

Based on this information, EPA assumed that for fixed platform facilities, cooling water intake structure control maintenance can occur during a regularly scheduled downtime and costs beyond the maintenance costs for screen inspection and cleaning were not required.

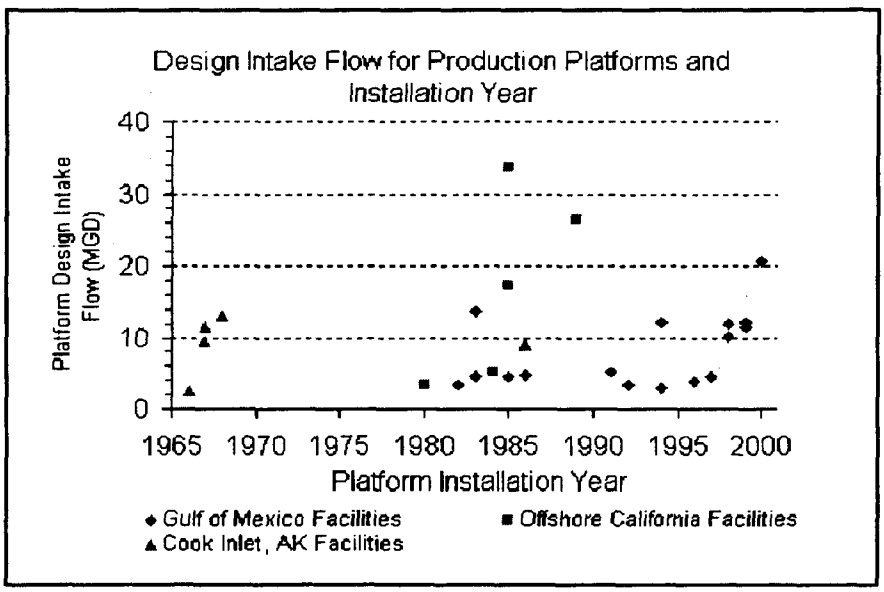
6.4 Drilling Equipment at Production Platforms

Drilling equipment is not generally permanently located on offshore fixed production platforms. However, some offshore fixed production platforms do have permanent on-site drilling equipment and do drill development wells and sidetracks, as well as perform

well workovers, throughout the life of a project. EPA estimates that 115 fixed platforms have drilling equipment on the platform out of roughly 2,500 platforms in the GOM. Some fixed production platforms that require more than 2 MGD of cooling water include platforms in deepwater, platforms with cooling needs for power equipment and machinery (e.g., winches), and platforms that require cooling for gas compression and other needs.

Based on data industry submitted to EPA, platforms with permanent drilling equipment are more often found in deepwater. Since passage of the Deep Water Royalty Relief Act (43 U.S.C. §1337) there has been an overall expansion in all phases of deepwater oil and gas extraction activity. This legislation provides economic incentives for operators to develop fields in water depths greater than 200 m (656 ft). areas. The number of producing deeperwater projects has dramatically increased from 1992 (6) and 1997 (17) to 2003 (86). Deepwater production rates have risen by well over 100,000 barrels of oil per day and 400 million cubic ft of gas per day, respectively, each year since 1997.[19] Initial data suggests that while cooling water needs may decrease over the life of some fixed platforms with drilling equipment, the water intakes for some fixed platforms will stay above 2 MGD for their production needs (e.g., gas cooling and compression). High speed reciprocating gas and rotary screw natural gas compressors range up to 8,800 HP. Assuming continuous once through cooling and a seawater temperature increase of 10 °C between intake and discharge, the volume of seawater required for cooling these engines can ranges up to 3.5 MGD. As an example, there some production platforms in shallow waters in mature fields that do very little drilling and withdraw more than 2 MGD of seawater (e.g., Offshore California, Cook Inlet, AK). Figure 3-77 demonstrates that design intake flows for some existing production platforms do not always fall below the 2 MGD flow threshold.

Figure 3-77. Design Intake Flow for Production Platforms with Surface Water Intakes Greater than 2 MGD and Installation Year



Finally, MODUs also serve fixed production platforms to drill development wells and sidetracks, as well as perform workovers, throughout the life of a project when the offshore platform does not have a permanent drilling rig. MODUs also have the potential to impinge and entrain aquatic organisms at these fixed facilities. Consequently, EPA evaluated and selected technology options for these fixed and mobile oil and gas extraction facilities, including fixed production platforms without drilling equipment, to reduce potential adverse environmental impacts. Since most fixed production platforms without drilling equipment have seawater intakes less than 2 MGD, they would not by subject to the 316(b) rule but must meet §316(b) requirements as specified by the NPDES permit authority on a case-by-case basis, using best professional judgment (BPJ) (see 40 CFR 125.80(c)). EPA also notes that when operators decommission intake structures and reduce their design intake flow to below 2 MGD, they would no longer be subject to permit specific BPJ requirements. EPA will request more data on this topic in the proposed rulemaking.

[19]U.S. Minerals Management Service, 2004. "Deepwater Gulf of Mexico 2004: America's Expanding Frontier," MMS 2004-021, http://www.gomr.mms.gov/homepg/whatsnew/techann/2004-021.pdf, May 2004.

6.5 Current Regulatory Requirements

EPA's discussions with the two main regulatory entities of offshore oil and gas extraction facilities (i.e., MMS, USCG) identified no Federal regulatory or information collection requirements for these cooling water intake structures. MMS generally does not regulate or considered the potential environmental impacts of these cooling water intake structures in either NEPA analyses or approval of drilling and exploratory plans. As previously mentioned, MMS could only identify one case where the environmental impacts of a new oil and gas extraction facility cooling water intake structure were considered (i.e., Liberty Island). Moreover, MMS does not collect information on cooling water intake volumes, velocities and durations for any oil and gas extraction facility. The U.S. Coast Guard does not investigate potential environmental impacts of MODU cooling water intake structures but does require operators to inspect sea chests twice in five years with at least one cleaning to prevent blockages of firewater lines.

EPA identified one State regulatory requirement for cooling water intake structures at oil and gas extraction facilities. As detailed in section 2.5, the State of Alaska has a standard clause in their oil and gas leasing agreements which controls potential impingement and entrainment impacts from oil and gas extraction facilities (screen size and intake velocity).

IV. TECHNOLOGY COST MODULES FOR LIQUEFIED NATURAL GAS FACILITIES

APPLICATION OF THE PROPOSED RULE

Under each of the co-proposed options, no offshore liquefied natural gas facilities would be subject to national performance standards. New land-based liquefied natural gas facilities may be subject to requirements under the Phase I rule.

INTRODUCTION

Liquefied natural gas (LNG) has become an increasingly important part of the U.S. energy market. Interest in LNG imports has been rekindled by higher U.S. natural gas prices in recent years, as well as increased competition and technological advances that have lowered costs for liquefaction, shipping, storing, and re-gasification of LNG.[1] LNG is cooled to about minus 260 °F and transported by vessels to import facilities for re-gasification.

During the re-gasification process, the LNG is warmed from minus 260 °F to 40 °F and experiences a three-fold increase in volume. Typically, LNG at import terminals is stored only until it can be re-gasified and injected into the pipeline grid or until it can be trucked directly to customers. In order to minimize wait times for the ships and to avoid congestion, operators of LNG marine terminals process cargoes quickly. Each U.S. import terminal is equipped with storage tanks capable of holding between two and three tanker loads of LNG. Some new and expanded facilities in the United States will have a capacity closer to four tanker loads. (DOE 2004) LNG import terminals may use surface waters for this heat exchange process and may also use surface waters for cooling purposes.

This chapter provides an overview of: (1) the existing and planned LNG import terminals in the U.S., (2) which LNG import terminals EPA evaluated for the Phase III rulemaking; and (3) the technology options available to control impingement and entrainment of aquatic organisms.

1.0 EXISTING LNG IMPORT TERMINALS IN THE U.S.

The LNG industry in the United States has experienced periods of prolonged downturns, in part owing to price competition from domestic sources of natural gas. (DOE 2004) Currently there are five existing onshore LNG import terminals and no existing offshore LNG import terminals. The five existing onshore LNG import terminals are presented in Exhibit 3-78.

Exhibit 3-78. Five Existing Onshore LNG Import Terminals

Location	2003 LNG Imports, Billion cubic feet (Bcf)	2004 LNG Storage Capacity, Billion cubic feet (Bcf)	Operator
Lake Charles, LA	238.2	6.3	Southern Union
Cove Point, MD	66.1	5.0	Dominion
Everett, MA	158.3	3.5	Tractebel
Elba Island, GA	43.9	4.0	El Paso/Southern LNG
Guayanilla Bay, Puerto Rico	130[2]	N/A	Enron/Edison Mission (EcoElectrica)

Sources: (DOE 2004), (DOE 1995)

Although LNG imports exceeded historical highs in 2003, even at the current pace they represent only about 2.7 percent of U.S. consumption and 13 percent of imports. Through expansions at three of the four facilities, the United States will increase its peak re-gasification capacity by more than 40 percent from the 2002 level (3.2 Bcf/d) to approximately 4.6 Bcf/d in 2005. Additionally, through recently announced additional expansion projects at Lake Charles and Cove Point, capacity would reach about 6.2 Bcf/d by 2008. (DOE 2004)

[1]U.S. Department of Energy, Energy Information Administration, 2004. "U.S. LNG Markets and Uses: June 2004 Update," http://www.eia.doe.gov/pub/oil_gas/natural_gas/feature_articles/2004/lng/lng2004.pdf.

[2]U.S. DOE, Office of Fossil Energy, Order Granting Long-Term Authorization to Import Liquified Natural Gas, Order No. 1042, http://www.fe.doe.gov/programs/gasregulation/authorizations/orders/ord1042.pdf, April 19, 1995.

2.0 PLANNED LNG IMPORT TERMINALS IN THE U.S.

A competition to build LNG import terminals is taking place among U.S. and foreign companies in many regions of North America because of the perceived opportunity in the growing LNG industry.[3] Interest in LNG imports has been rekindled by higher U.S. natural gas prices in recent years and technological advances that have lowered costs for liquefaction, re-gasification, shipping, and storing of LNG.[4,5] Potential investment in re-gasification facilities in the U.S. is estimated at $15 billion.[6] Although LNG imports currently make up a small percentage of total gas supplies, higher natural gas prices and recent expansions of existing LNG import terminals and the constructions of new terminals will likely boost the net import of LNG from overseas. Net LNG imports are estimated to increase from 0.2 trillion cubic feet in 2002 to 2.2 and 4.8 trillion cubic feet in 2010 and 2025, respectively, as planned expansions at the four existing terminals are completed and new terminals are projected to start coming into operation in 2007.[7]

As shown in Figure 3-78 a number of LNG import terminals have been proposed for development to meet the increased demand for natural gas. (FERC 2004) There are at least 40 company announcements of proposed terminals targeted for North America. Many of these projects are already before regulators, and, as of June 2004, some have achieved regulatory success. (DOE, 2004). Many of these proposed projects are planned for the Gulf of Mexico (GOM) area due to the area's largest demand for natural gas and significant pipeline infrastructure.[8] As shown in Figure 3-79, the Federal Energy Regulatory Commission (FERC) estimates that the planned and pending LNG import terminals will tripled the U.S. capacity to import LNG.[9] However, not all planned LNG import terminals will be built. It is estimated that in order to provide the needed LNG supply to the U.S. gas system, 10 to 12 LNG import terminals will be built within the decade with an investment of more than $5 billion.[10]

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[3]Remarks of Suedeen G. Kelly, Commissioner of Federal Energy Regulatory Commission, to the Natural Gas Roundtable of Washington, "The Challenge of Natural Gas Interchangeability and Quality," Washington, D.C., February 24, 2004. See http://www.ferc.gov/press-room/sp-current/02-24-04-kelly.pdf.

[4]Gaul, Damien, 2001. U.S. Department of Energy, Energy Information Administration, "U.S. LNG Markets and Uses," See http://www.eia.doe.gov/pub/oil_gas/natural_gas/feature_articles/2003/lng/lng2003.pdf

[5] University of Houston, 2003. "Introduction to LNG," http://www.energy.uh.edu/LNG/documents/IELE_introduction_to_LNG.pdf, January 2003.

[6] Kelly, Edward, 2004. "Factors Limit LNG's Role In U.S. Market," American Oil and Gas Reporter, March 2004.

[7]U.S. Department of Energy, 2004. "Annual Energy Outlook 2004 with Projections to 2025," DOE/EIA-0383 (2004), January 2004. See http://www.eia.doe.gov/oiaf/aeo/.

[8]Meyer, Keith, 2004. The Regasification of North America, World Energy, Vol. 7, No. 1, http://www.worldenergysource.com/articles/pdf/meyer_WE_v7n1.pdf.

[9]U.S. Federal Energy Regulatory Commission, 2004. "LNG Briefing," http://www.ferc.gov/industries/gas/indus-act/lng-briefing.pps, April 2004.

[10] Hall, Wayne F. 2004. "The North American LNG Supply Chain: Strategies for Economic Growth," World Energy, Vol. 7, No. 1, http://www.worldenergysource.com/articles/pdf/hall_WE_v7n1.pdf.

Figure 3-78. Existing and Proposed North American LNG Terminals

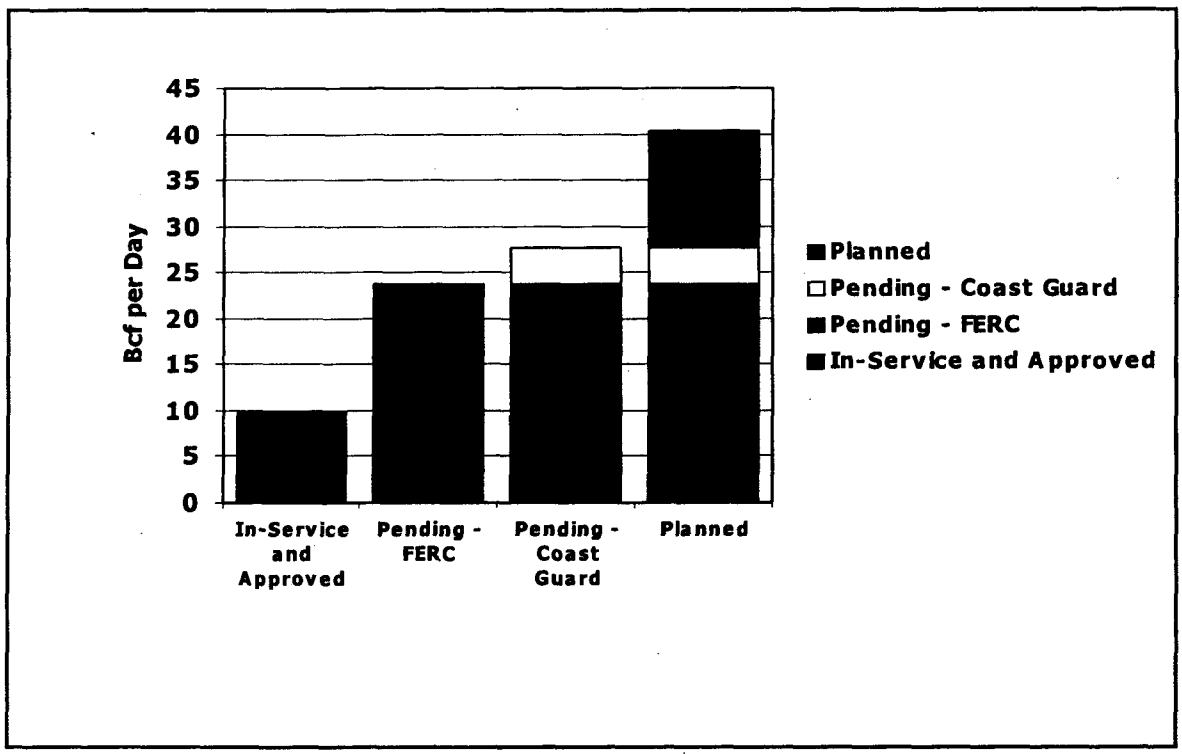
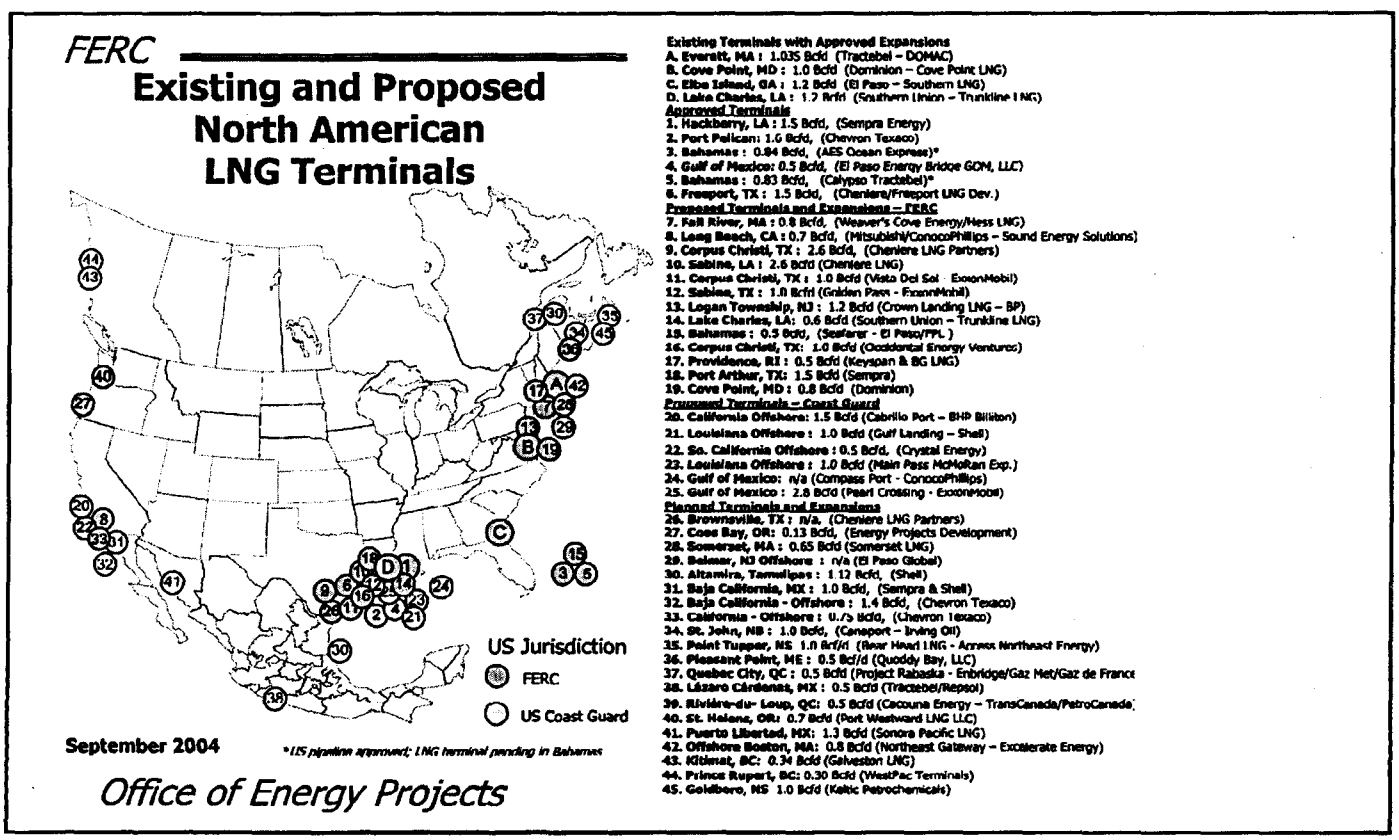


Figure 3-79. Current and Potential Future U.S. LNG Import Capacity



3.0 LNG IMPORT TERMINALS EPA EVALUATED FOR THE PHASE III RULEMAKING

EPA collected data on the re-gasification processes which are used at existing LNG import terminals and those that being proposed for new facilities. For each facility EPA estimated whether: (1) these facilities are subject to the NPDES Permit Program; (2) these facilities withdraw more than 2 MGD from surface waters; and (3) 25 percent of the surface water intake is use for cooling purposes. EPA collected this data in order to determine whether LNG import terminals could potentially be subject to CWA § 316(b) national technology-based standards to protect aquatic organisms from being killed or injured by impingement (being pinned against screens or other parts of a cooling water intake structure) or entrainment (being drawn into cooling water systems and subjected to thermal, physical or chemical stresses).

For many LNG import terminals most or all of the surface water intakes are used for the re-gasification process, an endothermic process, and are not consider "water withdrawn for cooling purposes." EPA stated in the preamble to the final Phase II rule that "water withdrawn for non-cooling purposes includes water withdrawn for warming by liquified natural gas facilities and water withdrawn for public water systems by desalination facilities," (July 9, 2004; 69 FR 41581). Consequently, warming waters used by a LNG import terminal would not be considered "water withdrawn for cooling purposes" in determining whether a LNG import terminal meets the threshold requirement of using at least 25 percent of water withdrawn for cooling purposes. Also, water used in a manufacturing process either before or after it is used for cooling is considered process water – not cooling water – for the purposes of calculating the percentage of a new facility's intake flow that is used for cooling purposes (see the definition of cooling water in 40 CFR 125.83).[11]

Thus, if an LNG import terminal uses less than 25 percent or none of its water for cooling purposes or does not meet the 2 MGD intake flow threshold, the new facility rule specifies that the facility must meet § 316(b) requirements as specified by the NPDES permit authority on a case-by-case basis, using best professional judgment (see 40 CFR 125.80(c)). (EPA, 2004 - clarification memo)

EPA is aware, however, that some new offshore LNG import terminals may use water for warming and cooling purposes. For example, the draft Environmental Assessment for the Excelerate (formerly El Paso Energy Bridge Gulf of Mexico, LLC) LNG import terminal notes that the total seawater demand for the vessel is 133 million gallons per day (MGD).[12] The sea water intake serves the following purposes: (1) total demand dedicated to the regasification system (76.1 MGD); (2) vessel's main condenser cooling system (46.9 MGD); and (3) vessel's other cooling systems (10 MGD). This offshore LNG import terminal is subject to the NPDES Permit Program[13]; withdraws more than 2 MGD; and uses more than 25 percent of the seawater intake for cooling purposes.

3.1 Existing Onshore LNG Import Terminals

Since the 1970s, none of the four existing continental U.S. LNG import terminals use surface water for warming or cooling purposes, only as an emergency backup source to their firewater systems.[14,15] For example, at the Dominion Cove Point, Maryland, facility all water used on site is withdrawn from groundwater wells and is heated in the vaporizers and used to warm the LNG and convert back to a gaseous state.[16] Additionally, the EcoElectrica facility in Puerto Rico does use surface water for makeup and discharges blowdown for the power plant cooling tower, but does not use surface water intakes directly for the LNG processing (warming or cooling). The

[11]U.S. EPA, 2004. "Clarification of Technology-based CWA § 316(b) Requirements for Liquified Natural Gas (LNG) import terminals," Memorandum, April 22, 2004.

[12]U.S. Coast Guard, 2003. Draft Environmental Assessment of the El Paso Energy Bridge Gulf of Mexico, L.L.C., Deepwater Port License Application, Docket No. USCG-2003-14294, September 2003.

[13]U.S. EPA, 2003. Letter from Lawrence E. Starfield, Acting U.S. EPA Region 6 Administrator to U.S. Coast Guard Commander Mark Prescott, "EPA Authority Over Construction and Operation, El Paso Energy Bridge Deepwater Port Project," March 28, 2003.

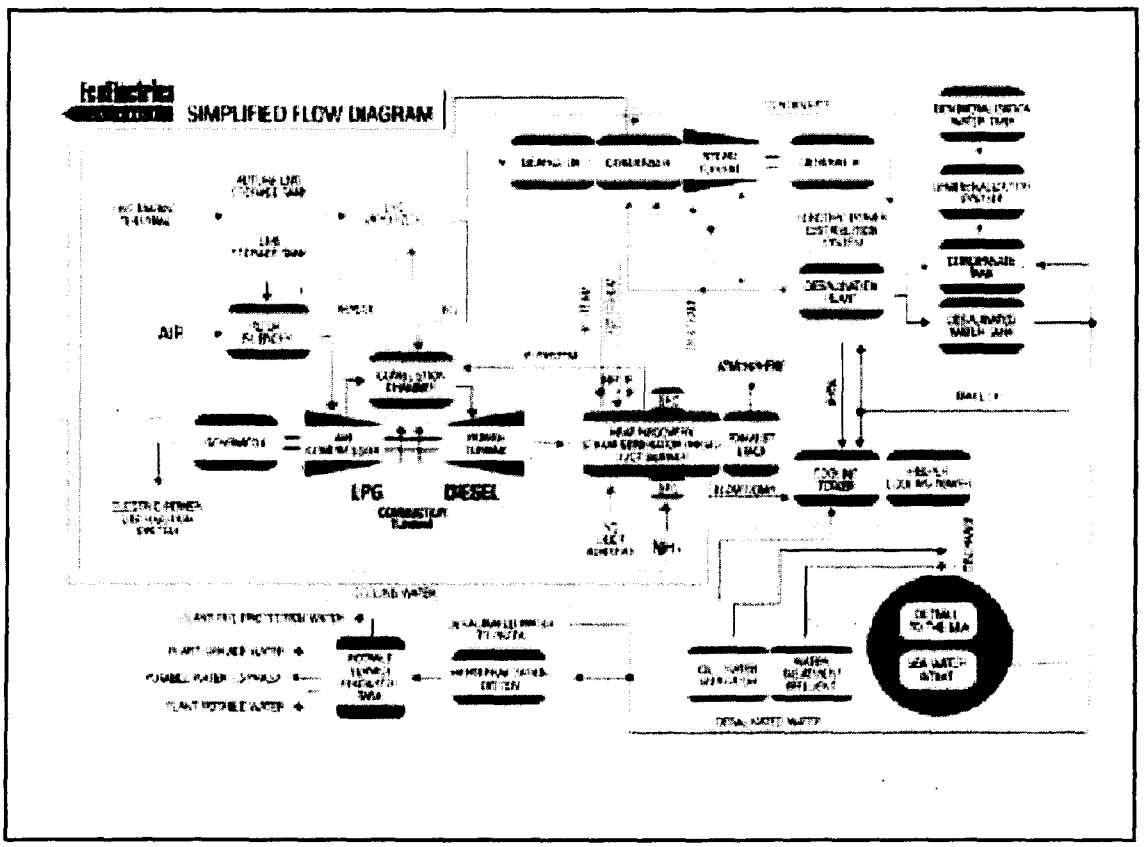
[14] E-mail communication from James Kelly, CH-IV International, to Carey A. Johnston, U.S. EPA, April 28, 2004.

[15] Frangesh, Neal, 2004. Memorandum from Neal Frangesh, LGA Engineering, to David Moses, U.S. DOE, "Existing U.S. LNG Import Terminals: Sources of Cooling Water and Firewater," July 19, 2004.

[16]E-mail communication from Elizabeth Aldridge, Hutton & Williams, to Carey A. Johnston, U.S. EPA, June 24, 2004.

EcoElectrica facility integrates LNG vaporization with its power plant operations. Figure 3-80 describes how this facility uses a glycol re-circulating heat exchanger in combination with a electric power generator to re-gasify the LNG.

Figure 3-80. EcoElectrica Simplified Flow Diagram



3.2 New Onshore LNG Import Terminals

Current information indicates that all new onshore LNG import terminals are proposing to use LNG vaporization systems with no surface water intakes (e.g., integration with other industrial facilities, ambient air vaporization through heating towers, gas-fired heaters). Exhibit 3-79 lists proposed new onshore LNG import terminals and their vaporization design.

Exhibit 3-79. Proposed U.S. Onshore LNG Import Terminals[17]

No.	Project Name/ Operator/ FERC Docket No.	Location	Storage Capacity	Sendout Capacity	Vaporizer Design	LNG Ship Frequency
1	Freeport LNG Project (Cheniere/Freeport) CP03-75-000 $400 million facility cost	Freeport, TX	320,000 m^3 (2 tanks each with 160,000 m^3)	1.5 Bcf/d	Closed-loop: Air heat exchanger (heating tower) Supplemental gas-fired heater for cold weather	200 ships/ year
2	Sabine Pass LNG and Pipeline Project (Cheniere) CP04-38-000 CP04-47-000 $600 million facility cost	Cameron Parish, LA (across from Sabine Pass)	480,000 m^3 (3 tanks each with 160,000 m^3)	2.6 Bcf/d	Closed-loop: Gas-fired heater	300 ships/ year
3	Cheniere Corpus Christi LNG Terminal and Pipeline Project (Cheniere) CP04-37-000 CP04-44-000 $450 million facility cost	Corpus Christi, TX	480,000 m^3 (3 tanks each with 160,000 m^3)	2.6 Bcf/d	Closed-loop: Gas-fired heater	300 ships/ year
4	Golden Pass LNG Terminal and Pipeline Project (ExxonMobil) PF04-1-000 $600 million facility cost	Sabine, TX	Phase 1: 480,000 m^3 (3 160,000 m^3 tanks) Phase 2: 800,000 m^3 (5 160,000m^3 tanks)	Phase 1: 1 Bcf/d Phase 2: 2 Bcf/d	Closed-loop: Gas-fired heater	Phase 1: 1 ship/4 days (91 ships/ year) Phase 2: 1 ship/2 days (183 ships/ year)
5	Vista del Sol LNG Terminal Project (ExxonMobil) PF04-3-000 PF04-9-000 $600 million facility cost	Corpus Christi, TX	480,000 m^3 (3 tanks each with 160,000 m^3)	Phase 1: 1 Bcf/d	Closed-loop: Gas-fired heater	1 ship/4 days (91 ships/year)
6	Ingleside Energy Center LNG Project (Occidental) PF04-9-000	Corpus Christi, TX	320,000 m^3 (2 tanks each with 160,000 m^3)	1 Bcf/d	Closed-loop: Water heat exchanger (waste water from the chemical plant)	1 ship/3 days

[17] E-mail communication from James Martin, FERC, to Carey A. Johnston, U.S. EPA, August, 4, 2004.

Exhibit 3-79. Proposed U.S. Onshore LNG Import Terminals (continued)

No.	Project Name/Operator/ FERC Docket No.	Location	Storage Capacity	Sendout Capacity	Vaporizer Design	LNG Ship Frequency
7	Port Arthur LNG Receiving Terminal Project (Sempra) Docket No. PF04-11-000	Port Arthur, TX	480,000 m^3 (3 tanks each with 160,000 m^3)	1.5 Bcf/d	Closed-loop: Gas-fired heater	150 ships/ year
8	Cameron LNG, LLC (Sempra Energy) CP02-374-000 CP02-376-000 CP02-377-000 CP02-378-000 $700 million facility cost	Hackberry, LA	480,000 m3 (3 tanks each with 160,000 m3)	1.5 Bcf/d	Closed-loop	210 ships/ year
9	Weaver's Cove LNG CP04-36-000 $250 million facility cost	Fall River, MA	200,000 m3 (1 tank)	0.4 Bcf/d	Closed-loop: Gas-fired heater	50-70 ships/ year
10	BP Crown Landing LNG PF04-2-000 PF04-5-000 $500 million facility cost	Logan Township, NJ	450,000 m^3	1.2 Bcf/d	Closed-loop: Gas-fired heater	100 ships/ year
11	Long Beach LNG (Sound Energy Solutions) CP04-58-000 $400 million facility cost	Long Beach, CA	320,000 m3 (2 tanks each with 160,000 m3)	0.7 Bcf/d	Closed-loop: Gas-fired heater	146 ships/ year
12	Keyspan & BG LNG CP04-223-000 CP04-293-000	Providence, RI	95,000 m^3	0.5 Bcf/d	Closed-loop: Gas-fired heater	50 ships/ year
13	Somerset LNG	Somerset, MA				
14	Cheniere Mobile	Mobile, AL (Pinto Island)		1.0 Bcfd	Closed-loop	
15	Cherry Point Energy LLC - online in 2008	Columbia River, OR		0.5 Bcf/d		
16	Somerset LNG	Somerset, MA				
17	Waterbury LNG - online in 2007	Waterbury, CT		1.2 Bcf/d		
18	Cheniere LNG	Brownsville, TX		2 Bcf/d		

Note: The FERC docket for each onshore LNG import terminal can be accessed using the docket number and the following website: http://elibrary.ferc.gov/idmws/docket_search.asp.

The CWA § 316(b) Phase I rule applies to new land-based facilities, including LNG import terminals, that (1) use cooling water intake structures to withdraw water from waters of the United States; (2) are required to obtain an NPDES permit issued under CWA § 402; (3) have a design intake flow of greater than 2 MGD; and (4) use at least 25 percent of water withdrawn for cooling purposes (see 40 CFR 125.81). (EPA, 2004 - clarification memo). Under the Phase I rule, new facilities include only greenfield or stand alone facilities. A greenfield facility is one that is constructed at a site at which no other source is located, or that totally replaces the process or production equipment at an existing facility (see 40 CFR 125.83). A stand alone facility is a new, separate facility that is constructed on property where an existing facility is located and whose processes are substantially independent of the existing facility at the same site (see 40 CFR 125.83). In addition to being either a greenfield or stand alone facility, the facility must have commenced construction after January 17, 2002 and must use a newly constructed cooling water intake structure or an existing cooling water intake structure whose design capacity is increased (see 40 CFR 124.83).

Any land-based facility that meets the applicability criteria is subject to the Phase I rule, even if the facility or industrial sector was not explicitly listed as a Phase I facility in the record to the Phase I rule. EPA found that the industries it analyzed could serve as surrogates for other industries to which the new facility rule applies. Therefore, new land-based LNG import terminals that meet the applicability criteria of the Phase I rule (see 40 CFR 125.81) are subject to the rule. EPA notes that the new facility rule does contain an alternative requirements provision for situations when a particular facility has costs wholly out of proportion to those considered by EPA in the rulemaking or when compliance would result in significant adverse impacts on local air quality, local water resources (other than impingement and entrainment) or local energy markets (see 40 CFR 125.85).

3.3 New Offshore LNG Import Terminals

The Phase I new facility rule does not apply to offshore facilities. EPA specifically exempted the offshore oil and gas extraction industry in the Phase I rule (see 40 CFR 125.80(d)) and confirmed the exclusion of new offshore LNG import terminals from the Phase I new facility rule in a recent memorandum to EPA Regions. (EPA, 2004 - clarification memo) EPA identified eleven company announcements of proposed U.S. offshore LNG import terminals with one company proposing a pilot study (see Exhibit 3-80). A large majority of the these facilities are planned for the Federal Outer Continental Shelf in the Gulf of Mexico (GOM). The Federal OCS generally starts three miles from shore and extends out to the outer territorial boundary (about 200 miles).[18]

The U.S. Coast Guard is responsible for developing and maintaining regulations and standards for deepwater ports. Current projects include regulations for deepwater ports (33 CFR Subchapter NN), specifically updating existing rules and adding provisions for natural gas. The passage of the Maritime Transportation Security Act of 2002 (MTSA), which added natural gas to the Deepwater Port Act, heightened interest within the energy industry to develop deepwater ports.

The U.S. Coast Guard has primary authority over construction and siting of offshore LNG facilities, and oversees preparation of environmental impact statements that examine the potential impact of the new facilities, as required by the National Environmental Policy Act and the Deepwater Port Act of 1974 (DWPA), as amended (33 USC 1501 et seq). As specified by the Deepwater Port Act, the environmental review and analysis must be completed within 356 days of the published Notice of Intent. Coast Guard oversight of the offshore facilities continues as long as the facilities are operational, as the agency has responsibility for the safety and security of LNG facilities and vessels in U.S. coastal waters. (DOE 2004) Eight deepwater port license applications have been received since the Maritime Transportation Security Act was signed into law.[19] EPA was able to summarize the most important information of these eight proposed offshore LNG import terminals.

Exhibit 3-80. Proposed U.S. Offshore LNG Import Terminals

No.	Company (Facility Name)	Offshore Location	EPA NPDES Permit Information	USCG Deepwater Port Licensing Information (Docket No.)
1	Excelerate (GOM Energy Bridge)	West Cameron 603 - GOM 100 miles offshore LA	Yes	Yes (14294)
2	ChevronTexaco (Port Pelican)	Vermillion 140 - GOM 37 nautical miles from LA	Yes	Yes (14134)
3	Shell (Gulf Landing)	West Cameron 213 - GOM 38 nautical miles from LA	Yes	Yes (16860)
4	BHP Billiton (Cabrillo Port)	Offshore Oxnard, CA 13.9 miles from CA	No	Yes (16877)
5	ConocoPhillips (Compass Port)	Mobile Block 910 88°12' West, 30°5' North	No	Yes (17659)
6	Freeport McMoRan (Main Pass Energy Hub)	Main Pass 299 - GOM 16 miles from LA	No	Yes (17696)
7	Crystal Energy (Clearwater Port)	Offshore Ventura, CA 11 miles from CA	No	Yes (TBD)

[18]The Federal OCS starts approximately 10 miles from the Florida and Texas shores.

[19] U.S. Coast Guard, 2004. Deepwater Ports Standards Division Website, http://www.uscg.mil/hq/gm/mso/mso5.htm.

Exhibit 3-80. Proposed U.S. Offshore LNG Import Terminals (continued)

No.	Company (Facility Name)	Offshore Location	EPA NPDES Permit Information	USCG Deepwater Port Licensing Information (Docket No.)
8	ExxonMobil (Pearl Crossing)	West Cameron 220 - GOM 41 miles offshore LA	No	Yes (18474)
9	ChevronTexaco (Port Penguin)	Offshore CA Exact Location: TBD	No	No
10	El Paso Global	Offshore Belmar, NJ Exact Location: TBD	No	No
11	Excelerate Energy (Northeast Gateway)	Offshore Boston, MA Exact Location: TBD	No	No
12	Conversion Gas Imports	Vermillion 179 - GOM	No	No

Note: "EPA NPDES Permit Information" indicates whether the company has applied for an NPDES permit application. "USCG Deepwater Port Licensing Information" indicates whether the company has applied for a deepwater port license. The USCG docket for each Deepwater Port license application can be accessed using the docket number and the following website: http://dms.dot.gov/search/searchFormSimple.cfm.

Excelerate - GOM Energy Bridge

Excelerate is proposing to construct, own, and operate an LNG import terminal 100 miles offshore in the GOM. The Excelerate GOM Energy Bridge deepwater port will consist of a submerged turret loading (STL) system that is comprised of a submerged turret buoy; chains, lines and anchors; a flexible riser; and a subsea manifold. Gas will be delivered to the deepwater port by conventional LNG vessels which incorporate shipboard re-gasification capabilities.[20] The vessels that will be used to deliver natural gas to the Excelerate GOM Energy Bridge deepwater port will have a capacity to hold 138,000 m^3 of LNG and, unlike all other LNG vessels currently in operation, will re-gasify the LNG on-board at the point of delivery so that imports will consist of gas in its vaporous state, rather than in a liquefied state. The a water depth at this deepwater port is 280 feet.[21] This import terminal will vaporize and deliver natural gas on average approximately 0.55 Bcfd of LNG. A fully loaded LNG vessel will be able to discharge its cargo in about six to eight days, depending on operating conditions. The approximate cost of the STL subsea system is $50.7 million with a projected completion date of December 2004. The following information comes from the Excelerate application for deepwater port license and draft Environmental Assessment. (USCG, 2003 - draft EA El Paso)

When the specially configured LNG vessels reach the location of the deepwater port, they will retrieve and connect to the STL system. For that purpose, a winch located on the LNG vessel will raise the submerged buoy from its subsurface location, where it is located when not connected to an LNG vessel. The buoy will be drawn into an opening in the hull of the vessel. After it is secured to the LNG vessel, the buoy will serve both as the mooring system for the vessel and as the offloading mechanism.

The maximum rate of discharge of the natural gas from an LNG vessel into the STL will be determined by a combination of the availability of capacity on downstream pipelines and the re-gasification capabilities of the facilities located on-board each specially configured LNG vessels. Each of the LNG vessels will have six shell-and-tube vaporizers located on-board. During the re-gasification process, five of the vaporizers will normally be in operation, with the sixth serving as a backup or available for peak demand. Each of the vaporizers will have a normal send-out capability of 0.1 Bcfd a peak capacity of 0.115 Bcfd.

Each specially configured LNG vessel will integrate complete offshore re-gasification capabilities into its shipboard system. The re-gasification system can operate in open loop mode, closed loop mode, or together in a combination mode. In the open loop mode, the LNG vessel will intake seawater from the surrounding area to heat the LNG. The warm seawater will pass through the shell and tube vaporizer indirectly heating the LNG. Then the LNG vessel will discharge this water through its keel.

[20]El Paso Energy Bridge GOM LLC Application for Deepwater Port License, http://dmses.dot.gov/docimages/pdf84/219001_web.pdf, December 20, 2002.

[21]U.S. EPA, 2003. El Paso Energy Bridge Gulf of Mexico, LLC Draft NPDES Permit No. GM0000003, Fact Sheet, http://www.epa.gov/region6/6wq/npdes/genpermt/gm3factsheet.pdf.

In the closed loop mode, steam from the LNG vessel propulsion boilers will heat water circulated in a closed loop through the shell and tube vaporizer and a steam heater. After the cycle, the water will be re-circulated through the system. There is no seawater intake or discharge for the re-gasification process in the closed loop mode. The closed loop mode allows for LNG re-gasification when surrounding seawater temperatures are too cold for the more efficient open loop mode. In the open loop mode, the system can re-gasify up to 0.69 Bcfd. However, due to operating constraints related to downstream pipelines, the system for the Excelerate LNG import terminal will re-gasify a maximum of 0.55 Bcfd in the open loop mode. Closed loop steam operations can re-gasify up to 0.45 Bcfd.

Excelerate is proposing to operate the specially configured LNG vessels in open loop mode exclusively. (USCG, 2003 - draft EA El Paso) The open loop mode would draw seawater from the surrounding area at approximately 23.0 ft below the water surface. Intake structures on the LNG vessels are sized to provide seawater for both standard ship operations and the warming water for the LNG vaporizers. To supply natural gas at a rate of 0.55 Bcfd, the LNG vessel would require a total intake flow of 76.1 MGD. As previously mentioned, this offshore LNG import terminal is subject to the NPDES Permit Program; withdraws more than 2 MGD in the open loop mode; and uses more than 25 percent of the seawater intake for cooling purposes in the open loop mode.

Using a single sea chest inlet, the combined cooling water and warming water intake velocities would be approximately 3.9 feet per second. A sea chest is an underwater compartment within the vessel's hull through which sea water is drawn in or discharged. A passive screen (strainer) is set along the flush line of the sea chest. Pumps draw seawater from open pipes in the sea chest cavity. Excelerate is proposing to connect two of the LNG vessels four sea chests internally to increase the intake area and reduce average intake velocity. Using this scenario, the intake velocity at the two sea chests would be approximately 1.0 feet per second. The sea chest intakes incorporate metal slotted grating on 21 millimeters spacings to reduce the impingement of aquatic organisms. This mesh size would not prevent the entrainment of eggs and larvae of marine fish species.

All of the seawater entering the sea chest intakes either for ship operations or for the re-gasification process will pass through a copper cathode antifouling system. The copper anodes release a small amount of copper into the ships seawater system at the intake to prevent biota in the seawater from establishing within the seawater flow path. This will also control non-native species. Temperature of the discharge water will be approximately 13.5 °F less than the temperature of the intake water. A marine growth prevention system with copper and aluminum anodes will treat seawater to prevent biological build-up in the onboard equipment.

ChevronTexaco - Port Pelican

Port Pelican LLC, a subsidiary of ChevronTexaco, is proposing to construct, own, and operate an LNG import terminal 37 nautical miles offshore.[22] The water depth at the offshore LNG import terminal will be approximately 79 to 86 feet. The Port Pelican import terminal will consist of two concrete gravity based structure (GBS) units fixed to the seabed, which will include integral LNG storage tanks, support deck mounted LNG receiving and vaporization equipment and utilities, berthing accommodations for LNG carriers, facilities for delivery of natural gas to a pipeline transportation system, and personnel accommodations.[23] The Port Pelican import terminal will be constructed in two phases. Phase I includes the installation of two GBS structures with internal storage tanks and facilities for LNG offloading, send out and vaporization to deliver a peak 1.0 Bcfd of natural gas to pipeline. Phase II will increase the capacity to 2.0 Bcfd of natural gas to pipeline. The approximate cost for this project is approximately $800 million for both phases. Phase I is expect to be complete by 2006 with Phase II completed by 2008. The following information comes from the Port Pelican LLC application for deepwater port license and draft Environmental Impact Statement.[24]

Sea water will flow through intake screens to eliminate debris and marine life before being pumped to the vaporizers through strainers. To control biofouling, sodium hypochlorite will be injected into the pump suction to achieve a free chlorine concentration of 0.2 ppm. In addition, each pump will be shocked for 20 minutes three times per day at a level of 2.0 ppm free chlorine.

Two parallel vaporization trains (average capacity of 0.8 Bcfd and peak capacity of 1.0 Bcfd each) will be provided, one in Phase I and a second in Phase II, to vaporize LNG and deliver natural gas at a pressure of up to 1,440 psig. Each 1.0 Bcfd train consists of six 0.2 Bcfd, each with an LNG sendout pump, an Open Rack Vaporizer (ORV), and a seawater lift pump. Five of the six trains will be

[22]U.S. EPA, 2003. Port Pelican LLC Draft NPDES Permit No. GM0000001, Fact Sheet, http://www.epa.gov/earth1r6/6wq/npdes/genpermt/draftgm0000001.pdf.

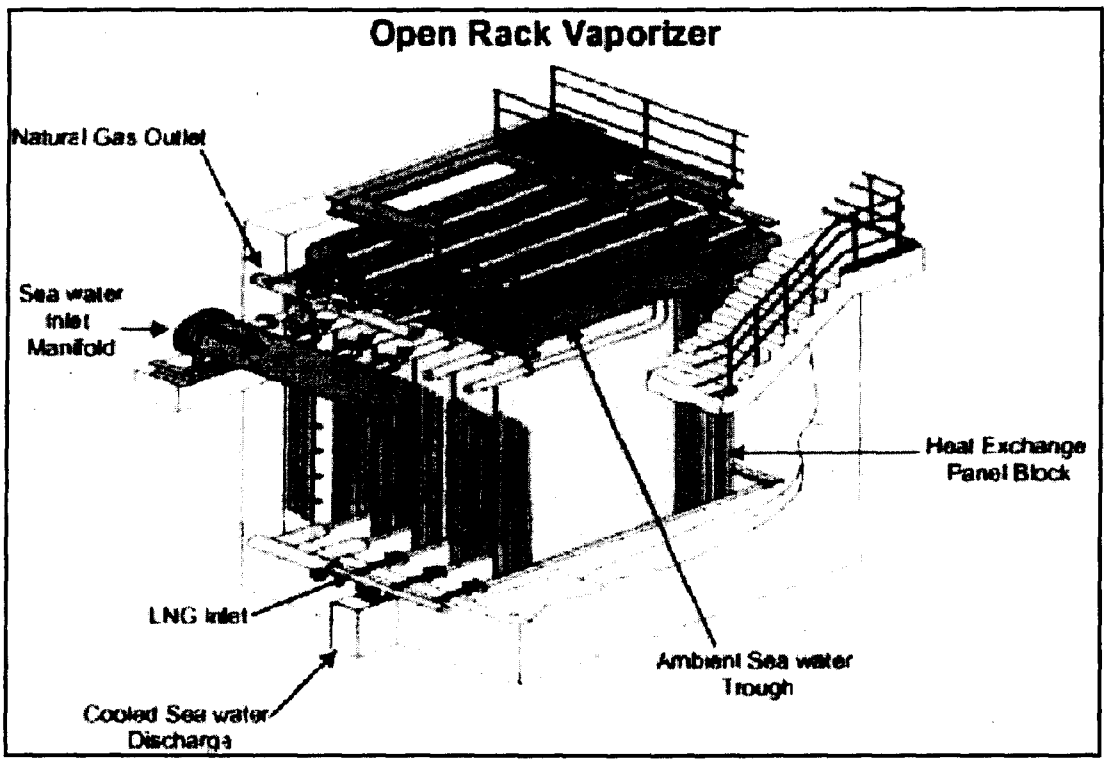
[23]Port Pelican LLC Application for Deepwater Port License, http://dmses.dot.gov/docimages/pdf84/210833_web.pdf, December 27, 2002.

[24]Draft Environmental Impact Statement for Port Pelican LLC Deepwater Port License Application, http://dmses.dot.gov/docimages/pdf86/244607_web.pdf,

operating during peak sendout rate (1.0 Bcfd each), and one will be used as a spare. The LNG flow rate will be approximately 178 tons/hour to deliver 0.2 Bcfd of gas. The intake water is not used for any cooling purposes.

The LNG sendout pumps will discharge LNG into the ORVs where it is warmed and flashed by seawater heat exchange at a peak vaporizing capacity of 0.2 Bcfd. ORV technology uses seawater flowing over a series of panel coils to warm the LNG that is flowing countercurrent within the panels (see Figure 3-81). Sea water flows through intake screens to eliminate debris and marine life, and is then pumped to ORVs through strainers. Intake screens are designed and operated at intake velocities set to minimize impingement and entrainment of marine organisms.

Figure 3-81. Open Rack Vaporizer (from Port Pelican LLC Deepwater Port License Application)



Seawater lift pumps bring treated seawater to the top of ORVs. From there it cascades over the ORV panel coils and creates a falling film of water which exchanges heat with the upward-flowing high pressure LNG from the sendout pumps. This process will warm the LNG to approximately 35°F and in the process vaporize it; and it will cool the water by approximately 20°F. The cooled water is collected in a concrete basin and discharged to the GOM after it passes once through the system.

The maximum seawater intake rate is 12,250 gallons per minute (GPM) per pump with an intake velocity of 0.5 feet per second per pump. Seawater then flows from the bottom of the ORVs into a trench routed to the seawater outfall. At peak capacity, the seawater lift pumps will circulate 88.2 MGD of water through the ORVs during Phase I (five out of six trains in use), and at the completion of the Phase II expansion, water circulated would be 176.4 MGD (10 out of 12 trains in use). During normal operations, four trains will circulate 70.5 MGD of seawater during Phase I, and eight trains will circulate 141 MGD of seawater during Phase II through the ORVs.

Shell - Gulf Landing

The Shell Gulf Landing LNG terminal facility (Gulf Landing LLC) will receive LNG from marine vessels, store the gas, then re-gasify the LNG and deliver it to pipelines for distribution and sales to the United States. The facility throughput is planned at 7.7 million tonnes per annum of LNG. This will be provided by approximately 135 carriers per year, dependent upon the size of the carriers used. Each LNG carrier will unload its cargo into the terminal storage tanks. This process takes approximately 24 hours from arrival to departure. The facility will vaporize and deliver natural gas at a rate of approximately 1.0 Bcfd on a continuous basis. The

approximate cost is $700 million. Installation of the terminal is schedule for the 4th quarter of 2008 with the first deliveries of LNG schedule for January 2009.[25]

Gulf Landing LLC has proposed discharges from six outfalls: (1) thermal water for open rack vaporizer (ORV) at 136 MGD; (2) deck drainage wastewater at 0.0058 MGD; (3) uncontaminated deck water at 0.0209 MGD; (4) desalinization rejected water at 0.0254 MGD; (5) treated sanitary & domestic wastewater at 0.0075 MGD; and (6) firewater bypass at 0.5035 MGD.[26] The intake water is not used for any cooling purposes.

Outfall 001 discharges seawater that is passed through the ORV process system. Seawater from the intake structure is screened and treated with sodium hypochlorite at the intake pumps to control marine growth in the system. The treated seawater is then distributed to the ORV system. The ORV serves as the warming energy to gasify the LNG. The water is cooled during this heat exchange to about 18°F from the ambient intake seawater temperature.

The seawater is treated with sodium hypochlorite, at a continuos rate of approximately 2.0 mg/l. Periodically, each pump will be shocked with 5.0 mg/l for one hour during every 8-hours of pump run time. At capacity, the facility will have four pumps. The ORV intake structure is designed to limit intake water velocity to less than 0.5 feet per second. This velocity will help to lessen impingement of marine aquatic organisms from the intake screens. The intake ports will be covered with a 0.25 inch mesh screen to lessen entrainment.

As discussed in the draft Environmental Impact Statement for the Gulf Landing LLC deepwater port license application[27] and in responses to EPA questions,[28] Gulf Landing LLC is taking the following steps to reduce entrainment and impingement of aquatic organisms:

- Intakes are located as close as practical to the sea bottom to reduce the potential for entrainment of smaller aquatic organisms which are more likely to be near the surface.
- The intakes are designed for horizontal flow to minimize the potential for water coning from the surface.
- Intake screens are provided with a 0.25 inch mesh screen to lessen entrainment.
- Intake screens with wedgewire technology to reduce the potential for impingement.
- Minimization of warming water throughput requirements for the installation by using the maximum practical inlet to outlet seawater temperature change of 18°F.
- Limit water intake velocity to less than 0.5 feet per second. (This is based on 2 x 100% intake systems, which allow for period cleaning; with the maximum throughput of the facility. In practice velocities during normal operation will significantly lower.)
- A commitment to monitor impingement and entrapment of marine life during the first two years of operation to establish the impact of the facility on marine life, and a commitment to implement reasonable and practical improvement measures if warranted scientifically through the monitoring program.

BHP Billiton - Cabrillo Port

The BHP Billiton proposes to construct, own, and operate an LNG import terminal, Cabrillo Port, approximately 13.9 miles off the coast of Ventura County in Southern California, in 2,900 feet of water. The permanently moored import facility (floating storage & re-gasification unit) will include three storage tanks, eight vaporizers, and an underwater, 21.1 mile pipeline that would connect to an existing onshore pipeline. Maximum water depth at the location of the planned mooring is about 2,900 feet. The floating storage and re-gasification facility will vaporize and deliver natural gas at a maximum rate of approximately 1.5 billion cubic foot a day, with an anticipated average rate of 0.6 to 0.9 Bcfd. The BHP Billiton LNG import terminal is designed to accommodate LNG carriers ranging

[25]Gulf Landing LLC Application for Deepwater Port License, http://dmses.dot.gov/docimages/pdf88/265164_web.pdf, January 14, 2004.

[26]U.S. EPA, 2003. Gulf Landing LLC Draft NPDES Permit No. GM0000004, Fact Sheet, http://www.epa.gov/earth1r6/6wq/npdes/gmpn/gm4fact.pdf.

[27]Draft Environmental Impact Statement for The Gulf Landing LLC Deepwater Port License Application, http://dmses.dot.gov/docimages/pdf89/286049_web.pdf, June 2004.

[28]E-mail communication from John Hritcko, Shell US Gas & Power, LLC, to Carey A. Johnston, U.S. EPA, March 12, 2004, "Shell Responses to EPA Questions Dated October 23, 2003, Regarding Liquefied Natural Gas Import Terminals."

in capacity from 100,000 m^3 to 220,000 m^3. LNG carriers typically will be offloaded at a rate of 80,000 gallons per minute of LNG through the liquid loading arms and stored in the LNG storage tanks at a temperature of approximately minus 260°F. This LNG import terminal is projected to have 320,000 m^3 in storage capacity at the receiving facility. The approximate cost of this project is $550 million with a projected completion date of 2008. The following information comes from the Cabrillo Port application for deepwater port license.[29]

The BHP Billiton LNG import terminal is designed to no use sea water for the re-gasification process. This facility is proposing to use submerged combustion vaporizers using LNG as the fuel. The LNG is pumped, as liquid, up to the 1,500 psig natural gas send out pressure and maintained at that pressure through the vaporization process. The vaporization portion of the process re-gasifies the LNG. The process will consist of eight submerged combustion vaporizers (SCVs). Each will have a maximum capacity of 198 short tons per hour of LNG vaporized. The SCVs will superheat the resultant natural gas to a temperature of about 41 °F at a pressure of about 1,500 psig. The combustion vaporization process is thermally stabilized by submersion in a water bath. No compression of the natural gas is required.

BHP Billiton evaluated several options including the intermediate fluid vaporizers (IF) and open rack vaporizers (ORV). IFV and ORV use seawater as a heat source while SCV uses natural gas combustion. For the BHP Billiton LNG import terminal the IFV and ORV alternatives would require about 50 MGD of seawater. In these alternatives, seawater would flow through the vaporizers and then would be returned to the ocean at a lower than ambient temperature. BHP Billiton identified that the primary benefit of IFV and ORV relative to the proposed SCV is lower air emissions. SCV burns natural gas equivalent to 2% of the LNG throughput to generate heat. Other industry estimates suggest that this energy penalty is closer to 1.5%. (Hall, 2004) This is similar to the 1.5% energy penalty identified in the 316(b) Phase I new facility rule for cooling towers at electric power generators. The combustion process relies on natural gas from LNG, so it is a cleaner fuel. With SCV the exhaust gases also flow directly through a water bath, which acts as a quench and abatement system. The SCV air emissions will include oxides of nitrogen (NOx), and carbon dioxide. IFV and ORV would introduce some air emissions, which are of an order of magnitude less than SCV's because of the incremental electricity necessary to operate the large seawater pumps.

BHP Billiton identified concerns over the potential intake of 50 MGD of seawater associated with the IFV and ORV alternatives. Specifically, BHP Billiton identified concerns over entrainment and impingement of marine species, thermal plumes, turbidity, treated water discharge and noise. Impingement could occur when fish and other aquatic life are trapped against the water intake screens. These screens prevent marine organisms and debris from entering and interfering with the re-gasification process. Entrainment occurs when aquatic organisms, including eggs and larvae, are drawn into the water intakes, through the facility, and then pumped back out.

Thermal plumes could result from the constant discharge of large quantities of relatively cold, and therefore relatively dense, water. BHP Billiton identified that the proposed mooring location is of sufficient depth that a thermal plume would not be likely to impact the sea floor. Turbidity would be a result of a thermal plume disturbing sea floor sediments. Additionally, the IFV and ORV alternatives would likely use sodium hypochlorite or another oxidizer to control the growth of marine organisms in the IFV and ORV equipment. BHP Billiton identified that discharge of the residual sodium hypochlorite in IFV and ORV water could impact marine organisms, and would require a NPDES permit. Noise would be generated by the large seawater pumps required for the seawater intake alternatives.

In general, BHP Billiton identified that the use of IFV and ORV would be difficult to permit and operate because of water discharge rules and restrictions and impacts to marine biota. The use of SCV would produce air emissions that could be minimized by emission control technology. BHP Billiton select SCV for the re-gasification process as the re-gasification alternatives to SCV do not provide clear environmental benefits.

ConocoPhillips - Compass Port

Compass Port LLC, a wholly owned subsidiary of ConocoPhillips Company, proposes to construct, own, and operate an LNG import terminal 33 miles from the southern city limit of Mobile, Alabama and 11 miles south of Dauphin Island, Alabama, in a water depth of approximately 70 feet. The facility will vaporize and deliver natural gas at a rate of approximately 1 billion cubic foot a day on a continuous basis. The maximum unloading period for a ship is designed to be 20 hours at this LNG import terminal. To achieve this rate, the unloading system will be designed to deliver 255,000 cubic meters of LNG from a ship to the storage tanks within 12 to 14 hours. The expected completion date is 2009.

As shown in Figure 3-82, Compass Port LLC import terminal will incorporate: (1) docking facilities for conventional LNG carriers; (2) unloading facilities for the unloading of LNG cargo; (3) two full containment tanks for the storage of LNG; (4) re-gasification facilities to convert LNG into natural gas; (5) an offshore natural gas pipeline; and (6) related facilities to support the operation of

[29]Cabrillo Port Application for Deepwater Port License, http://dmses.dot.gov/docimages/p77/265927.doc, January 21, 2004.

Compass Port.[30] Construction and installation of the proposed port will take approximately 42 months to complete, beginning in 2005, providing for approximately 12 months for pre-construction activities. The following information comes from the Compass Port LLC application for deepwater port license.

The Compass Port LLC import terminal will consist of two concrete gravity-based structures fixed to the seabed that contain the integral LNG storage tanks, the LNG re-gasification facilities, and other operational equipment including mooring platforms, a docking platform that contains LNG unloading equipment, and a flare platform. There also will be a separate platform for support facilities such as personnel quarters, and other auxiliary structures.

The Compass Port LLC import terminal will utilize a total of six water intake structures and ORV for the re-gasification process. Each intake structure will consist of a hollow steel caisson that will extend from a manifold on the cellar deck of the re-gasification platform to beneath the water surface. Each steel caisson will be fixed to the re-gasification platform jacket structure by a series of welded supports. A submersible pump will be located in each intake structure and will have a maximum design pumping capacity of 30.4 MGD. In normal operation only four pumps are working and in cold weather conditions five pumps are working for a total DIF of 152.2 MGD. The sixth pump is a kept and maintained as a spare.

Figure 3-82. Compass Port LLC Proposed LNG Import Terminal

Each intake caisson will be fitted with a cylindrical wedgewire screen with 0.25-inch slot size openings. Preliminary design estimates are that each intake screen will measure approximately 3.9 feet in diameter and approximately 14.8 feet in length. The center of each intake screen will be located at the mid-depth of the water column (approximately 36 feet below the water surface). The intake pumping systems and screens will be designed to maintain a through-slot velocity of no greater than 0.5 feet per second. As needed, a lifting mechanism will be used to lift the intake screens to the re-gasification platform for cleaning. The intake water is not used for any cooling purposes.

To minimize biological fouling, seawater will be treated with sodium hypochlorite applied at a continuous rate of approximately 0.2 mg/l. Periodically, each pump will be shocked with 2.0 mg/l of hypochlorite for 20 minutes during every 8 hours of pump run time. The facility will not shock any more than one unit at a time. Discharge seawater temperature will be approximately 14.8°F cooler than the ambient water at the discharge points. The thermal discharge plume at 100 meters from the discharge location is predicted to approach ambient temperature (less than 1°C below ambient).

Freeport McMoRan - Main Pass Energy Hub

The Main Pass Energy Hub (MPEH) is proposed to deliver an average of 1.0 Bcfd of LNG. The water depth at the LNG import terminal is approximately 210 feet. The project involves the reuse of four existing platforms and three smaller bridge supports along

[30]Compass Port Application for Deepwater Port License, http://dmses.dot.gov/docimages/pdf89/284087_web.pdf, March 29, 2004.

with the interconnecting bridges formerly used in sulphur mining operations at Main Pass 299. This LNG import terminal will use salt caverns its design and ORVs to re-gasify LNG at a design capacity of 1.6 Bcfd.[31] The vaporized natural gas heated to 40° F. The approximate cost of this project is $500 million with a projected completion date of 2006. The following description of the MPEH is from the deepwater port license application for the Main Pass Energy Project.

At peak vaporization rate, all the ORVs will be in operation. Nine operating ORVs are required to meet the 1.6 Bcfd design vaporization capacity with the gas conditioning plant in operation. ORVs utilize seawater as the heating medium for vaporization of LNG. The heat transfer surface will be vertical, panel-shaped tubes of aluminum-zinc alloy for seawater resistance, and an aluminum base/tube assembly. LNG will flow upward inside finned heat transfer tubes, with seawater flowing downward along the outside of the tubes.

Six seawater lift pumps will be provided, each with a design capacity of 33.4 MGD (total of approximately 200 MGD) and a differential head of 120 psi. Normally, five pumps will be in operation and one will be an installed spare. During winter operations when seawater temperatures are lower, the sixth seawater lift pump may be operated to obtain adequate heat transfer. Seawater will be pumped to the top of the ORVs where it will be distributed in overhead troughs to create a water film falling as a sheet in contact with the vertical tube surface. The seawater temperature will be reduced by approximately 22°F through the ORV and will be collected in a basin for discharge back to the sea. The intake water is not used for any cooling purposes.

Seawater lift pumps have intake screens to eliminate debris and minimize impacts on marine life. These screens are passive, cylindrical wedgewire-type screens. They have no moving parts and are easy to maintain. The screens are designed so that the intake flow is at a uniform low velocity across the entire screen surface and limited to 0.5 feet (0.2 meters) per second. The protective screen has a slot width of 0.25 inches (0.6 cm). This will minimize impingement and entrainment of marine organisms. Concentrations of marine organisms are greater near the water surface and decrease with depth. To minimize entrainment of marine organisms such as ichthyoplankton (fish eggs and larvae), the top of the intake screens will be located deeper than 65 feet (19.8 meters) below MSL. This location of seawater intake has the advantage of being well below the near-surface concentrations of marine organisms and shallow enough for routine diver maintenance access. An automated air backwash system will periodically remove impinged debris from the screen surface. The backwash system will be automated based on a timed sequence or measurement of pressure drop through the screens.

Waters used in the vaporization of the LNG will be discharged through three outfall pipes at least 120 feet (37 meters) below MSL. Each outfall pipe will have two 45-degree deflectors at the terminus in order to promote mixing with the surrounding waters. Sodium hypochlorite will be injected continuously into the suction of the operating seawater lift pumps for bio-fouling control at a rate to attain a residual chlorine level of 0.5 to 1.0 ppm. The system will be designed to inject up to 2.0 ppm continuously and up to 5.0 ppm on a "shock" basis into each of the operating pumps and operating ORV inlet branch headers for 20 minutes every 24 hours; these latter shock injections will be staggered so that no more than one point is shock-dosed at any one time. Operations will monitor the residual chlorine levels and adjust the dosing rate as needed.

At peak capacity, the seawater lift pumps will circulate approximately 200 MGD of water through the ORVs. ORV maintenance will consist of occasional cleaning, the frequency of which will depend on the cleanliness of the seawater. Daily observation will ensure that ice does not build up on the panels.

[31]Deepwater Port License Application for the Main Pass Energy Project, http://dmses.dot.gov/docimages/pdf89/284544_web.pdf, February 2004.

Crystal Energy - Clearwater Port

Crystal Energy LLC signed a long-term lease agreement to retrofit an existing offshore oil and gas facility (Platform Grace), located 11 miles offshore of Ventura County in Federal waters, as an LNG import terminal. The water depth at Platform Grace is 318 feet.[32] The proposed project is estimated to deliver more than 200 billion cubic feet of natural gas from Alaska annually to California.[33] Crystal Energy LLC estimates that approximately two to four ships per month will offload at this LNG import terminal. Each ship will carry approximately 2.75 billion cubic feet of LNG, which will take approximately four days to offload. The peak LNG transmission capacity for the project is projected to be 1.275 Bcfd with an average LNG transmission capacity of 0.8 Bcfd. This LNG import terminal will not store any of the offloaded LNG at the receiving facility (Platform Grace). The approximate costs of this project is $160 million with a projected completion date of 2006.

Use of this platform as a liquefied natural gas receiving and processing facility will require the installation of a cool down tank, four liquefied natural gas pumps, four liquefied natural gas vaporizers, and reinstalling and upgrading the platform's power production capability.[34] Crystal Energy LLC recently filed its deepwater port application with the U.S. Coast Guard, however, the docket for this application has not been established. Initial indications are that this facility will use SCVs to re-gasify the LNG and not use an open loop vaporization process with surface water intakes. This project also identifies that it would supply local jurisdictions with "up to 40 million gallons of clean water annually that are a byproduct of the re-gasification process."[35]

Construction costs for the Crystal Clearwater Port project, which is anticipated to begin operation in 2007, are estimated at $300 million. The estimated life of the facility is approximately 50 to 100 years. This is based upon the original structural design of the platform for offshore oil and gas drilling and production operations.

ExxonMobil (Pearl Crossing)

The application plan calls for the proposed deepwater port to be located in the Gulf of Mexico, approximately 41 miles south of the Louisiana coast in West Cameron Block 220. It will be located in a water depth of approximately 62 feet.[36]

The proposed Pearl Crossing LNG Terminal is a concrete Gravity Based Structure (GBS). The terminal proposes to install two integral liquefied natural gas storage tanks and serve as the platform for vessels to offload and regasify LNG. The proposed GBS is a double-walled concrete structure, rectilinear in shape, that would measure approximately 590 feet long by 295 feet wide. The structure would rest on the seabed with a total terminal footprint (GBS plus jacket structures) area of approximately 12 acres. T he terminal would include LNG storage tanks, equipment for receiving and vaporization of LNG, electric power generation, water purification, nitrogen generation, sewage treatment and accommodations for up to 60 persons. The total net working capacity of the two integral LNG storage tanks would be 250,000 m^3.

Pearl Crossing would have the ability to accommodate two LNG carriers alongside that will have capacities ranging from 125,000 to 250,000 m^3 per vessel. This would allow one incoming LNG carrier to be secured to prepare to offload cargo, while another LNG carrier is completing an offloading cycle. Offloading rates are expected to equal 14,000 m^3 per hour of LNG. Peak send out for this project is projected to average over 2.0 Bcfd with a peak capacity of 2.8 Bcfd.

[32]Larson, Eric, 2004. Presentation by Eric Larson, California Department of Fish and Game, "Navigational Safety & Environmental Issues", http://www.energy.ca.gov/lng/documents/2004-02-24_DFG_LARSON.PDF, February 24, 2004.

[33]Crystal Energy LLC, 2004. Press Release, "Crystal Energy Secures Agreement for Domestic Energy Supply to Meet Urgent Natural Gas Demand," http://www.crystalenergyllc.com/pdf/media/AGPA.pdf, January 28, 2004.

[34]See http://www.crystalenergyllc.com/faq_operation.php

[35]Crystal Energy LLC, 2004. Press Release, "Crystal Energy Moves Forward to Bring Needed Natural Gas to California," http://www.crystalenergyllc.com/pdf/media/CrystalFilingPressRelease_FINAL.pdf, February 11, 2004.

[36]Federal Register. 69 FR 43619. July 21, 2004.

The re-gasification process would be accomplished through thirteen electric pumps that will each supply 19 MGD of seawater for the ORV. Assuming a inlet to outlet water temperature decrease of 20°F, a volume of 247 MGD of surface water is required for peak vaporization.[37] The surface water intakes will utilize passive, cylindrical wedgewire-type screens with an automated air backwash system. The slot size would be 0.25 inch or less to minimize impingement or entrainment of marine organisms. Seawater would be treated with hypochlorite produced by an electrolytic chlorination unit prior to entering the seawater pump intake lines.

ChevronTexaco - Port Penguin

This is an off-shore Gravity Based Structure (GBS) project similar to the Chevron/Texaco project proposed for Baja California, Mexico. This project is to have an LNG throughput of 0.5 Bcfd. ChevronTexaco has discussed the project publicly but has not proposed a specific site. The location of this project has yet to be determined but will most likely be in southern California.[38]

El Paso Global (Belmar, NJ Offshore)

EPA was unable to gather information on this facility.

Excelerate Energy (Northeast Gateway)

This facility is proposed to be sited offshore of Boston, MA. The average vaporization rate is projected to be 0.8 Bcfd (see Figure 3-78). EPA was unable to gather other information on this proposed facility.

Conversion Gas Imports

Conversion Gas Imports (CGI) is conducting a study using salt caverns instead of man-made storage tanks to temporarily store LNG. The CGI proposed terminal is designed to receive LNG directly from the tanker, pump the liquid stream to cavern injection pressures, warm it to salt compatible temperatures, and inject the warmed dense phase natural gas into salt caverns for storage. There are no vaporizer send-out limitations associated with cavern storage. The caverns can receive flow from a ship and redeliver to a pipeline grid at rates greater than 3 Bcfd. LNG vessels are offloaded at rates comparable to the unloading rates at conventional liquid tank based terminals.

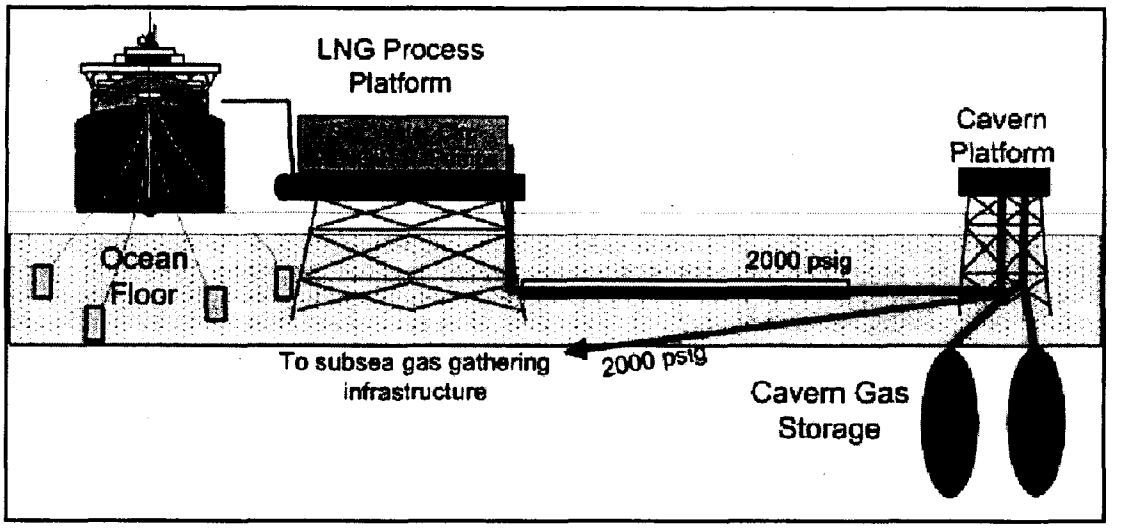
CGI chose a Gulf of Mexico location in 30 meters of water, 75 kilometers off Louisiana on Vermilion block 179, for the upcoming study because it is close to existing pipelines and on top of a salt formation starting 300 meters below the seabed.[39] As shown in Figure 3-83, CGI's proposed re-gasification system uses a simple pipe in pipe co-axial flow arrangement (LNG in inner pipe and seawater between the inner pipe and outer pipe) running a calculated distance (2,500 feet) along the ocean floor from the offshore underground salt caverns to shore. No gasified LNG is used in the warming process. It is unclear what quantity of seawater is used for this re-gasification system, system's the intake velocity of seawater, or the change in inlet to outlet seawater temperature. It is clear, however, that any seawater intakes associated with this system are associated with the re-gasification (warming system).

[37]Deepwater Port License Application for Pearl Crossing LNG Project, Environmental Report, http://dmses.dot.gov/docimages/pdf89/288088_web.pdf, May 2004.

[38]See http://www.energy.ca.gov/lng/projects.html.

[39]See http://www.conversiongas.com/html/news.html.

Figure 3-83. Conversion Gas Imports Re-Gasification Schematic



4.0 TECHNOLOGY OPTIONS AVAILABLE TO CONTROL IMPINGEMENT AND ENTRAINMENT OF AQUATIC ORGANISMS

4.1 Summary of Technology Options to Control Impingement and Entrainment of Aquatic Organisms

As highlighted in this Chapter, re-gasification process of LNG is an endothermic process and requires a heat source. The LNG would be pumped through some heating system, where it would absorb heat and vaporize, or re-gasify, into natural gas. Different impingement and entrainment control options are available for onshore verses offshore LNG import terminals. Offshore LNG import terminals may have significant space limitations which could significantly increase the costs and economic impacts and affect the technical feasibility of implementing technology options available for onshore facilities. Moreover, one technology option for onshore facilities, closed loop re-cycle with waste heat from another industrial facility, is not available for offshore facilities due to their remoteness.

a. Onshore LNG Import Terminals

The entrainment or impingement control technologies available for onshore LNG import terminals are similar to other industries. However, onshore LNG import terminals are better able to design their operations in order to not require surface water withdrawals. All existing onshore LNG import terminals use LNG vaporization systems with no surface water intakes and current information indicates that all new onshore LNG import terminals are proposing to use LNG vaporization systems with no surface water intakes.

Existing Onshore LNG Import Terminals

As previous mentioned, EPA identified that none of the four existing continental U.S. LNG import terminals use surface water for warming or cooling purposes, only as an emergency backup source to their firewater systems. For example, at the Dominion Cove Point, Maryland, facility all water used on site is withdrawn from groundwater wells and is heated in the vaporizers and used to warm the LNG and convert back to a gaseous state.

The remaining existing U.S. onshore LNG import terminal, the EcoElectrica facility in Puerto Rico, does use surface water for makeup and discharges blowdown for the power plant cooling tower, but does not use surface water intakes directly for the LNG processing (warming or cooling). The EcoElectrica LNG import terminal is a closed-loop facility that is integrated with a 500 megawatt electric power generator. This integration has benefitted the LNG import capabilities and boosted the electric power generator output by 10% (Hall, 2004).

The fact that all five existing onshore LNG import terminals use LNG vaporization systems with no surface water intakes demonstrates that this zero-water intake technology is available for this industrial sector.

New Onshore LNG Import Terminals

As detailed in Exhibit 3-78, current information shows that all new onshore LNG import terminals are proposing to use LNG vaporization systems with no surface water intakes (e.g., integration with other industrial facilities, heating towers, gas-fired heaters). Operating LNG import terminals in a closed-loop manner (i.e., no surface water withdrawals) is also consistent with recent recommendations by the Export-Import Bank of the United States and the Gulf of Mexico Fishery Management Council to reduce effluent discharges and minimize impingement and entrainment of aquatic organisms and the associated damages to recreational and commercial fisheries and essential fish habitat.[40,41] Some new facilities are also proposing to use waste heat from nearby industrial facilities for their re-gasification (e.g., Ingleside Energy Center LNG Import Terminal, Corpus Christi, TX).

The integration of an LNG import terminal with a nearby or on-site industrial operation is a 'win-win' solution as it provides a resource (cold water from LNG import terminal) to a nearby or on-site industrial facility. This integration can lead to the following benefits for the nearby or on-site industrial facility: (1) increase operational efficiency, reduce operating costs, and (2) reduce or eliminate thermal and chemical pollution and potential entrainment or impingement impacts from heat exchanger surface water intakes. One estimate suggests that an electric power generator using cold water from an LNG import terminal can boost its efficiency by 1 to 2%, resulting in cost savings (Hall, 2004). Finally, this integration reduces or eliminates the potential entrainment or impingement impacts associated with the LNG re-gasification process as well as the thermal and chemical pollution associated with the water intake LNG re-gasification processes.

b. Offshore Technology Options

As detailed in this chapter, the various re-gasification technologies proposed for offshore LNG import terminals include: (1) open rack vaporizers (ORV); (2) submerged combustion vaporizers (SCV); (3) shell and tube vaporizors (STV); (4) closed-loop heat exchangers; and (5) intermediate fluid vaporizers (IFV). Additionally, the CGI re-gasification process detailed above may find use in future LNG import terminals.

Open Rack Vaporizer (ORV) Technology

It appears likely that six proposed U.S. offshore LNG import terminals will use Open Rack Vaporizer (ORV) technology for re-gasification of LNG (i.e., Port Pelican, Gulf Landing, Compass Port, Main Pass Energy Hub, Pearl Crossing, Port Penguin). As describe above and in Figure 3-81, this re-gasification technology uses large quantities of seawater (e.g., 50 to 200 MGD) flowing over a series of panel coils to warm the LNG that is flowing countercurrent within the panels. Sea water flows through intake screens and is then pumped to ORVs through strainers. Sodium hypochlorite is often injected into intake pumps as an anti-biofouling agent.

Pumps bring treated seawater to the top of ORVs, where it is released and creates a falling film of water which exchanges heat with the upward-flowing high pressure LNG. This process will vaporize the LNG into natural gas, and seawater will be cooled by approximately 10 to 20°F. There is the potential for localized cooling at the ORV topside and generation of fog or mist. Cooled seawater is collected and discharged after it passes once through the system. The return seawater may contain 1 to 2 mg/L of hypochlorite.

ORVs do not require combustion and are considered safe, as no moving parts are in contact with flammable fluids. ORVs do not directly contribute to air emissions, but generate air emissions indirectly because of the electrical pump drives and electrical power generation requirements.

All LNG import terminals propose to use ORV technology are designing the intakes with a through-screen velocity of 0.5 feet per second or less in order to reduce impingement. Moreover, most of these LNG import terminals are proposing to use intake screens with wedgewire technology to reduce the potential for impingement. Some are proposing to use cylindrical wedgewire screen with 0.25- inch slot size openings to reduce impingement and entrainment of aquatic organisms. Finally, some of these import terminals using ORVs are proposing other control measures to reduce the impingement and entrainment of aquatic organisms:

- Locating the intakes as close as practical to the sea bottom to reduce the potential for entrainment of smaller aquatic organisms which are more likely to be near the surface;

[40]Export-Import Bank of the United States, 2004. Environmental Guidelines - Table 10 Liquefied Natural Gas (LNG) Liquefaction Plants And Regasification Facilities, http://www.exim.gov/products/policies/environment/envtbl10.html, Revised : July 2, 2004.

[41]Walker, Bobbi, 2004. Letter from Bobbi Walker, Gulf of Mexico Fishery Management Council, to Rolland Schmitten, NOAA National Marine Fisheries Service, June 9, 2004.

- Designing intakes for horizontal flow to minimize the potential for water coning from the surface; and
- Minimizing warming water throughput requirements for the installation by using the maximum practical inlet to outlet seawater temperature change of 18°F;
- Automated air backwash system; and
- Committing to monitor impingement and entrapment of marine life during the first two years of operation to establish the impact of the facility on marine life, and a commitment to implement reasonable and practical improvement measures if warranted scientifically through the monitoring program.

It should be noted that monitoring may be necessary for proper siting of water intake structures to avoid or minimize entrainment impacts.

Submerged Combustion Vaporizer (SCV) Technology

It appears likely that two proposed U.S. offshore LNG import terminals will use Submerged Combustion Vaporizer (SCV) technology for re-gasification of LNG (i.e., Cabrillo Port, Crystal Energy). As describe above, this re-gasification technology uses submerged combustion vaporizers using LNG as the fuel. The SCVs will superheat the resultant natural gas to a temperature of about 41 °F. The combustion vaporization process is thermally stabilized by submersion in a water bath. No compression of the natural gas is required. SCV burns natural gas equivalent to 1.5 to 2% of the LNG throughput to generate heat. This is similar to the 1.5% energy penalty identified in the 316(b) Phase I new facility rule for cooling towers at electric power generators. Moreover, this 1.5% consumption of LNG can be less than the LNG lost in transit on dedicated LNG tankers. The tanker's LNG cargo is kept cool by evaporating a fraction of the cargo ("boiloff") and burning it as boiler fuel. Typically, 0.15 to 0.25 percent of the cargo is consumed per day, during which the tanker will travel about 480 nautical miles.[42]

The combustion process relies on natural gas from LNG, so it is a cleaner fuel. With SCV the exhaust gases also flow directly through a water bath, which acts as a quench and abatement system. The SCV air emissions will include oxides of nitrogen (NOx), and carbon dioxide. The chief environmental benefit of this re-gasification technology is that it eliminates the issues associated with water intakes (i.e., impingement and entrainment of aquatic organisms) and discharges (i.e., thermal and chemical pollution).

Shell and Tube Vaporizors

It appears likely that one proposed U.S. offshore LNG import terminals will use shell and tube vaporizor (STV) technology for re-gasification of LNG (i.e., GOM Energy Bridge). This re-gasification technology uses seawater from seachests to provide the necessary heat. The warming seawater will pass through the shell and tube vaporizer and indirectly heat the LNG. As describe above, this re-gasification technology uses large quantities of seawater (e.g., approximately 80 MGD). The GOM Energy Bridge will draw seawater from the surrounding area at approximately 23.0 feet below the water surface. Intake structures on the LNG vessels are sized to provide seawater for both standard ship operations (including water intakes for cooling purposes) and the warming water for the LNG vaporizers. As previously mentioned, this offshore LNG import terminal is subject to the NPDES Permit Program; withdraws more than 2 MGD in the open loop mode; and uses more than 25 percent of the seawater intake for cooling purposes in the open loop mode.

Using a single sea chest inlet, the combined cooling water and warming water intake velocities would be approximately 3.9 feet per second. Excelerate is proposing to connect two of the LNG vessels four sea chests internally to increase the intake area and reduce average intake velocity. Using this scenario, the intake velocity at the two sea chests would be approximately 1.0 feet per second. The sea chest intakes incorporate metal slotted grating on 21 millimeters spacings to reduce the impingement of aquatic organisms. This mesh size would not prevent the entrainment of eggs and larvae of marine fish species. It appears that future designs could reduce this intake velocity to 0.5 feet per second to better control impingement. Other impingement and entrainment controls might include:

- Using intake screens with wedgewire technology to reduce the potential for impingement
- Locating the intakes as close as practical to the sea bottom to reduce the potential for entrainment of smaller aquatic organisms which are more likely to be near the surface;
- Designing intakes for horizontal flow to minimize the potential for water coning from the surface; and
- Minimizing warming water throughput requirements for the installation by using the maximum practical inlet to outlet seawater temperature change.

[42]U.S. DOE/EIA, 2001. U.S. Natural Gas Markets: Mid-Term Prospects for Natural Gas Supply, SR/OIAF/2001-06, http://www.eia.doe.gov/oiaf/servicerpt/natgas/pdf/sroiaf(2001)06.pdf, December 2001.

Closed-loop Heat Exchangers

It appears likely that one proposed U.S. offshore LNG import terminals has the potential to the use closed-loop heat exchangers for re-gasification of LNG (i.e., GOM Energy Bridge). In the closed loop mode, steam from the LNG vessel propulsion boilers will heat water circulated in a closed loop through the shell and tube vaporizer and a steam heater. After the cycle, the water will be re-circulated through the system. There is no seawater intake or discharge for the re-gasification process in the closed loop mode. The closed loop mode allows for LNG re-gasification when surrounding seawater temperatures are too cold for the more efficient open loop mode. The chief environmental benefit of this re-gasification technology is that it eliminates the issues associated with water intakes (i.e., impingement and entrainment of aquatic organisms) and discharges (i.e., thermal and chemical pollution). The main disadvantage of this re-gasification system verses the shell and tube vaporizors (open loop) re-gasification system is that decreased rate of LNG vaporization.

Intermediate Fluid Vaporizer (IFV) Technology

It appears likely that no proposed U.S. offshore LNG import terminals will use Intermediate Fluid Vaporizer (IFV) technology for re-gasification of LNG. This re-gasification technology uses glycol/water mix to exchange heat with the LNG via a shell and tube exchanger. The cold glycol mix is circulated continuously in a closed loop. A plate and frame or other type heat exchanger heats the glycol mix using seawater as the heating medium. The equipment necessary for this system includes common heat exchangers and pumps. Pumps are required for the seawater and for the circulated glycol mix. The quantity of circulated seawater is identical to that required for the ORV, given environmental limits between the inlet and return water temperature. The LNG is vaporized from the heat gained by the glycol and the glycol acquires heat from the seawater. The design must maintain LNG and glycol carefully to avoid freezing on the glycol side of the vaporizer. In general, LNG import terminals using IFVs can use the same control measures as LNG import terminals using ORVs to reduce the impingement and entrainment of aquatic organisms.

4.2 Incremental Costs Associated with Technology Options to Control Impingement and Entrainment of Aquatic Organisms

EPA estimated "sensitivity level" incremental technology option costs for new offshore LNG import terminals to control the impingement and entrainment of aquatic organisms. EPA compared these incremental costs to the total estimated cost for construction of a new offshore LNG import terminal to determine whether potential impingement and entrainment § 316(b) Phase III technology options would impact the decision to begin construction of the new facility. EPA used information from USCG deepwater port licensing applications (e.g., information on the type, size and number of the water intake structures) to estimate these "sensitivity level" incremental costs for installation of impingement and entrainment equipment for some of the offshore LNG import terminals identified in Exhibit 3-79.

EPA was unable to estimate "sensitivity level" incremental costs for all facilities in Exhibit 3-79 due to the lack of specific data on water intake structure (e.g., intake pipe or caisson dimensions). However, these "sensitivity level" incremental costs are representative for all facilities in Exhibit 3-79 as the facilities EPA used to develop "sensitivity level" incremental costs represent all major types of vaporization designs (e.g., ORV, STV) and fixed and mobile, deepwater and shallow water LNG import terminals.

4.2.1 Offshore LNG Import Terminal Water Intake Pipe Design

EPA had sufficient water intake structures data for the following five proposed offshore LNG import terminals: Compass Port, GMO Energy Bridge, Gulf Landing, Port Pelican, and Main Pass. To estimate a "sensitivity level" incremental cost for installation of impingement and entrainment equipment, EPA determined design information on the type, size and number of the surface water

intakes. EPA used design information for the five LNG import terminals from USCG dockets.[43,44,45,46,47] Exhibit 3-81 shows the design flow rate for each facility, the type of surface water intake that will be used, and the number of intake structures.

Exhibit 3-81. Number and Type of Surface Water Intake Structures at Five Proposed Offshore LNG Import Terminals

LNG Project Name	Location	Total Design Intake Flow* (MGD)	Intake Structure Type	Number of Intake Structures
Conoco Phillips (Compass Port)	Mobile Block 910 88°12' West, 30°5' North	182	Caisson with Submersible Pumps	6
Excelerate (GMO Energy Bridge)	LA, 116 miles South of Cameron	133	Sea Chest	4
Shell (Gulf Landing)	LA (West Cameron Block 213) south of Lake Charles	136	Simple Pipes	16
Chevron Texaco (Port Pelican)	LA, 36 miles S-SW of Freshwater City	176	Simple Pipes	5
Freeport McMoran (Main Pass Energy Hub)	LA; 17 miles east of Pass a Loutre	200	Sea Water Lift Pumps with Screened Intakes	6

* Note: Total design intake flow for the entire LNG terminal

4.2.2 LNG Impingement and Entrainment Equipment Technology Options

EPA evaluated several impingement and entrainment control technology options for the different types of surface water intake structures. EPA estimated incremental technology costs of velocity caps and screens for caissons, simple pipes, and suction lines using sea water lift pumps. Velocity caps prevent impingement of marine life against the surface water intake while cylindrical wedgewire screens prevent both impingement and entrainment of marine life into the surface water intake system. EPA evaluated flat panel wedgewire screens for the sea chests surface water intake structures in order to prevent entrainment, and horizontal flow diverters in order to prevent impingement by changing the direction of flow through the sea chest. Typically, stainless steel is used in the manufacture of these types of water intake equipment, however new copper-nickel (CuNi) alloys are demonstrated technology for improved bio-fouling control. In addition, air sparging can also be included with screening equipment to remove bio-fouling and clear water intake structures. EPA costed the following technology options for the proposed offshore LNG import facilities included in the sensitivity analysis:

- Cylindrical copper-nickel alloy wedgewire screens with air sparging on caissons and simple pipes;
- Cylindrical copper-nickel alloy wedgewire screens on sea water lift pumps; and
- Flat panel copper-nickel wedgewire screens on sea chests.

[43] U.S. Coast Guard, 2002. Port Pelican Environmental Report, Version 1.0, Port Pelican L.L.C. Deepwater Port Licence Application, Docket No. USGS-2002-14134.

[44] U.S. Coast Guard, 2003. Draft Environmental Assessment of the El Paso Energy Bridge Gulf of Mexico, L.L.C., Deepwater Port License Application, Docket No. USCG-2003-14294, September 2003.

[45] U.S. Coast Guard, 2004. Draft Environmental Impact Statement Section 2 (Detailed Description of Proposed Action and Alternatives) for The Gulf Landing LLC Deepwater Port License Application, Docket No. USCG-2004-16860-30, July 2004.

[46] U.S. Coast Guard, 2004. Compass Port Application for Deepwater Port License, Docket No. USCG-2004-17659, March, 2004.

[47] U.S. Coast Guard, 2004. Deepwater Port License Application for the Main Pass Energy Project, Docket No. USCG-2004-17696, February 2004.

EPA estimates that these costs are likely overestimates as only the GMO Energy Bridge LNG terminal will require the installation of horizontal flow diverters to lessen impingement.

4.2.3 LNG Cost Estimates for Impingement and Entrainment Options

EPA estimated installed capital costs for each technology option for the five LNG import terminals selected for this analysis. Technology option equipment costs were developed by regression analysis.[48] Exhibit 3-82 shows the cost equations for each technology option and the design variable.

Exhibit 3-82. Cost Equations and Design Variables for Entrainment and Impingement Equipment at LNG Import Terminals

Impingement and Entrainment Control Equipment	Surface Water Intake Structure Type	Cost Equation	Variable
Cylindrical copper-nickel alloy wedgewire screens with air sparging	Simple pipes and caissons	$ = 1360.3(x)+4087.2 (1st) $ = 883.67(x) - 5742.8 (additional)	Pipe Diameter (inches)
Cylindrical copper-nickel alloy wedgewire screens	Sea water pump intakes	$ = 564.71(x) - 1389	Pipe Diameter (inches)
Flat panel copper-nickel wedgewire screens	Sea Chests	$ = 6.7734(x) - 0.273	Flow (gpm)
Horizontal Flow Diverter	Sea Chests	$ = 3.4995(x) + 0.001	Flow (gpm)

Exhibit 3-83 shows design information and the estimated cost to install impingement and entrainment control equipment at each LNG import terminal. Exhibit 3-83 shows that the capital costs associated with the installation of impingement and entrainment control equipment for most new LNG import terminals can reasonably be expected to be between $0.2 million and $0.9 million.

[48]Hatch Associates, 2004. Draft Offshore and Coastal Oil and Gas Extraction Facilities Seawater Intake Structure Modification Cost Estimate: Caisson and Simple Pipe. March 12, 2004.

Exhibit 3-83. Estimated Total Costs for Impingement and Entrainment Equipment at Five Proposed LNG Import Terminals

Proposed LNG	Flow (MGD)	No. of Intakes	Intake Type	Design Variable*	Equipment Costed	Estimated Installed Capital Cost
Conoco Phillips (Compass Port)	182	6	Caisson	Intake diameter: 47"	Cylindrical copper-nickel alloy wedgewire screens with air sparging	$247,000
Excelerate (GMO Energy Bridge)	133	4	Sea Chest	Flow Rate: 23,000 gpm	Flat panel copper-nickel wedgewire screens and horizontal flow diverters.	$945,000
Shell (Gulf Landing)	136	16	Simple Pipes	Intake diameter: 60"	Cylindrical copper-nickel alloy wedgewire screens with air sparging	$795,000
Chevron Texaco (Port Pelican)	176	5	Simple Pipes	Intake diameter: 90"	Cylindrical copper-nickel alloy wedgewire screens with air sparging	$422,000
Freeport McMoran (Main Pass Energy Hub)	200	6	Sea Water Lift Pumps with Screened Inlets	Intake diameter: 52"	Cylindrical copper-nickel alloy wedgewire screens	$168,000

*Note: USCG docket information for Main Pass Energy Hub did not contain the sea water lift pump intake diameter so diameter was estimated from Compass Port data

Overall, the costs for installation of impingement and entrainment control equipment at LNG import terminal surface water intakes is very small relative to the total costs to construct a LNG import terminal. For example, the total construction costs for the Gulf Landing, Main Pass, and Port Pelican LNG import terminals are estimated at $700 million, $500 million, and $500 million, respectively (i.e., impingement and entrainment control equipment costs between $0.2 and $0.9 represent less than 0.1 percent of the overall new facility construction costs).

4.2.4 Options for Closed Loop Water Systems at LNG Import Terminals

EPA examined an additional option for reducing impingement and entrainment of marine life at LNG import terminals. Specifically, EPA examined the potential technology option of converting the vaporization systems from Open Rack Vaporizers (ORV) to Submerged Combustion Vaporizers (SCV). In general, the ORV system uses ambient seawater as its sole source of heat in an open, falling film type arrangement to vaporize LNG passing through tubes. SCV vaporize LNG contained inside stainless steel tubes in a submerged water bath with a combustion burner and require no sea water intake. The ORV system has a lower operating cost then the SVC, but normally a higher capital cost because of the larger equipment size, the added seawater intake/outfall system, the pumping system, the large diameter seawater pipes, and the seawater treating system. The SCV requires fuel for the LNG vaporization, and the fuel consumption amount is about 1.5% to 2% of the send-out gas. Thus, it has a higher operating cost than the ORV.[49]

A recent options study prepared for ConocoPhillips Compass Port LNG receiving terminal examined both the capital and operating costs for an ORV and SCV process. The study indicated the capital cost for the ORV and SCV processes at this 7.5 million tonne per year (MMTPA) gas send out LNG receiving terminal would be approximately $45.3 million dollars and $34.3 million dollars, respectively (Foster Wheeler USA, 2003). Operating costs for the ORV and SCV processes at the Compass Port LNG receiving terminal were estimated to be $2.3 millon/year and $17.1 million/year, respectively. These SCV costs were developed using the following price of natural gas: $1.9/MMBtu.

EPA used a ratio of the gas send-out capacities to relate the SCV costs derived for the Compass Port LNG receiving terminal to the Gulf Landing, Port Pelican, and Main Pass Energy Hub LNG receiving terminals. The Compass Port LNG terminal is expected to have a 7.5 MMTPA gas send-out rate when completed. Predicted peak natural gas send-out rates for Gulf Landing, Port Pelican, and Main Pass are 9, 15, and 22.5 MMTPA, respectively. Exhibit 3-84 presents estimated "screening level" capital and operating costs for using SCV systems at these facilities.

[49] Foster Wheeler USA Corp, 2003. LNG Vaporizer Options Study for ConocoPhillips Compass Port GBS LNG Receiving Terminal, First Draft. October 25, 2003.

Exhibit 3-84. Screening Level Estimates for LNG Import Terminals to Construct and Operate SCV Systems

	Compass Port (SCV)	Gulf Landing	Port Pelican	Main Pass Energy Hub
Gas Send-out Rate (MMTPA)	7.5	9	15	22.5
Ratio to Compass Port	1	1.2	2	3
Capital Costs (Million $)	34.3	41.2	68.6	102.9
Annual Operating Costs (Million $)	17.1	20.5	34.2	51.3

Overall the SCV system has lower capital costs than ORV systems and quick start-up but has higher operating costs (especially at gas prices higher than $1.9/MMBtu). However, EPA considers this technology option as potentially viable as two of the proposed offshore LNG import terminals are projecting to use SCV systems (i.e., Cabrillo Port, Crystal Energy). As previously mentioned, the chief environmental benefit of this re-gasification technology is that it eliminates the issues associated with water intakes (i.e., impingement and entrainment of aquatic organisms) and discharges (i.e., thermal and chemical pollution). Additionally, offshore LNG import terminals could use a combination of SCV and ORV systems to reduce surface water intakes and impingement and entrainment impacts. The combination of SCV and ORV systems also provides a benefit of redundant vaporization systems in case of equipment failure.

5.0 RATIONALE FOR ESTABLISHING IMPINGEMENT AND ENTRAINMENT CONTROLS USING BEST PROFESSIONAL JUDGMENT

As previously mentioned, all five existing onshore LNG import terminals do not use surface water intakes for warming or cooling purposes. The fact that all five existing onshore LNG import terminals use LNG vaporization systems with no surface water intakes demonstrates that this zero-water intake technology is available for this industrial sector. As all existing LNG import terminals are using zero-water intake technology, EPA decided not to set national technology-based standards for controlling impingement and entrainment for this industrial sector.

As previously mentioned, EPA excluded new onshore LNG import terminals from the § 316(b) Phase III rulemaking as these facilities are already regulated by the § 316(b) Phase I rulemaking (EPA, 2004 - clarification memo). If a new LNG import terminal uses less than 25 percent or none of its water for cooling purposes or does not meet the 2 MGD intake flow threshold, the new facility rule specifies that the new facility must meet § 316(b) requirements as specified by the NPDES permit authority on a case-by-case basis, using best professional judgment (see 40 CFR 125.80(c)). Moreover, current information indicates that all new onshore LNG import terminals are proposing to use LNG vaporization systems with no surface water intakes (e.g., integration with other industrial facilities, ambient air vaporization through heating towers, gas-fired heaters).

All new offshore LNG import terminals projected to use surface water for their vaporization systems are also designed to use more than 2 MGD of surface water. However, EPA could only identify one new offshore LNG import terminal (i.e., GOM Energy Bridge) that is projected to use 25 percent or more of its surface water intake for cooling purposes. This means that there is only one facility potentially within scope of the Phase III rule. As there is only one facility potentially within scope of the Phase III rule, EPA decided not to set national technology-based standards for controlling impingement and entrainment for this industrial sector. EPA will use best professional judgment (see 40 CFR 125.80(c)) to establish technology-based controls for this facility. Additionally, the other new offshore LNG import terminals must also meet § 316(b) requirements as specified by the NPDES permit authority on a case-by-case basis, using best professional judgment (see 40 CFR 125.80(c)).

V. FIXED AND VARIABLE O&M COSTS

1.0 DETERMINING FIXED VERSUS VARIABLE O&M COSTS

When developing the annual O&M cost estimates, the underlying assumption was that facilities were operating nearly continuously with the only downtime being periodic routine maintenance. This routine maintenance was assumed to be approximately four weeks per year. The economic model however, considers variations in capacity utilization. Lower capacity utilization factors result in additional generating unit shutdown that may result in reduced O&M costs. However, it is not valid to assume that intake technology O&M costs drop to zero during these additional shutdown periods. Even when the generating unit is shut down, there are some O&M costs incurred. To account for this, total annual O&M costs were divided into fixed and variable components. Fixed O&M costs include items that occur even when the unit is periodically shut down, and thus are assumed to occur year round. Variable O&M costs apply to items that are allocable based on estimated intake operating time. The general assumption behind the fixed and variable determination is that shutdown periods are relatively short (on the order of several hours to several weeks).

1.1 Overall Approach

The annual O&M cost estimates used in the cost models is the net O&M cost, which is the difference between the estimated baseline and compliance O&M costs. Therefore, the fixed/variable proportions for each facility may vary depending on the mix of baseline and compliance technologies. In order to account for this complexity, EPA calculated the fixed O&M costs separately for both the baseline technology and each compliance technology and then calculated the total net fixed and variable components for each facility/intake.

In order to simplify the methodology (i.e., avoid developing a whole new set of O&M cost equations), a single fixed O&M component cost factor was estimated for each technology application represented by a single O&M cost equation. To calculate fixed O&M factors, EPA first calculated fixed O&M cost factors for the range of data input values, using the assumptions described below, to develop the cost equation. For baseline technologies, EPA selected the lowest value in the range of fixed component factors for each technology application. The lowest value was chosen for baseline technologies to yield a high-side net compliance costs for intermittently operating facilities. Similarly, for compliance technologies, EPA selected the highest value in the range of fixed component factors for each technology application, again, to provide a high-side estimate.

For each O&M cost equation, a single value (expressed either as a percentage or decimal value) representing the fixed component of O&M costs, is applied to each baseline and compliance technology O&M cost estimate for each facility. The variable O&M component is the difference between total O&M costs and the fixed O&M cost component. The fixed and variable cost components were then separately combined to derive the overall net fixed and overall net variable O&M costs for each facility/intake.

1.2 Estimating the Fixed/variable O&M Cost Mix

Depending on the technology, the O&M cost estimates may generally include components for labor, power, and materials. The cost breakdown assumes facility downtime will be relatively short (hours to weeks). Thus, EPA assumes any periodic maintenance tasks (e.g., changing screens, changing nets, or inspection/cleaning by divers) are performed regardless of plant operation, and therefore are considered fixed costs. Fixed costs associated with episodic cost components are allocated according to whether they would still occur even if the downtime coincided with the activity. For example, annual labor estimates for passive screens includes increased labor for several weeks during high debris episodes. This increased labor is considered a 100% variable component because it would not be performed if the system were not operating during this period. A discussion of the assumptions and rationale for each general component is described below.

Power Requirements

In most cases, power costs are largely a variable cost. If there is a fixed power cost component, it will generally consists of low frequency, intermittent operations necessary to maintain equipment in working condition. For example, a 1% fixed factor for this component would equal roughly 1.0 hours of operation every four days for systems that normally operated continuously. Such a duration and frequency is considered as reasonable for most applications. For systems already operating intermittently, a factor that results in the equivalent of one hour of operation or one backwash every four days was used.

Labor Requirements

Labor costs generally have one or more of the following components:

- Routine monitoring and maintenance
- Episodes requiring higher monitoring and maintenance (high debris episodes)
- Equipment deployment and removal
- Periodic inspection/cleaning by divers.

Routine Monitoring and Maintenance

This component includes monitoring/adjustment of the equipment operation, maintaining equipment (repairs & preventive O&M), and cleaning. Of these the monitoring/adjustment and cleaning components will drop significantly when the intakes are not operating. A range of 30% to 50% will be considered for the fixed component.

Episodes requiring higher monitoring and maintenance

This component is generally associated with equipment that is operating and will be assumed to be 100% variable.

Equipment deployment and removal

This activity is generally seasonal in nature and assumed performed regardless of operation (i.e., 100% fixed).

Periodic Inspection/Cleaning by Divers

This periodic maintenance task is assumed to be performed regardless of plant operation, and therefore is considered as 100% fixed costs.

Equipment Replacement

The component includes two factors: parts replacement due to wear and tear (and varies with operation) and parts replacement due to corrosion (and occurs regardless of operation). A range of 50% to 70% of these costs will be considered the fixed component.

Technology-Specific Input Factors

Traveling Screens
To determine the range of calculated total O&M fixed factors, fixed O&M cost factors (Exhibit 3-85) were applied to individual O&M cost components for the various screen width values that were used to generate the O&M cost curves. As described earlier, the lowest value of this range was selected for the baseline O&M fixed cost factor and the highest of this range was selected as the compliance O&M fixed cost factor.

Exhibit 3-85. O&M Cost Component Fixed Factor

	Routine Labor	Parts Replacement	Equipment Power	Equipment Deployment
All Traveling Screens Without Fish Handling	0.5	0.7	0.05	1.0
All Traveling Screens With Fish Handling	0.3	0.5	0.01	1.0

Passive Screens

The fixed O&M component was based on the following:

- Seasonal high debris period monitoring labor set equal to 0 hours
- Routine labor set at 50% of full time operation

- Back washes are performed once every four days
- Dive team costs for new screens at existing offshore for high debris were set at 50% of full time operation
- Dive team costs for new screens at existing offshore were set equal to 0 assuming no net additional diver costs over what was necessary for existing submerged intake without screens.
- The same assumptions are applied to both fine mesh and very fine mesh screens.

Velocity Caps

Because the O&M cost for velocity caps was based on annual inspection and cleaning by divers, the entire velocity cap O&M cost is assumed to be fixed (100%).

Fish Barrier Nets

Fish barrier net O&M costs are based on deployment and removal of the nets plus periodic replacement of net materials. As described above, EPA assumes seasonal deployment and removal is a 100% fixed O&M cost. EPA has assumed that the need for net maintenance and replacement is a due to its presence in the waterbody and should not vary with the intake operation. Therefore, entire fish barrier net O&M cost is assumed to be fixed (100%).

Aquatic Filter barriers

The O&M costs for aquatic filter barriers (AFB) includes both periodic maintenance and repair of the filter fabric and equipment plus energy used in the operation of the airburst system. As with barrier nets the need for net repairs and replacement should not vary with the intake operation. There may be a reduction in the deposition of sediment during the periods when the intake is not operating and as a result there may be a reduction in the required frequency of airburst operation. However, the presence of tidal and other waterbody currents may continue to deposit sediment on the filter fabric requiring periodic operation. Thus, the degree of reduction in the airburst frequency will be dependent on site conditions. Additionally, the O&M costs provided by the vendor did not break out the O&M costs by component. Therefore, EPA concluded that an assumption that AFB O&M costs is 100% fixed is reasonable and represents a conservative estimate in that it will slightly overestimate O&M costs during periods when the intake is not operating.

Recirculating Wet Cooling Towers

Because the cooling tower O&M costs were derived using cost factors that estimate total O&M costs that are based on capital costs, a detailed analysis is not possible. However, using the pumping and fan energy requirements described in the Proposed Rule Development Document, EPA was able to estimate that the O&M energy component was under 50% of the total O&M cost. This energy requirement reduction, coupled with reductions in labor and parts replacement requirements, should result in a fixed cost factor of approximately 50%.

1.3 O&M Fixed Cost Factors

Exhibits 3-86 and 3-87 present the fixed O&M cost factors for baseline technologies and compliance technologies, respectively, derived using the above assumptions.

Exhibit 3-86. Baseline Technology Fixed O&M Cost Factors

Technology Description	Application	Water Type	Fixed Factor
Traveling Screen With Fish Handling	10 Ft Screen Wells	Freshwater	0.28
Traveling Screen With Fish Handling	25 Ft Screen Wells	Freshwater	0.30
Traveling Screen With Fish Handling	50 Ft Screen Wells	Freshwater	0.32
Traveling Screen With Fish Handling	75 Ft Screen Wells	Freshwater	0.33
Traveling Screen With Fish Handling	10 Ft Screen Wells	Saltwater	0.31
Traveling Screen With Fish Handling	25 Ft Screen Wells	Saltwater	0.34
Traveling Screen With Fish Handling	50 Ft Screen Wells	Saltwater	0.36
Traveling Screen With Fish Handling	75 Ft Screen Wells	Saltwater	0.38
Traveling Screen Without Fish Handling	10 Ft Screen Wells	Freshwater	0.45
Traveling Screen Without Fish Handling	25 Ft Screen Wells	Freshwater	0.47
Traveling Screen Without Fish Handling	50 Ft Screen Wells	Freshwater	0.48
Traveling Screen Without Fish Handling	75 Ft Screen Wells	Freshwater	0.49
Traveling Screen Without Fish Handling	10 Ft Screen Wells	Saltwater	0.49
Traveling Screen Without Fish Handling	25 Ft Screen Wells	Saltwater	0.51
Traveling Screen Without Fish Handling	50 Ft Screen Wells	Saltwater	0.53
Traveling Screen Without Fish Handling	75 Ft Screen Wells	Saltwater	0.53

Exhibit 3-87. Compliance Technology Fixed O&M Cost Factors

Technology Description	Application	Water Type	Fixed Factor
Aquatic Filter Barrier	All	All	1.0
Add Fish Barrier Net Using Anchors and Bouys	All	Freshwater	1.0
Add Fish Barrier Net Using Pilings for Support	10 Ft Net Depth	Saltwater	1.0
Add Fish Barrier Net Using Pilings for Support	20 Ft Net Depth	Saltwater	1.0
Add Fine Mesh Passive T-screens to Existing Offshore Intake	High Debris	All	0.21
Add Fine Mesh Passive T-screens to Existing Offshore Intake	Low Debris	All	0.27
Add Very Fine Mesh Passive T-screens to Existing Offshore Intake	High Debris	All	0.19
Add Very Fine Mesh Passive T-screens to Existing Offshore Intake	Low Debris	All	0.27
Relocate Intake Offshore with Fine Mesh Passive T-screens	High Debris	All	0.46
Relocate Intake Offshore with Fine Mesh Passive T-screens	Low Debris	All	0.56
Relocate Intake Offshore with Very Fine Mesh Passive T-screens	High Debris	All	0.38
Relocate Intake Offshore with Very Fine Mesh Passive T-screens	Low Debris	All	0.49
Traveling Screen With Fish Handling and Fine Mesh	10 Ft Screen Wells	Freshwater	0.38
Traveling Screen With Fish Handling and Fine Mesh	25 Ft Screen Wells	Freshwater	0.35
Traveling Screen With Fish Handling and Fine Mesh	50 Ft Screen Wells	Freshwater	0.37
Traveling Screen With Fish Handling and Fine Mesh	75 Ft Screen Wells	Freshwater	0.39
Traveling Screen With Fish Handling and Fine Mesh	10 Ft Screen Wells	Saltwater	0.41
Traveling Screen With Fish Handling and Fine Mesh	25 Ft Screen Wells	Saltwater	0.38
Traveling Screen With Fish Handling and Fine Mesh	50 Ft Screen Wells	Saltwater	0.40
Traveling Screen With Fish Handling and Fine Mesh	75 Ft Screen Wells	Saltwater	0.41
Traveling Screen With Fish Handling	10 Ft Screen Wells	Freshwater	0.40
Traveling Screen With Fish Handling	25 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	50 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	75 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	10 Ft Screen Wells	Saltwater	0.42
Traveling Screen With Fish Handling	25 Ft Screen Wells	Saltwater	0.43
Traveling Screen With Fish Handling	50 Ft Screen Wells	Saltwater	0.44
Traveling Screen With Fish Handling	75 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	10 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	25 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	50 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	75 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	10 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	25 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	50 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	75 Ft Screen Wells	Saltwater	0.44
Velocity Cap	All	All	1.0
Cooling Towers	All	All	0.5

Chapter 4: Impingement and Entrainment Controls

INTRODUCTION

This section provides a summary of the effects of impingement and entrainment, the development of the performance standards, and the regulatory options that EPA considered for today's proposed rule.

1.0 IMPINGEMENT AND ENTRAINMENT EFFECTS

The withdrawal of cooling water removes trillions of aquatic organisms from waters of the United States each year, including plankton (small aquatic animals, including fish eggs and larvae), fish, crustaceans, shellfish, sea turtles, marine mammals, and many other forms of aquatic life. Most impacts are to early life stages of fish and shellfish.

Aquatic organisms drawn into cooling water intake structures (CWIS) are either impinged on components of the intake structure or entrained in the cooling water system itself. Impingement takes place when organisms are trapped on the outer part of an intake structure or against a screening device during periods of intake water withdrawal. Impingement is caused primarily by hydraulic forces in the intake stream. Impingement can result in (1) starvation and exhaustion; (2) asphyxiation when the fish are forced against a screen by velocity forces that prevent proper gill movement or when organisms are removed from the water for prolonged periods; and (3) descaling and abrasion by screen wash spray and other forms of physical damage.

Entrainment occurs when organisms are drawn into the intake water flow entering and passing through a cooling water intake structure and into a cooling water system. Organisms that become entrained are those organisms that are small enough to pass through the intake screens, primarily eggs and larval stages of fish and shellfish. As entrained organisms pass through a plant's cooling water system, they are subject to mechanical, thermal, and/or toxic stress. Sources of such stress include physical impacts in the pumps and condenser tubing, pressure changes caused by diversion of the cooling water into the plant or by the hydraulic effects of the condensers, sheer stress, thermal shock in the condenser and discharge tunnel, and chemical toxemia induced by antifouling agents such as chlorine.

For a more detailed discussion of impingement and entrainment and the effects on aquatic organisms, refer to the preamble to the proposed rule and The Regional Benefits Assessment for the Proposed Section 316(b) Rule for Phase III Facilities (EPA-821-R-04-017).

2.0 PERFORMANCE STANDARDS

The performance standards for today's proposed rule are similar to those required in the final Phase II regulations. Overall, the performance standards that reflect best technology available under today's proposed rule are not based on a single technology but, rather, are based on consideration of a range of technologies that EPA has determined to be commercially available for the industries affected as a whole and have acceptable non-water quality environmental impacts. Because the requirements implementing section 316(b) are applied in a variety of settings and to Phase III facilities of different types and sizes, no single technology is most effective at all existing facilities, and a range of available technologies has been used to derive the performance standards.

EPA developed the performance standards for impingement mortality reduction based on an analysis of the efficacy of the following technologies: (1) design and construction technologies such as fine and wide-mesh wedgewire screens, as well as aquatic filter barrier systems, that can reduce mortality from impingement by up to 99 percent or greater compared with conventional once-through systems; (2) barrier nets that may achieve reductions of 80 to 90 percent; and (3) modified screens and fish return systems, fish diversion systems, and fine mesh traveling screens and fish return systems that have achieved reductions in impingement mortality ranging from 60 to 90 percent as compared to conventional once-through systems.

Available performance data for entrainment reduction are not as comprehensive as impingement data. However, aquatic filter barrier systems, fine mesh wedgewire screens, and fine mesh traveling screens with fish return systems have been shown to achieve 80 to 90 percent or greater reduction in entrainment compared with conventional once-through systems. EPA notes that screening to prevent organism entrainment may cause impingement of those organisms instead.

Based on the review of performance data, EPA continues to believe that an 80-95% reduction in impingement mortality and a 60-90% reduction in entrainment are appropriate and technologically achievable. In Phase II EPA provided examples of facilities in different areas of the country sited on different waterbody types that are currently meeting or exceeding the performance standards (69 FR 41602). Some examples of potential Phase III facilities include the Sherburne County Generating Plant and the Tosco Refinery, as described in the preamble. Possible examples of offshore oil and gas extraction facilities that also meet the performance standards (using a combination of intake technologies and/or reduced through-screen intake velocity) are the drillship Transocean Deepwater Discovery, the MODU Transocean Deepwater Horizon, the MODU Transocean Cajun Express, and the platform Aera Energy Ellen. The ability of these facilities to meet the performance requirements suggests that while site-specific factors can influence the performance of a given technology, it is the exceptional situation where no design or construction technology is capable of meeting the performance standards. EPA opted for performance ranges instead of specific compliance thresholds to allow both the permittee and the permitting authority a certain degree of flexibility in meeting the obligations under the final Phase II rule. Further, EPA recognizes that precise results may not be able to replicated in different waterbody types in different areas of the country.

3.0 REGULATORY OPTIONS CONSIDERED

In today's proposed rule, EPA co-proposes three regulatory options based on design intake flow and source waterbody type that define which facilities are Phase III existing facilities subject to uniform national requirements. These co-proposed options are:

- The facility has a total design intake flow of 50 MGD or more, and is located on any source waterbody type;
- The facility has a total design intake flow of 200 MGD or more, and is located on any source waterbody type;
- The facility withdraws water from an ocean, estuary, tidal river or stream, or Great Lake and has a total design intake flow of 100 MGD or more.

The proposed rule would require Phase III existing facilities to meet performance standards similar to those required in the final Phase II rule, including a 80-95% reduction in impingement mortality and a 60-90% reduction in entrainment. The proposed rule also provides for the same five compliance alternatives specified in the final Phase II rule. If a facility is a point source that uses a cooling water intake structure and has, or is required to have, an NPDES permit, but does not meet the definition of Phase III existing facility under the corresponding regulatory option (e.g., the intake is below the specified MGD design intake flow threshold or does not meet the 25% cooling purposes threshold) it would continue to be subject to permit conditions implementing section 316(b) of the Clean Water Act set by the permit director on a case-by-case basis, using best professional judgment.

In developing the proposed Phase III rule, EPA considered several regulatory options based on varying flow regimes and waterbody type. These options are based on applying the same performance standards and compliance alternatives as those being proposed (i.e. the final Phase II performance standards and requirements including the use of case-by-case permit determinations based on best professional judgment for facilities below the applicable thresholds) but using different design intake flow applicability thresholds. In addition, EPA considered a number of options (specifically options 2, 3, 4, and 7 below) that would establish different performance standards for certain groups or subcategories of Phase III existing facilities. Under these options, EPA would apply the proposed performance standards and compliance alternatives (i.e. the Phase II requirements) to the higher threshold facilities, apply the less-stringent requirements as specified below to the middle flow threshold category, and would apply best professional judgment below the lower threshold.

Each of the options considered for this proposal is described in detail below:

Option 1: Facilities with a design intake flow of 20 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this option, section 316(b) permit conditions for Phase III facilities with a design intake flow of less than 20 MGD would be established on a case-by-case, best professional judgment, basis.

Option 2: Facilities with a design intake flow of 50 MGD or greater, as well as facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) when located on estuaries, oceans, or the Great Lakes would be subject to the performance standards and compliance alternatives proposed in today's rule. Facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) that withdraw from freshwater rivers and lakes would have to meet the performance standards for impingement mortality only and not for entrainment. Under this option, section 316(b) requiremtns for Phase III facilities with a design intake flow of less than 20 MGD would be established on a case-by-case, best professional judgment, basis.

Option 3: Facilities with a design intake flow of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule. Facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) would have to

meet the performance standards for impingement mortality only and not for entrainment. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 20 MGD would be established on a case-by-case, best professional judgment, basis.

Option 4: Facilities with a design intake flow of 50 MGD or greater, as well as facilities with a DIF between 20 and 50 MGD (20 MGD inclusive) when located on estuaries, oceans, or the Great Lakes would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Facilities that withdraw from freshwater rivers and lakes and all facilities with a design intake flow of less than 20 MGD would have requirements established on a case-by-case, best professional judgment, basis.

Option 5 (Co-proposed Option): Facilities with a design intake flow of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 50 MGD would be established on a case-by-case, best professional judgment, basis.

Option 6: Facilities with a design intake flow of greater than 2 MGD would be subject to the proposed performance standards and compliance alternatives. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of 2 MGD or less would be established on a case-by-case, best professional judgment, basis.

Option 7: Facilities with a design intake flow of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Facilities with a design intake flow between 30 and 50 MGD (30 MGD inclusive) would have to meet the performance standards for impingement mortality only and not for entrainment. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 30 MGD would be established on a case-by-case, best professional judgment, basis.

Option 8 (Co-proposed Option): Facilities with a design intake flow of 200 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 200 MGD would be established on a case-by-case, best professional judgment, basis.

Option 9 (Co-proposed Option): Facilities with a design intake flow of 100 MGD or greater and located on oceans, estuaries, and the Great Lakes would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this regulatory option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 100 MGD would be established on a case-by-case, best professional judgment, basis.

Exhibit 4-1 summarizes which facilities would be defined as existing Phase III facilities and which performance standards would apply under each of the above options:

Exhibit 4-1. Performance Standards for the Regulatory Options Considered

Option	Minimum Design Intake Flow Defining Facilities as Existing Phase III Facilities					
	2 MGD	20 MGD	30 MGD	50 MGD	100 MGD	200 MGD
1	BPJ	I&E				
2	BPJ	Freshwater rivers and lakes: I only All other waterbodies: I&E		I&E		
3	BPJ	I only		I&E		
4	BPJ	Estuaries, oceans, Great Lakes: I&E All other waterbodies: BPJ		I&E		
5	BPJ			I&E		

Exhibit 4-1. Performance Standards for the Regulatory Options Considered (continued)

Option	Minimum Design Intake Flow Defining Facilities as Existing Phase III Facilities				
	2 MGD	20 MGD	30 MGD	50 MGD	100 MGD
6	I&E				
7	BPJ	I only	I&E		
8	BPJ				I&E
9	BPJ			Estuaries, oceans, Great Lakes: I&E All other waterbodies: BPJ	

Key:
BPJ - Best Professional Judgment
I&E - 80-95% reduction in impingement mortality and a 60-90% reduction in entrainment
I only - 80-95% reduction in impingement mortality
Estuaries - includes tidal rivers and streams
Lakes - includes lakes and reservoirs

4.0 OTHER CONSIDERATIONS

EPA considered a number of other issues relating to performance standards for Phase III facilities, including closed-cycle cooling and the use of sea chests.

4.1 Closed Cycle Cooling

EPA based the Phase I (new facility) final rule performance standards on closed-cycle, recirculating systems (see 66 FR 65274). Available data suggest that closed- cycle, recirculating cooling systems (e.g., cooling towers or ponds) can reduce mortality from impingement by up to 98 percent and entrainment by up to 98 percent when compared with conventional once-through systems (see 69 FR 41601). In the final Phase II rule, EPA did not select a regulatory scheme based on closed- cycle, recirculating cooling systems at existing facilities based on (1) its generally high costs (due to conversions); (2) the fact that other technologies approach the performance of this option, (3) concerns for potential energy impacts due to retrofitting existing facilities, and (4) other considerations (see 69 FR 41605). For individual high-flow facilities to convert to wet towers the capital costs range from $130 to $200 million with annual operating costs in the range of $4 to $20 million (see Phase II final TDD, DCN 6-0004). Thus, basing the Phase III existing facility proposed rule on closed- cycle, recirculating cooling systems would cost more than $2 billion, a more than four-fold increase in total national pre-tax annualized costs compared to today's proposed option of $125 million, without proportionally greater benefits than the proposed option. Therefore, EPA did not further consider closed- cycle, recirculating cooling systems as a basis for today's proposed performance standards for existing facilities.

4.2 Entrainment Reductions for Offshore Oil and Gas Facilities Using Sea Chests

Facilities using seachests may have limited opportunities to control entrainment as required by the Phase I rule. A 2003 literature survey by Mineral Management Services (DCN 7-0012) identified no studies of impingement and entrainment impacts by oil and gas extraction facilities with seachests, or evidence of entrainment controls successfully fitted to offshore oil and gas extraction facilities such as drill ships, jack-ups, MODUs, and barges. EPA's data suggests the only physical technology controls for entrainment at facilities with seachests would entail installation of equipment projecting beyond the hull of the vessel. Such controls may not be feasible, even for new facilities that could avoid the challenges of retrofitting control technologies.

Chapter 5: Costing Methodology for Model Facilities

INTRODUCTION

This chapter describes the methodology used to estimate engineering compliance costs associated with implementing the regulatory options proposed for section 316(b) Phase III facilities. Chapter 3 of this document describes in detail the technologies and practices used as the basis for the regulatory options. Section 1.0 of this chapter describes the regulatory control options considered by the Agency. To assess the economic impact of these control options, EPA estimates the costs associated with regulatory compliance. The methodology for technology and control costs for electric power generators and manufacturers is in section 2.0 of this chapter. The full economic burden is a function of these costs of compliance, which may include initial fixed and capital costs, annual operating and maintenance (O&M) costs, downtime costs, recordkeeping, monitoring, studies, and reporting costs. The results of the economic impact analysis for the proposed regulation is found in the Economic Analysis (DCN 7-0002).

For the purpose of estimating incremental compliance costs attributable to the proposed rules, EPA traditionally develops either facility-specific or model facility costs. Facility-specific compliance costs require detailed process information about many, if not all, facilities in the industry. These data typically include production, capacity, water use, wastewater generation, overall management, monitoring data, geographic location, financial conditions, and other industry-specific data that may be required for the analyses. EPA used a detailed technical survey of electric power and manufacturing facilities[1] to determine how each regulatory option will impact that facility, and to estimate the cost of installing new or additional controls. The cost and basis for each control is described in section 1 of this chapter.

When facility-specific data are not available, EPA develops model facilities to provide a reasonable representation of the industry. EPA then determines the number of facilities that are represented by each model. Industry level costs are then calculated by multiplying the model-specific costs by the number of facilities that are represented by each particular model.

For the section 316(b) Phase III proposed rule, EPA used the model facility approach. EPA primarily used facility-specific data, supplemented where necessary by industry supplied data and follow-up interviews to clarify a facility's responses. However, EPA did not have sufficient data for all facilities potentially subject to the proposed Phase III rule. Therefore, EPA first calculated the facility-specific costs for 346 facilities, and applied the model facility approach to each facility-specific cost to calculate the industry level costs for 650 manufacturing and electric power producing facilities. EPA used the Cost Test Tool described in section 2.0 to calculate the model-facility costs. Section 3.0 provides some examples. Section 4.0 provides an analysis of the confidence in accuracy of the 316(b) compliance cost modules. Section 5.0 provides an estimate of facility downtime.

1.0 REGULATORY OPTIONS

EPA proposed requirements for the location, design, construction, and capacity of cooling water intakes based on the waterbody type and the volume of water withdrawn by a Phase III facility. The proposed rule describes three regulatory options based on design intake flow and source waterbody type that define which facilities are Phase III existing facilities subject to uniform national requirements:

- The facility has a total design intake flow of 50 MGD or more, and located on any waterbody type;
- The facility has a total design intake flow of 200 MGD or more, and located on any waterbody type;
- The facility withdraws water from an ocean, estuary, tidal river or stream, or Great Lake and has a total design intake flow of 100 MGD or more.

If a facility is a point source that uses a cooling water intake structure and has, or is required to have, an NPDES permit, but does not meet the appropriate flow/source waterbody type threshold or the 25% cooling purposes threshold, it would be subject to permit conditions implementing section 316(b) of the Clean Water Act set by the permit director on a case-by-case basis, using best

[1] EPA focused its survey and data collection efforts on six industrial categories that, as a whole, were estimated to account for over 99 percent of all cooling water withdrawals: Utility Steam Electric, Nonutility Steam Electric, Chemicals & Allied Products, Primary Metals Industries, Petroleum & Coal Products, and Paper & Allied Products.

professional judgment. For example, under the 100 MGD coastal and Great Lakes option, facilities withdrawing from a freshwater river or stream would not be subject to national requirements.

Under the proposed rule, these facilities would be subject to the same requirements as under the final 316(b) rule for Phase II, with Phase III requirements specified in Part 125, Subpart K. Data analyzed from EPA's detailed technical survey shows cooling water intake structures at Phase II electric power generating facilities are, in general, no different than those intake structures employed by Phase III facilities, particularly manufacturing facilities and lower flow electric power generating facilities. These factors, plus EPA's additional experiences in section 316(b) Phase I and Phase II rulemakings (see EPA's Final Response to Comments Document DCN 6-5049A and the Phase II Final Preamble 69 FR 41575), as well as Phase III stakeholders (such as small business concerns) led EPA to develop the regulatory options described above. Facilities that would be subject to requirements on a case-by-case, best professional judgment (BPJ) basis were assigned no costs.

The proposed Phase III rule also would make new offshore oil and gas extraction facilities subject to requirements similar to those under the final Phase I new facility regulation (40 CFR 125 Subpart I). Requirements for new offshore oil and gas extraction facilities are proposed in a new Subpart N. For purposes of this proposed rule, new offshore oil and gas extraction facilities are those facilities that are subject to the Oil and Gas Extraction Point Source Category Effluent Guidelines (i.e., 435.10 Offshore Subcategory or 435.40 Coastal Subcategory), and meet the definition of "new offshore oil and gas extraction facility" in proposed Subpart N, § 125.133.

1.1 Analysis of Capacity Utilization Rate

The final Phase II rule includes a provision that allows facilities that have either a historic capacity utilization rate of less than 15 percent or those agreeing to limit their future utilization rate to less than 15 percent to comply with impingement reduction requirements only. For Detailed Questionnaire facilities expected to upgrade technologies as a result of the rule, the Agency determined that 1.0 percent of the total actual annual intake of these facilities would be associated with those facilities falling below the 15 percent capacity utilization threshold. Furthermore, 0.7 percent of the total actual annual intake of the Detailed Questionnaire facilities expected to upgrade technologies could be attributed to those receiving relief from entrainment requirements due to the threshold. For this small number of facilities and negligible percentage of affected intake flow, the Agency concludes that the capacity utilization threshold will have no measurable national effect on the entrainment reduction of the final rule.

There is a potential for facilities to choose to operate at a lower capacity utilization rate in order to avoid entrainment requirements, forego electricity production as a result, and thereby have an impact on local or regional energy markets. EPA examined the electricity generation implications of the capacity utilization rate threshold at those facilities that are within close range of the capacity utilization rate (i.e., those between 15 and 20 % historic capacity utilization) to determine if the facilities would economically benefit from reduced entrainment requirements. EPA conducted a break-even analysis of the net revenue from electricity production foregone compared against the savings of removing entrainment requirements for those facilities between 15 and 20 % historic capacity utilization rates. Exhibit 5-1 presents the results of the break-even analysis. The median and average break-even capacity utilization rates are less than 15.1 %. The Agency found one facility in its database of Phase II facilities that might fall between 15 and 15.1 % capacity utilization. The amount of electricity production foregone as a result of this facility's change to avoid entrainment controls would be on the order of 3,000 MWh per year. This is a negligible amount of electricity generation in any local or regional market.

The Agency analyzed all facilities projected under the threshold and examined the likely operating periods for these facilities. Of the 42 facilities projected to fall under the threshold 17 of these facilities would be subject to impingement only requirements regardless of the existence of the utilization threshold. Further, of the 25 facilities (5 percent of Phase II facilities) that would receive reduced entrainment requirements under the capacity threshold, the total median operation period per year would be 28 days. Considering that this operational period is broken about in two likely periods in winter and summer, the approximate 2-week period in each season would likely overlap only a small portion of potential spawning periods. The operational flow of the facilities receiving reduced entrainment requirements over the typical 28 days per year would be 1 % of the total annual intake of facilities within the scope of the rule that are subject to entrainment reduction requirements. Therefore, the capacity utilization rate threshold will not appreciably decrease the entrainment efficacy of the final rule.

EPA analyzed the cost to revenue ratios of facilities above and below the capacity utilization threshold. In addition, the Agency analyzed cost to revenue ratios for facilities in absence of the capacity utilization threshold relief. The Agency determined that facilities falling below the capacity utilization rate threshold of 15 percent would experience average cost to revenue ratios of 4.4 % (median of 1.2 %) with the threshold relief from entrainment and approximately 6 % (median of 2.4 %) without the presence of the utilization threshold. The Agency determined that facilities above the threshold would experience far lower average cost to revenue ratios of 1.2 % (median of 0.4 %).

As can be seen from the results of the cost to revenue, operating period, and flow analysis in Exhibit 5-2, the Agency's capacity utilization rate of 15 percent for the final rule balances the competing factors of providing needed compliance relief while providing environmental protection. The Agency notes that the possible environmental improvement in the average operating periods in the 10 percent compared to the 15 percent capacity utilization rate is very small (one week per year). Further, the difference in the amount of flow subject to entrainment requirements between the 10 and 15 percent rates is also very small. Therefore, the Agency concludes that the improvement in average cost to revenue relief between the lower thresholds is sufficient to warrant the 15 percent rate. On the higher side, the Agency notes that both the operating periods and the percentage of flow receiving entrainment relief under the 20 and 30 % rates are considerably higher than for 15 percent. In addition, the improvement in cost to revenue relief is not as great between 15 and 30 percent (and 20 percent, for that matter) as the difference improvement between 10 and 15 percent. The Agency concludes that its selection of the 15 % rate is the most reasonable balance for all four threshold factors analyzed in Exhibit 5-2.

Exhibit 5-1. Break-Even Analysis for Facilities that *Might* Reduce Capacity Utilization Rates To Avoid Entrainment Controls

Average Capacity Utilization Rate (1995-1999)	Average Annual Generation (MWh)	Annual Costs of Entrainment Reduction	Annual Costs of Impingement Only Reduction	Annual Cost Diff. Between Entrainment and Impingement Reduction	Annual Generation Loss (MWh / year) to Meet 15 % Capacity Utilization	Cost of Annual Generation Foregone ($ / year) to meet 15 %	Capacity Utilization Break-even Solver Value
15.8%	2,478,619	$ 2,434,420	$ 78,065	$ 2,356,355	829,440	$ 25,712,628	15.0693%
16.4%	128,032	$ 510,945	$ 62,589	$ 448,356	72,620	$ 2,251,210	15.2586%
16.6%	1,202,511	$ 358,071	$ 100,591	$ 257,480	770,455	$ 23,884,099	15.0061%
16.7%	200,024	$ 704,805	$ 59,781	$ 645,025	134,919	$ 4,182,475	15.2378%
17.1%	620,453	$ 684,882	$ 33,398	$ 651,484	502,939	$ 15,591,113	15.0766%
18.4%	574,367	$ 1,073,438	$ 149,075	$ 924,364	708,362	$ 21,959,212	15.1177%
19.2%	2,319,433	$ 1,636,977	$ 69,723	$ 1,567,254	3,413,875	$ 105,830,123	15.0492%
19.4%	6,406,991	$ 94,825	$ 81,322	$ 13,503	9,712,022	$ 301,072,695	15.0002%
19.7%	708,553	$ 610,068	$ 47,283	$ 562,785	1,129,631	$ 35,018,568	15.0579%

Exhibit 5-2. Threshold Comparison Analysis

Threshold	Average CTR below threshold w/ entrainment relief	Average CTR below threshold if no entrainment relief	Average CTR of all facilities	Average operating days per year of facilities w/ entrainment relief	Percent of total flow subject to entrainment requirements receiving relief
10 percent	5.7%	7.3%	1.5%	21	0.3%
15 percent	4.4%	6.0%	1.5%	28	1.0%
20 percent	3.8%	4.7%	1.5%	40	2.6%
30 percent	3.4%	3.3%	1.5%	62	7.8%

CTR = Cost-to-revenue ratio.

1.2 Analysis of Cooling System Type for Electric Power Generating Facilities

Combination Cooling Systems

Fifty facilities reported combination-cooling systems in the 316(b) survey (in the short-technical or detailed questionnaire). EPA analyzed the intake-level and cooling system-level information reported in the survey for each of these facilities. The Agency found that the median percentage of overall facility flow associated with the recirculating intake feed was 5.3 percent. Therefore, 95 percent of the facility's flow would be associated with the once-through intakes.

EPA attempted to gauge the degree to which national costs may be overstated by examining these facilities with combination cooling systems and adjusting their technology upgrade costs to reflect the fact that a recirculating intake at the facility may have lesser requirements than as assumed. Because the Agency determined that 5 percent of the total facility intake would be typically associated with the recirculating intake, to which the Agency assigned costs for reducing entrainment and/or impingement mortality through technology upgrades, the Agency adjusted those annual cost items that are primarily a function of flow by multiplying by – 5 %. The cost items that are primarily a function of flow include capital cost, operating and maintenance (O&M) cost, and pilot study costs. For adjustments to downtime costs the Agency necessarily examined the portion of the plant's intakes associated with the recirculating system. Typically, the recirculating portion of the cooling system corresponded to one of several intakes at the facility. The most

common occurrence was for one of two intakes to be dedicated to a recirculating system and the other to a once-through configuration. The average number of intakes at each of the facilities with combination cooling systems was close to three intakes. A frequent occurrence also was for one of three intakes to be dedicated to the recirculating system. Rarely was more than three intakes reported, and in these cases multiple intakes were generally associated with a recirculating system. Based on these facts, the Agency believes that a reasonable characterization for the "typical" combination cooling system in the data base was for one of three intakes to correspond to a recirculating system and the others to be dedicated as once-through. Hence, for the case of downtime costs, the Agency considered a reasonable adjustment to be one-third of the cost of the downtime at the facility-level. The logic is that should a generating unit with a unique intake not require a downtime, yet the Agency assign one, then the cost of the downtime for the facility would be overestimated. Because the typical configuration for the combination cooling system if one facility of three dedicated to the recirculating system, then a facility-wide downtime assumption would potentially overstate downtimes by one-third, provided all units roughly generate equivalent amounts of electricity. This is a relatively conservative assumption due to the fact that in the cases the Agency is familiar with, the recirculating systems typically are associated with the newest generating units at the plant. Therefore, significantly more than one-third of the plant-wide generation may come from the recirculating portion.

For the purposes of determining the extent to which costs may be overstated for these facilities, the Agency calculated for each of the 50 combination cooling system facilities an annualized adjustment cost. These costs totaled approximately $3.7 million annually (in 2002 $).

Facilities Utilizing Strategic Flow Reductions

Eleven facilities reported in the detailed questionnaire that they utilize strategic flow reduction. The Agency examined the assumed entrainment and/or impingement mortality requirements it utilized for the technology cost development and found that five of the strategic flow reduction facilities utilize significant strategic flow reductions and were assigned entrainment technology upgrades. The Agency considers that this may overstate costs for this portion of facilities given that the median flow reduction percentage was 40 percent. Strategically implemented, an annual flow reduction of 40 percent (targeted to periods of spawning and the presence of large numbers or high density of organisms) could assist a facility in achieving entrainment reductions comparable to the entrainment reduction targets of the final rule. Overall, the fact that the Agency identified only five such facilities reinforces the Agency's assumption that costs for these facilities with strategic flow reduction are relatively accurate in the record. Nonetheless, the Agency analyzed the difference in costs attributable to the entrainment technology upgrades assigned for these facilities to the cost of impingement controls.

For the purposes of determining the extent to which costs may be overstated for these facilities, the Agency calculated an annualized adjustment cost for each of the 5 entrainment-upgrade facilities already utilizing strategic flow reduction. These costs totaled approximately $4.7 million annually (in 2002 $).

1.3 Regulatory Options for Offshore Oil and Gas Facilities

Using the cost modules developed as described in Chapter 1, two compliance alternatives, impingement mortality reduction and impingement mortality and entrainment reduction were costed. Exhibit 5-3 below presents the different technology options for the two compliance options costed for offshore oil and gas extraction facilities.

Exhibit 5-3. Proposed Regulatory Options for Offshore Oil and Gas Extraction Facilities

	Option A	Option B	Option C	Option D	Option E
Option Requirements	I&E control for facilities with >2 MGD	I control for facilities with >2 MGD	I&E control for facilities with > 50 MGD and I control for facilities with 2-50 MGD	I&E control for facilities with > 50 MGD	I control for facilities with > 50 MGD
Type of Rig	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Platforms and Drill Barges which use simple pipes and caissons for cooling water intake	Cylindrical Wedgewire Screens for >2 MGD	Velocity Caps for > 2 MGD	Cylindrical Wedgewire Screens for > 50 MGD and Velocity Caps for 2-50 MGD	Cylindrical Wedgewire Screens for >50 MGD	Velocity Caps for >50 MGD
Jack Ups which use sea chests while in transport and simple pipes/ caissons when stationary for cooling water intake	Cylindrical Wedgewire Screens plus Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >2 MGD	Horizontal Flow Diverter and Velocity Caps for > 2 MGD	Cylindrical and Flat Panel Wedgewire Screens plus Horizontal Flow Diverter for pipes and sea chests for >50 MGD and Velocity Caps and Horizontal Flow Diverter for 2-50 MGD	Cylindrical Wedgewire Screens plus Flat Panel Wedgewire Screens and Horizontal Flow Diverter for > 50 MGD	Horizontal Flow Diverter and Velocity Caps for > 50 MGD
Submersibles, Semi-submersibles and Drill Ships which use sea chests for cooling water intake	Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >2 MGD	Horizontal Flow Diverter for >2 MGD	Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >50 MGD and Horizontal Flow Diverter for 2-50 MGD	Flat Panel Wedgewire Screens and Horizontal Flow Diverter for >50 MGD	Horizontal Flow Diverter for >50 MGD

I = Impingement Control (includes velocity caps and horizontal flow diverters)
I&E = Impingement and Entrainment Control (includes cylindrical wedgewire screens and flat panel wedgewire screens with a horizontal flow diverter)

Based on interviews with technical personnel, it was concluded that most of the offshore oil and gas extraction facilities employing cooling water intake structures have minimal to no technologies in place in order to reduce impingement mortality and/or entrainment. Further, as discussed in this document, entrainment controls were generally found to be infeasible for offshore oil and gas extraction facilities.

1.4 Regulatory Options for Seafood Processing Vessels

Using the cost modules developed as described in Chapter 3, two compliance alternatives, impingement reduction and impingement and entrainment reduction were costed. Exhibit 5-4 below presents the different technology options for the two compliance options costed for seafood processing vessels.

Exhibit 5-4. Proposed Technology Options for Seafood Processing Vessels

Type of CWIS	Compliance Alternatives	Proposed Technology	Comments
Sea chest intake	Impingement	Replace Grill with fine mesh screen	Two options, stainless steel and Cu/Ni fine mesh screens were costed
		Horizontal Flow Diverter	Similar mechanism as a velocity cap. Two configurations for sea chests were costed; (1) located at the bottom of the vessel and (2) on the sides of the vessel.
	Impingement & Entrainment	Enlarged Intake Structure (Internal)	Two options, stainless steel and Cu/Ni fine mesh screens were costed
		Enlarged Intake Structure (External)	Two options, stainless steel and Cu/Ni fine mesh screens were costed

Based on site visits to shipyards and interviews with technical personnel, it was concluded that most of the seafood processing vessels employing cooling water intake structures have minimal to no technologies in place in order to reduce impingement mortality and/or entrainment. Further, as discussed in this document, entrainment controls were generally found to be infeasible for seafood processing vessels.

2.0 COST TEST TOOL APPLIED TO MODEL FACILITIES

The cost-test tool is a spreadsheet program that creates facility-specific or model-specific compliance costs. The cost-test tool (version 4.1) was developed to predict facility-specific costs needed to implement the cost-cost compliance alternative of the final Phase II rule. The tool accepts site-specific intake data for an electric power generating facility, executes the methodology and analyses that EPA used to derive the costs of the Phase II final rule, and then outputs a set of costs for use in a cost-to-cost comparison. Data analyzed from EPA's detailed technical survey shows cooling water intake structures at electric power generating facilities are, in general, no different than those intake structures employed by manufacturing facilities. Therefore the Phase II technologies and costs attributed to control technologies were applied to Phase III manufacturers and electric power generators.

Exhibit 5-5 lists the technology modules EPA used to cost potential Phase III existing facilities to comply with the regulatory options described in section 1.0. Section 2.1 describes how technology modules were assigned to each facility. See Chapter 3 for detailed descriptions of each technology.

Exhibit 5-5. Technology Codes and Descriptions

Technology Codes	Technology Description
1	Addition of fish handling and return system to an existing traveling screen system
2	Addition of fine-mesh screens to an existing traveling screen system
3	Addition of a new, larger intake with fine-mesh and fish handling and return system in front of an existing intake system
4	Addition of passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 1.75 mm
5	Addition of a fish net barrier system
6	Addition of an aquatic filter barrier system
7	Relocation of an existing intake to a submerged offshore location with passive fine-mesh screen inlet with mesh width of 1.75 mm

Exhibit 5-5. Technology Codes and Descriptions (continued)

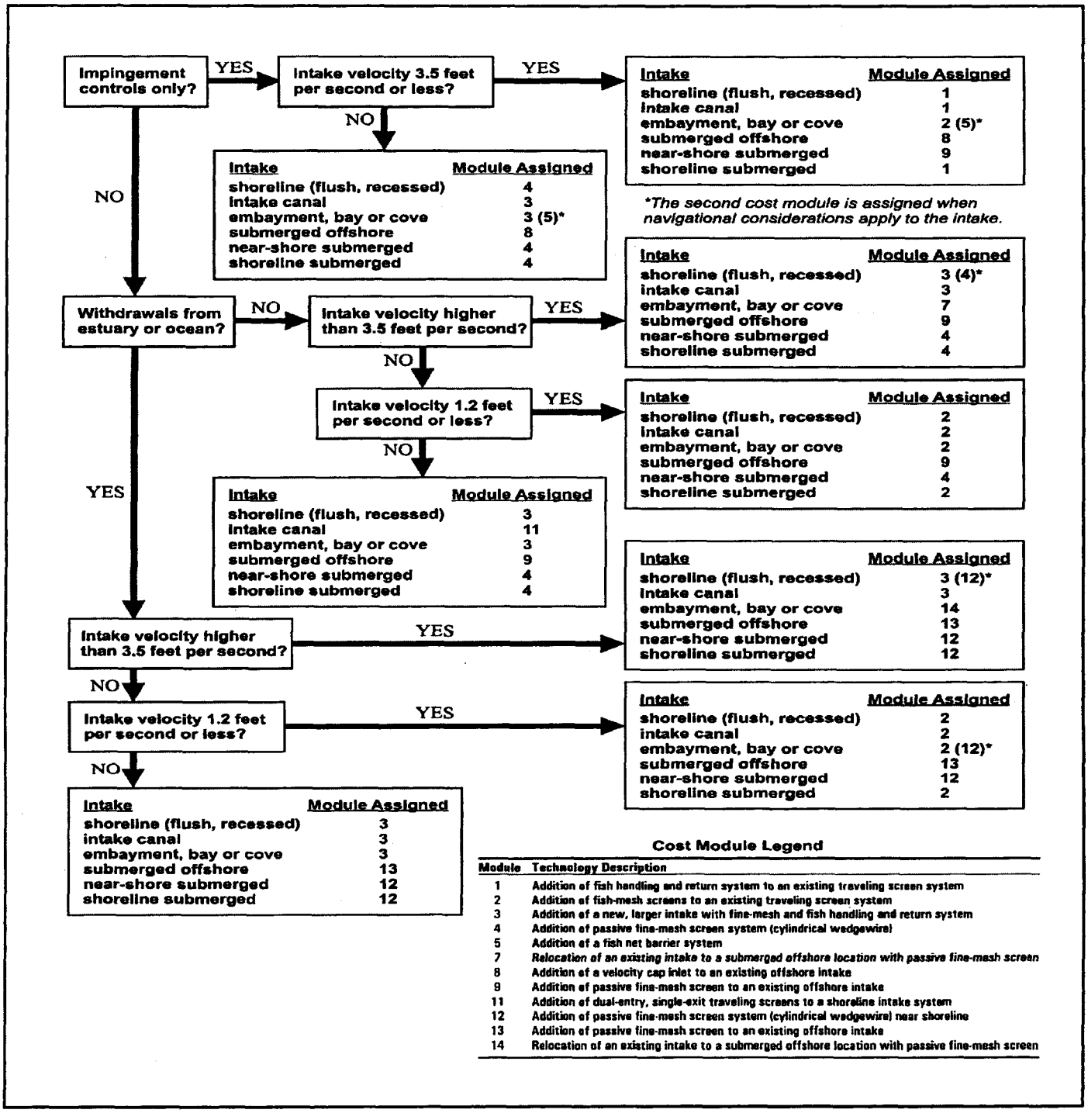
Technology Codes	Technology Description
8	Addition of a velocity cap inlet to an existing offshore intake
9	Addition of passive fine-mesh screen to an existing offshore intake with mesh width of 1.75 mm
10	[Module 10 not used]
11	Addition of dual-entry, single-exit traveling screens (with fine- mesh) to a shoreline intake system
12	Addition of passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 0.76 mm
13	Addition of passive fine-mesh screen to an existing offshore intake with mesh width of 0.76 mm
14	Relocation of an existing intake to a submerged offshore location with passive fine-mesh screen inlet with mesh width of 0.76 mm

2.1 The Cost-Test Tool Structure

The cost test tool program makes use of basic database retrieval functions and logical statements to mirror the costing methodology hierarchy used by EPA for development of the final Phase II rule costs. (This costing methodology was published in the Phase II Notice of Data Availability and was, in turn, available for public comment. The cost-test tool makes no changes to the methodology in its approach.)

The cost model described here modifies the cost-test tool to version 5.1 to calculate the costs the Agency developed and considered for the proposed Phase III. The cost-tool combines the varied analyses and data presented in Chapter 1 into an automated decision tree that ultimately assigns a technology cost to each facility. In the "User Inputs" sheet of the cost-test tool, the user supplies data on the facility level, or the user may choose to input information at the intake level where multiple intakes at a single facility have different features that might affect which technology modules are feasible for that intake. Once the "user inputs" have been entered, the cost-test tool determines one of two possible performance expectations: impingement requirements only or both impingement and entrainment requirements. The cost-tool then determines a compliance response for the facility/intake by accounting for existing technologies (such as wedgewire screens) and conditions (such as a shoreline intake location or the through-screen velocity). Next the cost-test tool applies EPA's decision tree for assigning site-specific cost modules; see Figure 5-1 for a schematic of this decision tree. Finally, the costing methodology is performed through a combination of calculations and functions (that is, an algorithm). This work is mostly carried out in the sheet titled "Calc. and Data" and is supplemented by a few logical functions and data retrieval in the "Output" sheet. The cost outputs include capital costs, incremental operating and maintenance (O&M) costs, and downtime (in weeks).

Figure 5-1. Flow Chart for Assigning Cost Modules

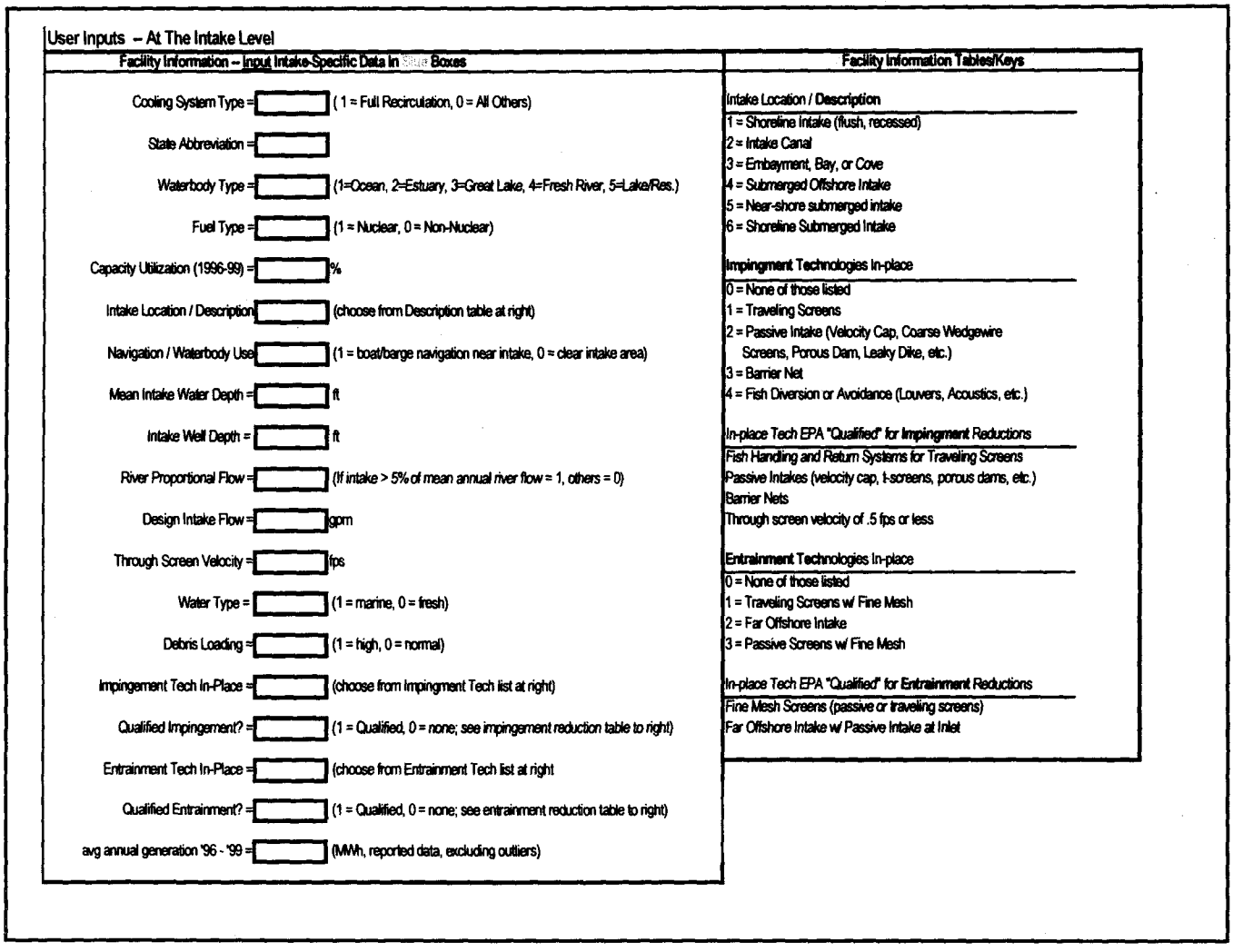


The Agency used the costing equations it developed for the Phase II NODA, the cost-methodology published in the Phase II NODA, and the data obtained from the surveys in the same way it did for developing the costs of the final rule in putting together this cost-test tool. Every effort has been made to utilize the original methodology published in the Phase II NODA (accounting for comments

received from the public), to account for the judgment determinations (through empirical data analysis when possible), to combine the varied analyses conducted for development of the costs, and to ensure that the final program outputs reflect the costs developed by EPA.

The data fields requested in the "User Inputs" sheet (see Figure 5-2) come from questions in the surveys plus a few basic observations about the intake (such as a judgment about the degree of debris loading at the intake: "high" or "low", or whether there are navigational considerations for the location of the intake based on GIS maps). The program reproduces the methodology the Agency utilized to develop final costing decisions in order to determine what technology would best suit a particular intake.

Figure 5-2. Screen Capture of Cost-Test Tool User Inputs



2.2 Cost-Test Tool Inputs

This section describes the inputs to the Cost Test Tool (see Figure 5-2), and defines the default values used for Phase III facility costing. The default value was used when facility level information was not available from EPA's survey.

Cooling System Type. A value of 1(one) indicates the facility was identified in EPA's survey as using a fully recirculating system. A fully recirculating system uses minimum makeup and blowdown flows to withdraw cooling water, where the heat is dissipated by a cooling canal or channel, lake, pond, or tower. A facility identified as having a fully recirculating system does not receive any further

technology costs, but still receives permit costs. A value of 0 (zero) indicates the facility was identified in EPA's survey as using one of the following systems: once-through, combination, other, or unknown.

For the development of compliance technology costs, the Agency considered facilities with recirculating systems in-place to need no technology upgrades. For the purposes of the cost analysis the Agency defined facilities with recirculating systems as only those facilities with recirculating cooling systems for the facility's entire intake system. If a facility had a combination of intakes that utilized once-through and recirculating systems, the Agency treated the facility as a full once-through facility. In addition, if a facility had a once-through or combination system and exercised strategic flow reductions (as reported in questions 26 of the detailed questionnaire), the Agency still treated the facility as a full once-through facility.

State Abbreviation. The two letter state abbreviation is used to identify the state where the intakes are located. The state is used to assign state-specific capital cost factors from the "location cost factor database" in RS Means Cost Works 2001. The state also is used to identify whether zebra mussels are a potential problem at a facility. Where zebra mussels are a potential problem, the costs include using CuNi alloys for intake upgrades located in freshwater.

Waterbody Type. The numeric values 1 through 5 represent the waterbody type for each intake's location. These values are 1=Ocean, 2=Estuary, 3=Great Lake, 4=Fresh River, 5=Lake/Reservoir. A facility located on a waterbody with unobstructed access to a Great Lake, and located within 30 miles of a Great Lake shoreline is classified as Great Lake.

Criteria for delineating/defining tidal rivers and estuaries. EPA uses salinity as the principle criterion (EPA, 2001). From the final Phase I and final Phase II regulatory language (§ 125.83 and § 125.93, respectively):

"Estuary means a semi-enclosed body of water that has a free connection with open seas and within which the seawater is measurably diluted with fresh water derived from land drainage. The salinity of an estuary exceeds 0.5 parts per thousand (by mass) but is typically less than 30 parts per thousand (by mass)."

EPA reviewed all of the waterbody types supplied by facilities in their survey using data from NOAA and other sources to plot the facilities in GIS and confirm the waterbody type. EPA also used NOAA data on tidal movements to cross-check the designations.

Fuel Type. A value of 1 (one) indicates the intake is part of a nuclear facility, and results in additional cost factors. A value of 0 (zero) indicates the intakes is non-nuclear. Construction and material costs tend to be substantially greater for nuclear facilities due to burden of increased security and to the requirements for more robust system design. Therefore, nuclear facilities in freshwater are assigned cost factor of 1.33 and those in saltwater 1.45. See Phase II Technical Development Document for further discussion.

Capacity Utilization Rate (CUR). This percentage value reflects the ratio between the average net annual net generation of power by the facility (in MWh) and the total net capability of the facility to generate power (in MW) multiplied by the number of hours during a year. EPA used the year 2008 CUR as projected by the IPM model as the base case. See Preamble to Phase II (69 FR 41650) for a discussion of the sensitivity of costs to this assumption. Facilities with a CUR of 15 percent or higher and making cooling water withdrawals from tidal rivers, estuaries, oceans, or one of the Great Lakes (see waterbody type) are subject to entrainment requirements under the Phase 2 rule. The default CUR is 20 percent. Manufacturing facilities do not have a CUR, and are assigned the default value of 20.

Intake Location. The numeric values 1 through 6 represent the location and description for each intake. These values are 1=shoreline intake (flushed, recessed), 2= intake canal, 3=embayment, bank, or cove, 4=submerged offshore intake, 5=near-shore submerged intake, 6=shoreline submerged intake. Several facilities did not provide their intake location information in their industry questionnaire and EPA used data from other parts of the facility's survey to determine the intake location. For example, a facility that gives no intake location but states that it has a vertical traveling screen likely has a shoreline intake. Other facilities might give information on the length of an intake canal or the presence of a wedgewire screen, indicating an intake canal and a submerged intake, respectively.

Navigation/Waterbody Use. A value of 1(one) indicates the intake is located where boat/barge navigation near the intake is a consideration when making any modifications to the intake. A value of 0 (zero) indicates navigation does not occur in the vicinity of the intake. Navigational considerations affect which technology modules may be used by intakes located in embayments, banks, or coves (see intake location). EPA used maps and satellite imagery obtained from *mapquest* to identify which intakes were located in areas of boat/barge traffic. The default value is 1.

Design Intake Flow (DIF). The DIF is the numerical value assigned during the facility's design to the total volume of water withdrawn. For facilities reporting one intake, the reported DIF was used. If a facility reports multiple intakes, all intakes were used

for purposes of the facility's total DIF. For costing purposes, only those intakes with a screen velocity greater than 0.5 feet per second were costed for impingement controls (i.e. the DIF for the total facility is greater than the DIF used for costing; this occurs in 12 cases.) If an intake is for a hydroelectric station, the flows are not used for exchange of waste heat and therefore do not meet the definition of cooling water. Furthermore, intakes at Phase III facilities with hydro plants do not meet the 25% of water use criterion for defining a CWIS, and these flows are not included for purposes of calculating costs; this occurs in 2 cases.

Canal Length and Distance to Submerged Offshore Intake. Though these values are not direct inputs, they are a function of waterbody type. The default constructed canal length is the median of all reported values from Phase II facilities. This is used to determine how long the fish return system is, and the default ranges from 683 feet (fresh water river) to 3668 feet (for oceans). Submerged offshore intake distance affects construction and civil costs as well as O&M costs, and is a critical parameter for relocating intakes. The default distance of submerged offshore intakes is the median of all reported values from Phase 2 facilities by waterbody type. The default value ranges from 100 feet (tidal river) to 2773 feet (Great Lakes). These defaults were not revised for Phase III facilities.

Mean Intake Water Depth and Intake Well Depth. The screen well depth is the distance from the intake deck to the bottom of the screen well, and includes both water depth and distance from the water surface to the deck. The default value used in Phase III costing is the mean of all reported values by Phase III facilities as shown in the following table. Gray denotes the default values used in Phase II.

Exhibit 5-6. Mean Intake Water Depth and Well Depth at Phase III Facilities

Industry	Design Capacity = or > 50 MGD		Design Capacity < 50 MGD	
	Mean Intake Water Depth (ft)	Mean Intake Well Depth (ft)	Mean Intake Water Depth (ft)	Mean Intake Well Depth (ft)
manufacturing (n>22)	19	22	16	17
electric generating (n>46)	15	18	12	14

River Proportional Flow. A value of 1 (one) indicates the design intake flow is greater than 5 percent of the mean annual flow of a freshwater river or stream. A value of 0 (zero) indicates the design intake flow is equal or less than 5 percent of the mean annual flow of a freshwater river or stream.

Through-Screen Velocity. A through screen velocity of 0.5 feet per second or less meets the performance standards for impingement mortality and does not incur any capital costs to meet impingement requirements. The Phase II default value is the mean reported value for all electric generators with greater than 50 MGD design intake flow, shown in gray in the table below. For Phase III facilities not reporting a through-screen velocity, EPA used mean reported values of Phase III facilities as shown in the following table:

Exhibit 5-7. Through-Screen Velocity at Phase III Facilities

Industry	Design Capacity = or > 50 MGD	Design Capacity < 50 MGD
	Screen Velocity (feet per second)	Screen Velocity (feet per second)
manufacturing (n>22)	1.2	0.8
electric generating (n>46)	1.5	0.6

Fourteen Phase III facilities had multiple intakes. EPA used the weighted average through-screen velocity for all intakes reported provided the screen velocity was greater than 0.5 feet per second. If the through-screen velocity for a particular intake was 0.5 feet per second or less, the intake meets impingement requirements and EPA did not assign technology controls to that particular intake. EPA assigned weights according to the design intake flow of each reported intake.

Water Type. A value of 1 (one) indicates the water is marine. A value of 0 (zero) indicates the water is fresh water. The default is 0 (zero).

Debris Loading. A value of 1(one) indicates high levels of debris and trash near the intake. A value of 0 (zero) indicates debris is low or negligible. The default is 1 (one). A facility reporting use of a trash rack in the survey is assumed to have high debris loading.

Impingement Tech In-Place. A numerical value of 0 through 4 is used to indicate the intake has impingement technologies reported as in-place by the facility. A value of 1= Traveling Screens, 2= Passive Intake (Velocity Cap, Coarse Wedgewire Screens, Porous Dam, Leaky Dike, etc.), 3= Barrier net, and 4 = Fish Diversion or Avoidance (Louvers, Acoustics, etc.). A facility is treated as having a traveling screen if the facility reported having both an intake screen and shoreline intake location. A value of zero means no controls or none of the above identified controls. The default is 0 (no controls).

Exhibit 5-8. Data Sources for Baseline Impingement and Entrainment Technologies In-place

TYPE OF TECHNOLOGY	SOURCE OF INFORMATION	
	Detailed Questionnaire	**Short Technical Questionnaire**
Impingement & Entrainment Technology		
Passive Intake Systems		14(b)
Wedgewire Screen *	21(b)G	
Perforated Pipe	21(b)H	
Porous Dike	21(b)I	
Leaky Dams	21(b)J	
Artificial Filter Bed	21(b)K	
Impingement Technology		
Fish Diversion or Avoidance Systems		14(a)
Velocity Cap	22(b)M	
Louver Barrier	22(b)N	
Fish Net Barrier	22(b)P	
Fish Handling and bypass Systems with any Traveling Screen		14(c) and 14(d)
Fish Pump	19(b)A, B, E1-E6 & 23(b)W	
Fish Conveyance System(troughs of pipes)	19(b)A, B, E1-E6 & 23(b)X	
Fish Elevator/Lift baskets	19(b)A, B, E1-E6 & 23(b)Y	
Fish Bypass System	19(b)A, B, E1-E6 & 23(b)Z	

Exhibit 5-8. Data Sources for Baseline Impingement and Entrainment Technologies In-place (continued)

TYPE OF TECHNOLOGY		SOURCE OF INFORMATION
		Detailed Questionnaire
Aquatic Filter Barrier Systems or "Gunderboom"	***	***
*Traveling fine mesh screens***	19(b)E1-E6&19(c)(3)-(2)	

* Only a *Wedgewire with a Fine Mesh Screen* meets requirement for entrainment.
** Fine Mesh is 5mm or less
*** Not implemented at Phase III cooling water intake structures.

Qualified Impingement. Facilities with Impingement Tech In-Place = 2 (Passive Intake) receive a numerical value of 1 (one). All other facilities receive a value of 0 (zero). The default is 0 (zero).

Entrainment Tech in-Place. A numerical value of 0 through 3 is used to indicate the intake has entrainment technologies reported as in-place by the facility. A value of 1= Traveling Screens w/ Fine Mesh, 2= Far Offshore Intake, and 3 = Passive Screens w/ Fine Mesh. A value of zero means no controls or none of the above identified controls. The default is 0 (no controls).

Qualified Entrainment. Facilities with qualified entrainment controls receive a numerical value of 1 (one) and receive no further capital costs for entrainment controls. Entrainment Tech in-Place = 1 or 3 are qualified as meeting the entrainment controls. Facilities with Entrainment Tech in-Place=2 (far offshore) AND also with Impingement Tech In-Place = 2 (Passive Intake) are qualified, and receive a value of 1 (one). All other facilities receive a value of 0 (zero). The default is 0 (zero).

2.3 Limitations of the Cost Test Tool

In Phase II, EPA allocated less than a dozen intakes to install more than one intake technology. The cost-test tool does not account for this fact, but rather assumes that a single best technology available can be prescribed for each intake. The end effect of this might be such that a few intakes that actually require multiple technologies to meet the rule would compare the costs of these to the individual technology cost derived in this tool. Additionally, technology Module 6 (Gunderboom) and Module 10 (for submerged offshore intakes) are used sparingly in practice. To simplify the decision tree for assigning a compliance technology, these two technology modules are not included in the cost-test tool.

In Phase II, facilities have 5 compliance alternatives for meeting the final requirements. Under each regulatory option evaluated for Phase III facilities, the facility would have the same compliance alternatives described in the final Phase II rule. These compliance alternatives are not addressed by the cost-test tool. All facilities are costed for one of the technology modules, which does not reflect the most cost-effective compliance option for certain facilities.

Costs for permitting, monitoring, and recordkeeping are not included in the cost-test tool. Costs for these activities were developed separately, and may be found in the Information Collection Request for the Phase III proposed rule (ICR 2169.01, DCN 7-0001).

2.4 Fixed and Variable Costs

The annual O&M cost estimates used in the cost modules is the net O&M cost, which is the difference between the estimated baseline O&M and the incremental compliance O&M costs. Therefore, the fixed or variable proportions for each facility may vary depending on the mix of baseline and compliance technologies. When a facility has baseline O&M costs, and incurs no additional O&M costs as a result of new technology, the incremental O&M cost is 0 (zero). To calculate fixed and variable costs, EPA used the following equations and baseline cost factors:

Eqn 2.41 Fixed baseline O&M = (baseline O&M) * (baseline cost factor)
Eqn 2.42 Fixed compliance O&M = (compliance O&M) * (technology cost factor)
Eqn 2.43 Net Total O&M = (Compliance O&M) - (Baseline O&M)
Eqn 2.44 Net Fixed O&M = (Fixed baseline O&M) + (Fixed compliance O&M)
Eqn 2.45 Net Variable O&M = (Net Total O&M) - (Net Fixed O&M)

Exhibit 5-9. Baseline Cost Factors for Control Technologies

Technology	COST FACTOR
Baseline Technology Fixed O&M Cost Factors	0.41
Add Fish Handling and Return System	0.40
Add Fine Mesh Traveling Screens with Fish Handling and Return	0.40
Add New Larger Intake Structure with Fine Mesh, Handling and Return	0.24
Add Passive Fine Mesh Screens (1.75 mm mesh) at Shoreline	0.24
Add Velocity Cap at Inlet	1.0
Add Passive Fine Mesh Screen (1.75 mm mesh) at Inlet of Offshore Submerged	0.24
Add Double-Entry, Single-Exit with Fine Mesh, Handling and Return	0.385
Add 0.75 mm Passive Fine Mesh Screen at Shoreline for Estuary & Ocean only	0.24
Add 0.75 mm Passive Fine Mesh Screen at Inlet of Offshore Submerged for Estuary & Ocean only	0.24

Exhibit 5-10. Baseline Technology Fixed O&M Cost Factors

Technology Description	Application	Water Type	Fixed Factor
Traveling Screen With Fish Handling	10 Ft Screen Wells	Freshwater	0.28
Traveling Screen With Fish Handling	25 Ft Screen Wells	Freshwater	0.30
Traveling Screen With Fish Handling	50 Ft Screen Wells	Freshwater	0.32
Traveling Screen With Fish Handling	75 Ft Screen Wells	Freshwater	0.33
Traveling Screen With Fish Handling	10 Ft Screen Wells	Saltwater	0.31
Traveling Screen With Fish Handling	25 Ft Screen Wells	Saltwater	0.34
Traveling Screen With Fish Handling	50 Ft Screen Wells	Saltwater	0.36
Traveling Screen With Fish Handling	75 Ft Screen Wells	Saltwater	0.38
Traveling Screen Without Fish Handling	10 Ft Screen Wells	Freshwater	0.45
Traveling Screen Without Fish Handling	25 Ft Screen Wells	Freshwater	0.47
Traveling Screen Without Fish Handling	50 Ft Screen Wells	Freshwater	0.48
Traveling Screen Without Fish Handling	75 Ft Screen Wells	Freshwater	0.49
Traveling Screen Without Fish Handling	10 Ft Screen Wells	Saltwater	0.49
Traveling Screen Without Fish Handling	25 Ft Screen Wells	Saltwater	0.51
Traveling Screen Without Fish Handling	50 Ft Screen Wells	Saltwater	0.53
Traveling Screen Without Fish Handling	75 Ft Screen Wells	Saltwater	0.53

Exhibit 5-11. Compliance Technology Fixed O&M Cost Factors

Technology Description	Application	Water Type	Fixed Factor
Aquatic Filter Barrier	All	All	1.0
Add Fish Barrier Net Using Anchors and Bouys	All	Freshwater	1.0
Add Fish Barrier Net Using Pilings for Support	10 Ft Net Depth	Saltwater	1.0
Add Fish Barrier Net Using Pilings for Support	20 Ft Net Depth	Saltwater	1.0
Add Fine Mesh Passive T-screens to Existing Offshore Intake	High Debris	All	0.21
Add Fine Mesh Passive T-screens to Existing Offshore Intake	Low Debris	All	0.27
Add Very Fine Mesh Passive T-screens to Existing Offshore Intake	High Debris	All	0.19
Add Very Fine Mesh Passive T-screens to Existing Offshore Intake	Low Debris	All	0.27
Relocate Intake Offshore with Fine Mesh Passive T-screens	High Debris	All	0.46
Relocate Intake Offshore with Fine Mesh Passive T-screens	Low Debris	All	0.56
Relocate Intake Offshore with Very Fine Mesh Passive T-screens	High Debris	All	0.38
Relocate Intake Offshore with Very Fine Mesh Passive T-screens	Low Debris	All	0.49
Traveling Screen With Fish Handling and Fine Mesh	10 Ft Screen Wells	Freshwater	0.38
Traveling Screen With Fish Handling and Fine Mesh	25 Ft Screen Wells	Freshwater	0.35
Traveling Screen With Fish Handling and Fine Mesh	50 Ft Screen Wells	Freshwater	0.37
Traveling Screen With Fish Handling and Fine Mesh	75 Ft Screen Wells	Freshwater	0.39
Traveling Screen With Fish Handling and Fine Mesh	10 Ft Screen Wells	Saltwater	0.41
Traveling Screen With Fish Handling and Fine Mesh	25 Ft Screen Wells	Saltwater	0.38
Traveling Screen With Fish Handling and Fine Mesh	50 Ft Screen Wells	Saltwater	0.40
Traveling Screen With Fish Handling and Fine Mesh	75 Ft Screen Wells	Saltwater	0.41
Traveling Screen With Fish Handling	10 Ft Screen Wells	Freshwater	0.40
Traveling Screen With Fish Handling	25 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	50 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	75 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	10 Ft Screen Wells	Saltwater	0.42
Traveling Screen With Fish Handling	25 Ft Screen Wells	Saltwater	0.43
Traveling Screen With Fish Handling	50 Ft Screen Wells	Saltwater	0.44
Traveling Screen With Fish Handling	75 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	10 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	25 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	50 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	75 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	10 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	25 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	50 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	75 Ft Screen Wells	Saltwater	0.44
Velocity Cap	All	All	1.0
Cooling Towers	All	All	0.5

3.0 EXAMPLES OF APPLICATION OF TECHNOLOGY COST MODULES TO MODEL FACILITIES

Exhibit 5-12. Initial Capital-Cost Equations for Phase III Technology Upgrades

Technology Upgrade	Well Depth Range (ft)	Capital Cost Equation	Equation
Module 1 (freshwater): Add Fish Handling and/or Return System	10	Y = 1.5111W^2 + 12863W + 56372	1-1
	25	Y = 13.296W^2 + 18517W + 48889	1-2
	50	Y = 8.5055W^2 + 27952W + 76555	1-3
	75	Y = 12.91W^2 + 35525W + 97459	1-4
	100	Y = 16.308W^2 + 42746W + 129320	1-5

Exhibit 5-12. Initial Capital-Cost Equations for Phase III Technology Upgrades (continued)

Technology Upgrade	Well Depth Range (ft)	Capital Cost Equation	Equation
Module 1 (saltwater): Add Fish Handling and/or Return System	10	Y = 7.4491W^2 + 22493W + 79504	1-6
	25	Y = 31.476W^2 + 32889W + 60070	1-7
	50	Y = 22.351W^2 + 50846W + 110933	1-8
	75	Y = 31.616W^2 + 65080W + 148273	1-9
	100	Y = 38.869W^2 + 78611W + 207527	1-10
Technology Upgrade	**Distance Offshore (m)**	**Capital Cost Equation**	**Equation**
Module 12 (freshwater w/o zebra mussels): Add 0.75 mm Passive Fine Mesh Screen at Shoreline	20	Y = -0.000002X^2 + 8.6127X + 99538	12-1
	125	Y = -0.000001X^2 + 15.183X+ 111563	12-2
	250	Y = -0.000003X^2 + 23.006X+125879	12-3
	500	Y = 0.000003X^2 + 38.65X+ 154511	12-4
Module 12 (freshwater w/ zebra mussels): Add 0.75 mm Passive Fine Mesh Screen at Shoreline	20	Y = -0.000003X^2 + 12.322X+ 97733	12-5
	125	Y = -0.000001X^2 + 18.893X+ 109758	12-6
	250	Y = -0.0000001X^2 + 26.715X+ 124074	12-7
	500	Y = 0.000003X^2 + 42.359X + 152706	12-8
Module 12 (saltwater): Add 0.75 mm Passive Fine Mesh Screen at Shoreline	20	Y = -0.000002X^2 +9.7123X + 99830	12-9
	125	Y = -0.000001X^2 + 17.696X+ 113409	12-10
	250	Y = -0.0000005X^2 + 27.201X+ 129575	12-11
	500	Y = 0.000004X^2 + 46.211X+ 161906	12-12

Note: The costing equations presented in this table do not include the cost factors to correct for different plant type and regional location.
Note: W is the screen width per costing unit in feet. X is the total design intake flow per costing unit in gallons per minute.

Exhibit 5-13. Plant Type Cost Factors

Plant Type	Capital Cost Factor	O&M Cost Factor
Non-nuclear	**1**	**1**
Nuclear in freshwater	**1.8**	**1.33**
Nuclear in saltwater	**1.8**	**1.45**

Exhibit 5-14. Regional Cost Factors and List of States with Freshwater Zebra Mussels as of 2001

STATE	STATE MEDIAN	Zebra Mussels?	STATE	STATE MEDIAN	Zebra Mussels?
AK	1.264	No	NC	0.766	No
AL	0.823	Zebra	ND	0.864	No
AR	0.811	No	NE	0.853	No
AZ	0.905	No	NH	0.94	No
CA	1.108	No	NJ	1.11	No
CO	0.926	No	NM	0.927	No
CT	1.0695	Zebra	NV	1.018	No
DE	1	No	NY	1.039	Zebra
FL	0.84	No	OH	0.9885	Zebra
GA	0.828	No	OK	0.8305	Zebra
HI	1.257	No	OR	1	No
IA	0.942	Zebra	PA	1.008	Zebra
IL	1.028	Zebra	RI	1.063	No
IN	0.955	Zebra	SC	0.763	No
KS	0.96	No	SD	0.796	No
KY	0.908	Zebra	TN	0.828	Zebra
LA	0.832	Zebra	TX	0.807	No
MA	1.1075	No	VA	0.861	No
MD	0.931	No	VI	1	
ME	0.952	No	VT	0.749	Zebra
MI	1.0125	Zebra	WA	1	No
MN	1.093	Zebra	WI	0.989	Zebra
MO	0.9765	Zebra	WV	0.963	Zebra
MS	0.783	Zebra	WY	0.841	No
MT	0.932	No			

Exhibit 5-15. Baseline O&M Cost Equations for Phase II Technology Upgrades

Existing Technology	Well Depth Range (ft)	Baseline O&M Cost Equation	Equation
(Freshwater): Traveling Screens w/o Fish Handling and/or Return System	10	B = -0.4155W^2 + 921.84W + 3239.8	B-1
	25	B = -0.2419W^2 + 1082.2W + 3489.7	B-2
	50	B = -0.6885W^2 + 1329.4W + 4633.2	B-3
	75	B = -0.8842W^2 + 1508.1W + 5702.5	B-4
	100	B = -1.0776W^2 + 1679.2W + 7012.9	B-5
(Freshwater): Traveling Screens with Fish Handling and/or Return System	10	B = -0.6031W^2 + 3303.7W + 7189.7	B-6
	25	B = -0.0221W^2 + 3826W + 7582	B-7
	50	B = -0.6059W^2 + 4682.6W + 10003	B-8
	75	B = -0.79W^2 + 5370.4W + 12541	B-9
	100	B = -0.8662W^2 + 6050.4W + 15301	B-10
(Saltwater): Traveling Screens w/o Fish Handling and/or Return System	10	B = -0.329W^2 + 1060.4W+ 3562.6	B-11
	25	B = 0.1181W^2 + 1283.4W + 3457.4	B-12
	50	B = -0.6261W^2 + 1655.4W + 5238.8	B-13
	75	B = -0.8367W^2 + 1902.3W +6763.2	B-14
	100	B = -1.0778W^2 + 2131.2W + 8860.3	B-15
(Saltwater): Traveling Screens with Fish Handling and/or Return System	10	B = -0.2468W^2 + 3881.6W + 8577.6	B-16
	25	B = 1.0687W^2 + 4688.4W + 8252.8	B-17
	50	B = 0.2248W^2 + 6056.3W + 12066	B-18
	75	B = 0.3324W^2 + 7143.7W + 15590	B-19
	100	B = 0.4874W^2 + 8202.3W+ 19994	B-20

Note: Only facility with existing traveling screens have baseline O&M cost.

Exhibit 5-16. Initial Gross Compliance O&M Cost Equations for Phase III Technology Upgrades

Technology Upgrade	Well Depth Range (ft)	Gross Compliance O&M Cost Equation	Equation
Module 1 (freshwater): Add Fish Handling and/or Return System	10	G = -0.6031W^2 + 3303.7W + 7189.7	G1-1
	25	G = -0.0221W^2 + 3826W + 7582	G1-2
	50	G = -0.6059W^2 + 4682.6W + 10003	G1-3
	75	G = -0.79W^2 + 5370.4W + 12541	G1-4
	100	G = -0.8662W^2 + 6050.4W + 15301	G1-5

Exhibit 5-16. Initial Gross Compliance O&M Cost Equations for Phase III Technology Upgrades (continued)

Technology Upgrade	Debris Loading	Capital Cost Equation	Equation
Module 12 : Add 0.75 mm Passive Fine Mesh Screen at Shoreline	low debris	G = -0.0000005X^2 + 0.1381X+ 17229	G12-1
	high debris	G = -0.0000008X^2 + 0.2952X+ 43574	G12-2

Note: W is screen width per costing unit in feet. X is total design intake flow per costing unit in gallons per minute.

Exhibit 5-17. Information Collection Request Cost for Facility A and Facility B

Average per Facility Costs for each Information Collection Request Activities				Facility A (Example 1)	Facility B (Example 2)
NPDES Permit Application Activities[a]	Labor Cost (2002$)	Capital[b] (2002$)	O&M (2002$)		
Start-up Activities	$449	$0	$10	$459	$459
Permit Application Activities	$2,121	$0	$100	$2,221	$2,221
Proposal for Collection of Information for Comprehensive Demonstration Study	$2,598	$0	$150	$2,748	$2,748
Source Waterbody Flow Information	$732	$0	$40	$772	$772
Design and Construction Technology Plan	$1,027	$0	$80	$1,107	$1,107
Freshwater Impingement Mortality and Entrainment Characterization Study	$87,454	$0	$16,641	n/a	n/a
Marine Impingement Mortality and Entrainment Characterization Study	$159,68	$0	$33,020	n/a	$192,700
Freshwater Pilot Study for Impingement Only Technology	$10,488	$0	$200	$10,688	n/a
Freshwater Pilot Study for Impingement & Entrainment Technology	$16,200	$23,538	$1,400	n/a	n/a
Marine Pilot Study for Impingement Only Technology	$12,043	$34,580	$200	n/a	n/a
Marine Pilot Study for Impingement & Entrainment Technology	$18,796	$66,787	$1,760	n/a	$87,343
Verification Monitoring Plan	$1,253	$0	$80	$1,333	$1,333
Annual Monitoring and Reporting Activities					
Biological Monitoring (Impingement, Freshwater)	$18,727		$500	$19,227	n/a
Biological Monitoring (Impingement, Marine)	$23,837		$650	n/a	$24,487
Biological Monitoring (Entrainment, Freshwater)	$30,724		$8,800	n/a	n/a

Exhibit 5-17. Information Collection Request Cost for Facility A and Facility B (continued)

Average per Facility Costs for each Information Collection Request Activities				Facility A (Example 1)	Facility B (Example 2)
NPDES Permit Application Activities[a]	Labor Cost (2002$)	Capital[b] (2002$)	O&M (2002$)		
Yearly Status Report Activities	$17,402		$750	$18,152	$18,152
Verification Study[a]	$1,391		$100	$1,491	$1,491
			TOTAL	$58,198	$382,620

a: Average per facility labor and O & M costs for each NPDES Permit Application activity and Verification Study were distributed over a five year period to reflect the permit term using Phase III 316b Information Collection Request costs.
b: Capital costs were annualized using 7% discount rate and 10 year amortization period.

Example 1. Facility Requires Upgrade to Add Fish Handling and/or Return System to Existing Traveling Screen System

Facility A is an imaginary coal-fired steam electric facility located on a freshwater river in Tennessee. The facility has a design intake flow of 25 million gallons per day (mgd), a shoreline intake, and an existing traveling screen system with 3/8 inch mesh (coarse mesh). In addition, Facility A produces electricity at near-full capacity and its intake flow is less than 5% of the river annual flow. It has been determined that to comply with the example Phase III regulatory requirements ("Example A"), Facility A would be required to meet impingement performance standards.

Assumptions

- Facility A's existing through-screen velocity is 0.9 feet per second.
- Facility A's mean intake water depth is 12 feet.
- Facility A's intake well depth is 14 feet.
- There is no significant navigation or waterbody use near the intake entrance.
- There is normal debris loading.

Step 1: Select the appropriate costing module from Exhibit 5-11.

Using the through-screen velocity, the intake location, and regulatory requirements, you can determine which technology best suits the application. Since Facility A would be required to reduce impingement only, has low-range through-screen velocity, and has a shoreline intake, the appropriate costing module is module number 1.

Module 1 = Add fish handling and return system.

Step 2: Select the appropriate equation from Exhibit 5-121.

Using the intake well depth and the costing module identified in Step 1, you can select the appropriate equation from Exhibit 5-12. to use in determining the "Initial Capital Costs." Since Facility A has an intake well depth of 14 feet, the appropriate equation to use from Exhibit 5-12. is Equation 1-2 because it is for costing module one and corresponds to intake well depth that range between 11 and 25 feet.

$$Y = (13.296W^2 + 18517W + 48889) \quad \text{[See Eqn 1 - 2, Exhibit 5-12]}$$

Where: W is the screen width per costing unit (in feet) which is calculated by dividing the total design intake flow by the through-screen velocity; mean intake water depth; and open area factor, and Y is the Initial Capital Costs (in 2002 U.S. dollars)

Step 3: Determine the total design intake flow for the facility.

The records indicate that the design intake flow for Facility A is 25 mgd. The Phase III rule would define design intake flow as "the value assigned during the facility's design to the total volume withdrawn from the source waterbody over a specific time period."

Facility may have the design intake flow value available in their records or it can be estimated based on the size of the intake pumps. The design intake flow must be in the units "cubic feet per second (cfs)" for use with the equation in Step 4. Therefore, to convert the design intake flow from mgd to cfs you can perform a dimensional analysis using the following equation.

$$X(gpm) = X(mgd) \times \frac{1{,}000{,}000\,gallons}{1\,million\,gallons} \times \frac{1\,cubic\,feet}{7.48\,gallons} \times \frac{1\,day}{24\,hours} \times \frac{1\,hour}{60\,minutes} \times \frac{1\,minute}{60\,seconds}$$

Convert the 25 mgd to cfs as follows:

$$X(cfs) = 25mgd \times \frac{1{,}000{,}000\,gallons}{1\,million\,gallons} \times \frac{1\,cubic\,feet}{7.48\,gallons} \times \frac{1\,day}{24\,hours} \times \frac{1\,hour}{60\,minutes} \times \frac{1\,minute}{60\,seconds}$$

X = 38.68 cfs

Step 4: Determine the screen width per costing unit (feet), W.

The screen width per costing unit is calculated from the following equation:

W(ft) = [X(cfs)] ÷ [Through -screen Velocity (fps)] ÷ [Mean Intake Water Depth (ft)] ÷ [open area factor]

$$W(ft) = \frac{38.68\,cubic\,feet}{second} \times \frac{second}{0.9\,feet} \times \frac{1}{12\,feet} \times \frac{1}{0.68}$$

W = 5.267 feet

Note: Flat per traveling screen unit width should not exceed 140 feet.

Step 5: Calculate the "Initial Capital Costs."

Using the screen width per costing unit in Step 4 and the equation identified in Step 2, the Initial Capital Cost is calculated as follows:

$$Y = (13.296(5.267)^2 + 18517(5.267) + 48889)$$

Y = $146,787

Step 6: Identify the appropriate cost factors from Exhibits 5-12 and 5-14.

Plant type cost factors are listed in Exhibit 5-13. Since Facility A is a non-nuclear facility, the plant type cost factor is one (1). Regional cost factors are listed in Exhibit 5-14. Since Facility A is located in Tennessee, the regional cost factor is 0.828.

Step 7: Calculate the Total Estimated Capital Costs (TECC)

To calculate the total estimated capital costs (TECC) use the following equation:

TECC = (Initial Capital Cost) x (Plant Type Cost Factor) x (Regional Cost Factor)

Entering the initial capital cost calculated in Step 5 and cost factors identified in Step 6, the total cost can be calculated as follows:

TECC = ($146,787) x (1) x (0.828)

TECC = $121,540

Step 8: Select the appropriate equations from Exhibits 5-15 and 5-16 to use in determining the "Baseline Operation and Maintenance Costs", if applicable, and the "Gross Compliance Operation and Maintenance Costs."

To calculate the annual operation and maintenance (O&M) costs, you need to determine the gross compliance O&M costs (GCOM) and the baseline O&M costs, if applicable. Only facilities with existing traveling screens have baseline O&M costs.

BASELINE O&M COSTS (B)

Using the intake well depth (ft) you can select the appropriate equation from Exhibit 5-15 to use in determining the "Baseline Operation and Maintenance Costs." Since Facility A has an existing traveling screen without fish handling system and an intake well depth of 14 feet, the appropriate equation to use from Table 5 is Equation B-2 because it corresponds to well depth range between 11 and 25 feet.

$$B = (-0.2419W^2 + 1082.2W + 3489.7) \quad \text{[See Eqn B - 2, Exhibit 5-15]}$$

Where: W is the screen width per costing unit (in feet), and B is the Baseline Operation and Maintenance Costs (in 2002 U.S. dollars)

INITIAL GROSS COMPLIANCE O&M COSTS (G)

Using the intake well depth (ft) and the cost module identified in Step 1, you can select the appropriate equation from Exhibit 16 to use in determining the "Initial Gross Compliance Operation and Maintenance Costs." Since Facility A has an intake well depth of 14 fee t, the appropriate equation to use from Exhibit 5-16 is Equation G1-2 because it is for costing module one and corresponds to well depth range between 11 and 25 feet.

$$G = (-0.0221W^2 + 3826W + 7582) \quad \text{[See Eqn G1 - 2, Exhibit 5-16]}$$

Where: W is the screen width per costing unit (in feet), and G is the Initial Gross Compliance Operation and Maintenance Costs (in 2002 U.S. dollars)

GROSS COMPLIANCE O&M COSTS (GCOM)

To determine the Gross Compliance Operation and Maintenance Costs (GCOM), you need the plant type cost factor from Exhibit 5-13 and the following equation:

$$GCOM = (\text{Initial Gross Compliance O\&M}) \times (\text{Plant Type Cost Factor})$$

Step 9: Calculate the Yearly Operation and Maintenance Costs.

To calculate the yearly operation and maintenance costs, use the following equation:

$$\text{Net Annual O\&M Cost} = (\text{GCOM}) - (\text{Baseline O\&M})$$

BASELINE O&M COSTS (B)

Entering the screen width per costing unit calculated in Step 4, W=5.267, the baseline operation and maintenance costs can be calculated as follows:

$$B = (-0.2419W^2 + 1082.2W + 3489.7)$$

$$B = \$\ 9{,}183$$

INITIAL GROSS COMPLIANCE O&M COSTS (G)

Entering the screen width per costing unit calculated in Step 4, W=5.267, the initial gross compliance operation and maintenance cost can be calculated as follows:

$$G = (-0.0221(5.267)^2 + 3826(5.267) + 7582)$$

$$G = \$\ 27{,}733$$

GROSS COMPLIANCE O&M COSTS (GCOM)

Entering the plant type cost factor from Exhibit 5-13, plant type cost factor is 1, the gross compliance operation and maintenance cost can be calculated as follows:

$$GCOM = (G) \times (\text{Plant Type Cost Factor})$$

$$GCOM = (\$27,733) \times (1)$$

$$GCOM = \$27,733$$

NET ANNUAL O&M COSTS

Entering the calculated gross compliance operation and maintenance cost and the baseline operation and maintenance cost from above, the yearly operational and maintenance cost can be determined as follows:

$$\text{Net Annual O\&M Cost} = (GCOM) - (\text{Baseline O\&M})$$

$$\text{Net Annual O\&M Cost} = (\$27,733) - (\$9,183)$$

$$\text{Net Annual O\&M Cost} = \$18,550$$

Summary of Costs for Facility A at Different Design Intake Flow (DIF)

	DIF= 2 mgd	DIF= 10 mgd	DIF= 25 mgd	DIF= 30 mgd	DIF= 40 mgd
Total Estimated Capital Costs	$46,943	$72,833	$121,540	$137,831	$170,477
Annualized TECC	$6,684	$10,370	$17,305	$19,624	$24,272
Net Annual O&M Costs	$5,249	$9,874	$18,551	$21,444	$27,232
ICR Costs	$58,198	$58,198	$58,198	$58,198	$58,198
TOTAL	$70,131	$78,442	$94,054	$99,266	$109,702

Note: Annualized TECC is calculated using 7% discount rate and 10 years amortization period.
Note: See Table 7 for additional information on the ICR costs.

Example 2. Facility Requires Upgrade to Add Passive Fine Mesh Screen

Facility B is an imaginary manufacturer located on an estuary in Massachusetts. The facility has a design intake flow of 100 million gallons per day (mgd), a near-shore submerged intake with a coarse mesh. It has been determined that to comply with the example Phase III regulatory requirements ("Example A"), Facility B would be required to meet impingement and entrainment performance standards.

Assumptions

- Facility B's existing through-screen velocity is 1.5 feet per second.
- Facility B's mean intake water depth is 19 feet.
- Facility B's intake well depth is 22 feet.
- Facility B's existing intake entrance is approximately 50 feet (15.3 meter) offshore.
- There is no significant navigation or waterbody use near the intake entrance.
- There is norm al debris loading.

Step 1: Select the appropriate costing module from Exhibit 5-11.

Using the through-screen velocity, the intake location, and regulatory requirements, you can determine which technology best suits the application. Since Facility B would be required to reduce impingement and entrainment, has mid-range through-screen velocity, and has a near-shore submerged intake, the appropriate costing module is module number 12.

Module 12 = Add Passive Fine Mesh Screen (0.75 mm).

Step 2: Select the appropriate equation from Exhibit 5-12.

Using the existing intake distance offshore and the costing module identified in Step 1, you can select the appropriate equation from Exhibit 5-12 to use in determining the "Initial Capital Costs." Since Facility B intake is 50 feet offshore the appropriate equation to use from Exhibit 5-12 is Equation 12-9 because it is for costing module 12 and corresponds to distance offshore that is less than 20 meter.

$$Y = (-0.000002X^2 + 9.7123X + 99830) \quad \text{[See Eqn 12 - 9, Exhibit 5-12]}$$

Where: X is the total design intake flow per costing unit in gallons per minute (gpm), and Y is the Initial Capital Costs (in 2002 U.S. dollars)

Step 3: Determine the total design intake flow for the facility.

The records indicate that the design intake flow for Facility B is mgd. The Phase III rule would define design intake flow as "the value assigned during the facility's design to the total volume withdrawn from the source waterbody over a specific time period." Facility may have the design intake flow value available in their records or it can be estimated based on the size of the intake pumps. The design intake flow must be in the units "gallons per m inute (gpm)" for use with the equation in Step 4. Therefore, to convert the design intake flow from mgd to gpm you can perform a dimensional analysis using the following equation.

$$X(gpm) = X(mgd) \times \frac{1{,}000{,}000\,gallons}{1\,million\,gallons} \times \frac{1\,day}{24\,hours} \times \frac{1\,hour}{60\,minutes}$$

Convert the 100 mgd to gpm as follows:

$$X(gpm) = 100\,mgd \times \frac{1{,}000{,}000\,gallons}{1\,million\,gallons} \times \frac{1\,day}{24\,hours} \times \frac{1\,hour}{60\,minutes}$$

X = 69,444 gpm

Note: Flow per screen unit must stay below 165,000 gpm for passive intake technology.

Step 4: Calculate the "Initial Capital Costs."

Using the total design intake flow in Step 3 and the equation identified in Step 2, the Initial Capital Cost is calculated as follows:

$$Y = (-0.000002(69444)^2 + 9.7123(69444) + 99830)$$

Y = $764,646

Step 5: Identify the appropriate cost factors from Exhibit 5-13 and Exhibit 5-14.

Plant type cost factors are listed in Exhibit 5-13. Since Facility B is a non-nuclear facility, the plant type cost factor is one (1). Regional cost factors are listed in Exhibit 5-14. Since Facility B is located in Massachusetts, the regional cost factor is 1.1075.

Step 6: Calculate the Total Estimated Capital Costs (TECC)

To calculate the total estimated capital costs (TECC) use the following equation:

TECC = (Initial Capital Cost) x (Plant Type Cost Factor) x (Regional Cost Factor)

Entering the initial capital cost calculated in Step 4 and cost factors identified in Step 5, the total cost can be calculated as follows:

TECC = ($764,646) x (1) x (1.1075)

TECC= $ 121,540

Step 7: Select the appropriate equations from Exhibits 5-15 and 5-16 to use in determining the "Baseline Operation and Maintenance Costs", if applicable, and the "Gross Compliance Operation and Maintenance Costs."

To calculate the annual operation and maintenance (O&M) costs, you need to determine the gross compliance O&M costs (GCOM) and the baseline O&M costs, if applicable. Only facilities with existing traveling screens have baseline O&M costs.

BASELINE O&M COSTS (B)
There is no baseline O&M cost for Facility B because it does not have existing traveling screens.

INITIAL GROSS COMPLIANCE O&M COSTS (G)
Using the debris loading information and the cost module identified in Step 1, you can select the appropriate equation from Exhibit 5-16 to use in determining the "Initial Gross Compliance Operation and Maintenance Costs." Since Facility B has low debris loading, the appropriate equation to use from Exhibit 5-16 is Equation G12-1.

$$G = (-0.0000005X^2 + 0.1381X + 17229) \quad \text{[See Eqn G12 - 1, Exhibit 5-16]}$$

Where: X is the total design intake flow per costing unit (in gpm), and G is the Initial Gross Compliance Operation and Maintenance Costs (in 2002 U.S. dollars)

GROSS COMPLIANCE O&M COSTS (GCOM)
To determine the Gross Compliance Operation and Maintenance Costs (GCOM), you need the plant type cost factor from the following equation:

GCOM = (Initial Gross Compliance O&M) x (Plant Type Cost Factor)

Step 8: Calculate the Yearly Operation and Maintenance Costs.

To calculate the yearly operation and maintenance costs, use the following equation:

Net Annual O&M Cost = (GCOM) - (Baseline O&M)

BASELINE O&M COSTS (B)
There is no baseline O&M cost for Facility B because it does not have existing traveling screens.

INITIAL GROSS COMPLIANCE O&M COSTS (G)
Entering the total design intake flow from Step 3, X=69444 gpm, the initial gross compliance operation and maintenance cost can be calculated as follows:

$$G = (-0.0000005(69444)^2 + 0.1381(69444) + 17229)$$

G = $ 24,408

GROSS COMPLIANCE O&M COSTS (GCOM)
Entering the plant type cost factor from Exhibit 5-13, for Facility B it is 1, the gross compliance operation and maintenance cost can be calculated as follows:

GCOM + (G) x (Plant Type Cost Factor)

GCOM = ($24, 408) x (1)

GCOM = $24, 408

NET ANNUAL O&M COSTS

Entering the calculated gross compliance operation and maintenance cost and the baseline operation and maintenance cost from above, the yearly operational and maintenance cost can be determined as follows:

Net Annual O&M Cost = (GCOM) - (Baseline O&M)

Net Annual O&M Cost = ($24,408) - ($0)

Net Annual O&M Cost = $24,408

Summary of Costs for Facility B at Different Design Intake Flow (DIF)

	DIF= 2 mgd	DIF= 10 mgd	DIF= 30 mgd	DIF= 40 mgd	DIF= 100 mgd
Total Estimated Capital Costs	$125,497	$185,152	$333,691	$407,641	$846,845
Annualized TECC	$17,868	$26,361	$47,510	$58,039	$120,571
Net Annual O&M Costs	$17,420	$18,164	$19,889	$20,679	$24,408
ICR Costs	$382,620	$382,620	$382,620	$382,620	$382,620
TOTAL	$417,908	$427,145	$450,019	$461,338	$527,599

Note: Annualized TECC is calculated using 7% discount rate and 10 years amortization period.
Note: See Table 7 for additional information on the ICR costs.

4.0 ANALYSIS OF THE CONFIDENCE IN ACCURACY OF THE COMPLIANCE COST MODULES

This section provides an overview of the confidence in the accuracy of the compliance capital and O&M costs developed using the 316(b) Phase II Compliance Technology Cost Modules. A key element in cost estimation is the available data and information about site conditions. Some site conditions are favorable to design and construction works while others may involve higher degrees of uncertainty. In sites with favorable conditions design and construction costs are expected to be lower than the cost of the same project designed and constructed under "typical" or "normal" site conditions. On the other end of the spectrum, the costs are expected to be significantly higher than that for the "typical" job site. The cost estimates developed for the compliance technologies assume a "typical" rather than the exceptional job site, except where noted below.

In every design and construction endeavor a level of confidence is developed based on many factors. These factors include factual or data attributes and non-factual or information attributes. The data attributes have to do with level of detail that is available to the designer, the estimator, and the contractor. Also important is the information about the end product function and architectural features of the job site where construction or installation of equipment needs to take place. The confidence also has to do with the confidence in the source data and how the data was used to generate the information and confidence in the experience that is often used by engineers and cost estimators to bridge gaps in the available data. As such, many professional organizations and authorities in the engineering and construction arena have developed scales to identify necessary confidence levels at every stage of a project in order to keep a project within the realm and context of reasonableness within budget and execution potential limits.

For example, the American Association of Cost Engineers International (AACE) recommends the following three construction cost estimating categories with the corresponding different levels of accuracy shown in Exhibit 5-18. EPA generally develops budgetary level cost estimates to forecast compliance cost estimates for a regulation. However, for the compliance technology cost estimates, EPA took an additional step in developing costs that were closer to definitive or preliminary design costs estimates.

Exhibit 5-18. Construction Cost Estimating Categories

Category	Purpose	Timing	Expected Accuracy
1) Conceptual Estimate	-Preliminary estimates for proposed projects -Generally used for screening of alternatives	-Major equipment is sized and specified -Process flow is approved -Utility requirements are specified -Preliminary plot layout	+50% to -30%
2) Budget Estimate	-To commit engineering budget -To commit purchase of critical delivery of equipment -Appropriation request -Check contractor's bids	Same as above except: -process design basis is approved -selection of alternatives has been made	+30% to -15%
4) Definitive Estimate	-Detailed control budget -Cost control and reporting -Finalize contract structure -Fee: adjust or convert	-Plot plan finalized or approved -Equipment size and specs firm -Flow diagrams complete -Complete set of specifications -Production engineering may be completed up to 40%	+15% to -5%

Source: (AACE 1996)

As described below some of the cost components such as equipment costs and technologies available from a limited number of providers have an accuracy level that is much higher than a budgetary cost estimate. In general, given the context of the 316b developed cost estimates, the accuracy of any module is not expected to be less than that of a "budget estimate."

The discussion below attempts to generally assess in more detail the accuracy of elements of the cost modules. For clarification purposes, examples concerning the selection of assumed values used in the technology design or input variables are presented below. In order to ensure that the national totals are reasonably accurate or exceed median values high-side design values were assumed where noted.

In some modules, median values of the data provided by the detailed questionnaire facilities are assumed for facilities where specific data input are not available (e.g., short technical questionnaire facilities). In some cases the overall median is used and in others waterbody specific medians are used. The use of medians is intended to produce the best estimate of costs at the national level by equally over- and under-estimating individual facility costs as a result of the assumed median value being higher or lower than the actual value. A select set of modules were designed to err on the high side (i.e., overestimating the costs) because of the known unpredictability of job sites and technology performance.

Inaccuracies due to regional differences in labor and materials costs are accounted for where necessary through the use of regional cost factors. Where unit costs are based on RS Means data, the unit costs should be considered as having an accuracy of a definitive estimate as these costs are derived and routinely updated using numerous national construction project data sources.

The Agency also considered the elevated costs for capital and operation and maintenance costs at nuclear stations. These costs were applied as numerical multipliers to the costs discussed below. As such, the analysis of confidence levels discussed below for fossil-fuel facilities will apply to nuclear facilities as well.

PASSIVE SCREENS

Cost Modules Covered:

- Module #4: Add Passive Fine Mesh Screens (1.75 mm mesh) at Shoreline
- Module #7: Relocate Intake to Submerged Offshore with Fine Mesh Passive Screen (1.75 mm mesh)
- Module #9: Add Passive Fine Mesh Screen (1.75 mm) at Inlet of Offshore Submerged
- Module #12: Add Very Fine Mesh (0.75 mm) Passive Screen at Shoreline
- Module #13: Add Very Fine Mesh (0.75 mm) Passive Screen at Inlet of Offshore Submerged
- Module #14: Relocate Intake to Submerged Offshore with Very Fine Mesh (0.75 mm) Passive Screen.

The differences between the fine mesh (1.75 mm) and very fine mesh (0.75 mm) screens were that the "per screen" flow rate was set lower for finer mesh similar sized screens based on vendor recommendations. The per screen cost was slightly higher for similar sized screens, and O&M cost were adjusted upward for finer mesh due to higher retention of debris with finer mesh. The analysis below focuses on fine mesh screens but should also apply to the very fine mesh screen modules.

Passive Screen Capital Costs

Input Variables

The primary input variable was the intake design flow. Other variables included saltwater versus freshwater, and distance offshore. To reduce inaccuracy due to differences in distance offshore, costs are developed for 4 distances offshore; 20 meters (which corresponds to the "near shoreline" modules #4 and #12), 125 meters, 250 meters, and 500 meters. As can be seen in Exhibit 5-19 the distance offshore has a significant effect on the costs. Inevitably some inaccuracy will exist due to the potential mismatch of the module distance and the actual distance. For adding passive screens to existing offshore intakes at facilities where the distance was known, the next highest module distance was selected with a maximum of 500 meters. In general, this tended to bias the capital costs upward but increased the confidence that the costs would not be underestimated. However, for those with existing distances greater than 500 meters the costs were biased downward. For the short technical questionnaire facilities, the distance offshore for existing submerged intakes was assumed to be equal to the median value for the data provided in the detailed questionnaires for each waterbody category. This value was then rounded up to the next of the four module distances to increase the confidence that the costs would not be underestimated. The assumption that there would be sufficient depth for larger size screens, provides a potential bias of costs towards the low side where high design flows require large screens to be installed near shore in shallow water. For larger flows, shallow water requires multiple smaller screens which would tend to increase screen and piping costs. To limit this potential bias, facilities requiring multiple large screens were rarely considered as candidates for near shore applications.

Capital Cost Components:

The total estimated capital costs for adding passive wedgewire t-screens consists of the following cost components:

- Screens
- Backwash Equipment
- Backwash Air Piping
- Steel Pipe
- Connecting Wall

The proportion and significance of each to the total capital cost depends on the specific application. The proportion of the total for each component varies most with distance offshore. Exhibit 5-19 presents the proportion of each component calculated as an average of those for each of the 10 input flow values ranging from 2,500 to 163,000 gallons per minute (gpm) for the shortest (20 meters) and longest (500 meters) submerged intake pipes in freshwater applications. Each component cost includes installation costs and is discussed separately below.

Exhibit 5-19. Relative Proportion of Each Capital Cost Component for Freshwater Applications for Adding Screens to Existing Submerged Intakes and Relocating Submerged Offshore for 20 Meters and 500 Meters Offshore

Relocate Passive Screens Offshore Components	Add to Existing Submerged Intake		Relocate Offshore	
	20 Meters Offshore	500 Meters Offshore	20 Meters Offshore	500 Meters Offshore
Screens	64%	20%	29%	6%
Backwash Equipment	17%	6%	7%	2%
Backwash Air Piping	20%	74%	9%	24%
Steel Pipe	0%	0%	28%	62%
Connecting Wall	0%	0%	27%	6%

Screen Costs

The screen cost component includes the sum of the cost of the screens, installation, mobilization, and steel fittings. Installation and mobilization can comprise from 80% of the screen costs for low flow operations to about 20% for high flow operations. The screen costs were obtained from a vendor who reported that the accuracy of the screen costs as that of a detailed estimate (+15% to -5%) (Whitaker 2004). The installation and mobilization costs are based on the BPJ application of vendor-provided cost estimates for velocity caps. While the equipment costs were reported be relatively accurate, vendors of nearly all of the technologies have noted that installation costs are much more variable and dependent on site-specific conditions making a "typical" estimate potentially less accurate. As such, the installation and mobilization component costs (20% to 80% of total screen costs) should be viewed as having the accuracy of a budget estimate.

Actual project screen costs were obtained for six-48 in. screens installed at the Zimmer Power Plant on the Ohio River. The reported screen equipment cost when adjusted to 2002 dollars for inflation was $204,680. Comparable total screen costs using the cost module component data was $190,000 for Cu Ni screens. In this example the actual screen costs were 8% higher than the Module Cost and are well within the estimated accuracy range.

Backwash Equipment

The backwash equipment costs were also obtained from a vendor. This backwash equipment cost data came with the caveats that "the Air Burst system is very custom, based upon distance from screen, multiple compressors, receiver size, controls, etc." Thus, the accuracy of this cost component is difficult to quantify and the costs provided by the vendor should be viewed as having the accuracy of a budget estimate since it included variation due to differences in equipment sizes.

Backwash Air Piping

The costs for backwash air piping is based on unit costs reported in RS Means Costworks 2001 for installed stainless steel pipe (in an above ground application) multiplied by an underwater installation factor of 2 which was derived from looking at similar data for the steel pipe installation costs. While the cost of materials for the stainless steel pipe should have the accuracy of a definitive estimate, the installation factor was developed using BPJ and should be viewed as having the accuracy of a budget estimate.

Steel Pipe

The steel pipe costs were derived from the submerged steel pipe cost estimating methodology as described in Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule, Appendix A, but modified based on a design pipe velocity of 5 feet per second. The pipe cost estimate is the result of a detailed engineering estimate and should have the accuracy of a budget estimate. The actual methodology used in the installation of the manifold piping may differ from the method used in developing the module costs.

The use of different pipe installation methods, however, does not necessarily indicate costs will vary widely. For example, a comparison of the bid costs provided for installation (using a coffer dam in this instance) of a 220 meter 10 ft diameter steel pipe on a submerged drinking water intake on the Potomac River for the Fairfax County Water Authority was $2,856,000 for the wining low bid. The comparable Module component for a 250 meter pipe was $2,818,000. Note that the module pipe length was 14% greater than the example, but the cost of the accepted bid was within nearly one percent of the cost predicted by the module. While the installation method was different the costs were very similar.

Connecting Wall

The connecting wall design is based on the use of a sheet pile using sheet pile cost from RS Means. The primary independent variable used to develop costs for different flow values was the cross-sectional area of the front of the intakes to be covered. Several general assumptions were made that tended to bias the costs of this component upward, including assuming an existing through screen velocity of 1.0 feet per second (whereas the median was around 1.5 feet per second) and a percent open area of 50% (rather than 68% for "typical" coarse mesh screens cited by traveling screen vendors). The cost was developed using a detailed engineering estimate and should have an accuracy of a budget estimate but biased somewhat on the high side.

Relocate to Submerged at Shoreline or Offshore

As described above the screen equipment costs have the greatest accuracy (approximately +15% to -10%) but this only comprises 20% to 80% of the installed screen cost which itself is 29% to 6% of the total capital cost depending on distance offshore.

Combined, the screen equipment costs component (accuracy of +15% to -10%) constitutes roughly 25% to 1.2% of the total capital cost. The remaining components are considered as having an accuracy of a budget estimate (+30% to -15%). In addition, as noted above several of the assumed engineering values were selected such that, on average, the capital costs would be biased towards the high side.

Add to Existing Submerged Offshore

In this option the installed screen cost represent a greater portion of the total costs (64% to 20%) and therefore the total capital cost will have a greater overall accuracy. Combined together, the screen equipment costs component (accuracy of +15% to -10%) constitutes roughly 51% to 4% of the total capital cost. The remaining components are considered as having an accuracy of a budget estimate (+30% to -15%). As with the relocate offshore option, the non-screen costs increase as the distance offshore increases. In addition, as noted above several of the assumed engineering values were selected such that, on average, the capital costs would be biased towards the high side.

Passive Screen O&M Costs

O&M Input Variables

The primary independent variable was the intake design flow. High and low debris was selected as a secondary variable to increase confidence that the costs would be accurate for different environments. Distance offshore and saltwater versus freshwater were not considered as additional sources of variation in O&M costs. However, freshwater and saltwater determinations did play a role in designation of the debris level.

O&M Cost Components

O&M costs consist of labor, power requirements and periodic underwater inspection and cleaning. A high debris and low debris option was developed for each scenario to increase the confidence of the estimates by accounting for the differences in backwash frequency and underwater inspection and cleaning frequency that would be expected for waterbodies with higher and lower amounts of debris. Costs for existing submerged intakes do not include any additional dive team costs above that which is already being performed prior to the installation of the screens. Exhibit 5-20 presents the average proportion of each component over the range of flow values costed for fine mesh screens. As can be seen the power cost component represents a very minor proportion and therefore will not be discussed further.

Exhibit 5-20. Relative Proportion of Each O&M Cost Component for Freshwater Applications for Adding Screens to Existing Submerged Intakes and Relocating Submerged Offshore

Relocate Passive Screens Offshore O&M Component	Add to Existing Submerged Intake		Relocate Offshore	
	Low Debris	High Debris	Low Debris	High Debris
Power	1.6%	4.5%	2%	5%
Labor	64%	62%	98%	75%
Dive Team Inspection & Cleaning	35%	33%	0%	20%

Labor

The O&M labor rate per hour is $41.10/hr. The rate is based on Bureau of Labor Statistics (BLS) Data using the median labor rates for electrical equipment maintenance technical labor (SOC 49-2095) and managerial labor (SOC 11-1021); benefits and other compensation are added using factors based on SIC 29 data for blue collar and white collar labor. The two values were combined into a single rate assuming 90% technical labor and 10% managerial. This labor rate is fairly accurate being based on national average BLS data and is used in other module O&M cost development as well. The number of hours applied is based on vendor quotes of several hours per week with a notation that during certain periods some systems must be manned 24 hours/day for a week or more during seasonal high debris. The selected rates of 2-4 hours per week plus one week at 24 hours per day for low debris or 3 weeks 24 hours per day for high debris are based on BPJ interpretation of the vendor supplied information for "typical" operations. It is expected that the actual labor annual total will be quite variable. Therefore, while the labor dollar per hour rate is very accurate,

the labor hours are considered to have a moderate accuracy with a wide range resulting in the derived costs being that of a budget estimate.

Dive Team Inspection and Cleaning

The dive team costs are based on a vendor quote for a supervisor, tender and diver, including equipment, boat, and mobilization/demobilizations. Costs are calculated in single day increments. These costs should be considered as fairly accurate for typical diver costs. However, as with the labor hourly requirements, the frequency and duration of the dive team requirements are based on general vendor quotes with caveats that actual frequencies and durations may vary greatly from site to site. As such, the dive team costs are considered as having an accuracy of a budget estimate.

Several facilities with submerged intakes were surveyed and annual underwater inspection and cleaning costs were reported by three facilities, the total annual costs were $3,800, $10,000, and $30,000. The first value is below the minimum one day module dive team cost of $5,260 (-28%) and the $30,000 value is greater than the high debris annual cost of $18,480 (+62%) for a comparable flow. This reported range confirms that such costs do vary considerably on a site-specific basis. However, it does show that EPA's estimates do represent a middle or "typical" value. Note that the higher value was for a facility experiencing zebra mussel problems that may have not been designed to prevent this problem. The EPA module technology applied to such situations include higher up front costs for screen materials (CuNi) that tend to inhibit mussel colonization.

Overall O&M

Considering the above discussion, the O&M costs for passive screens should be considered as having the accuracy a budget estimate without any bias.

TRAVELING SCREENS

Cost Modules Covered:

- Module #1: Add Fish Handling and Return System
- Module #2: Add Fine Mesh Traveling Screens with Fish Handling and Return
- Module #11: Add Double-Entry, Single-Exit with Fine Mesh, Handling and Return

Based on the advise of traveling screen vendors, facilities receiving technology Module #1 received costs for replacement of the traveling screen units as well as the addition of a fish return sluice. The alternative was to replace only the baskets and screens and add fish spray equipment. This was based on vendor advise that a partial retrofit that would retain a portion of the original equipment would cost approximately 75% of the cost of replacement units saving only about 25% but possibly compromising system effectiveness and longevity. Thus, this was a conservative (high cost side) assumption that could offset future costs that would be difficult to quantify. This increases the confidence in the O&M cost estimates for module #1 by eliminating any uncertainty with regard to future performance and the need for corrective measures.

Facilities where module 2 was specified, received different costs depending on whether the data available indicated they a fish handling and return system already in-place. If they did not, then the compliance costs included replacing the traveling screens as well as adding a fish return sluice. If they did, then only the costs for adding fine mesh overlays applied. With the exception of Module #3 (add new larger intake), the screen equipment size for traveling screens is limited to the size of the existing intake.

In general, the above approach increased confidence in the accuracy of the capital and O&M costs by tailoring the cost estimates to the known technology in-place.

Traveling Screen Capital Costs

Input Variables

The cost of traveling screens are dependent on both the height (well depth) and width of screen unit. Screen cost data indicates that two screens with the same effective screen area but with different size height and width will have different costs. To increase the confidence in the cost estimates for this final rule applying to existing facilities, the design flow was combined with other data such as intake water depth and through-screen velocity to determine the calculated total effective screen width of the existing intake screens. Since the size of replacement screens is limited to the size of the existing intake structure, the estimated total screen width was considered a much better variable for estimating screen equipment costs compared to design flow alone. For all facilities the

percent open area (POA) of screens already in-place was assumed to be 68% which was identified by screen vendors as the prevalent POA for coarse mesh screens. One vendor said that approximately 97% of existing intake screens use coarse mesh with 3/8 inch mesh upon which this value is based. Flow data and through-screen velocity data were available for most facilities, while intake water depth was only available for detailed questionnaire facilities. Median values from the detailed questionnaire facility data were assumed for those without data. Well depth was another important screen sizing variable. In order to simplify the effort but still retain confidence in the costs over a range of sizes, costing scenarios for five different well depths were developed (10 feet, 25 feet, 50 feet, 75 feet, 100 feet). One of these five costing well depths was then applied to each facility based upon the actual or calculated well depth. Calculated or actual intake well depths that exceeded approximately 20% greater than any category was assigned to the next highest category. In general, this tended to bias this portion of costs slightly upward as the majority of those falling in-between the well depth categories were costed for deeper wells. In many cases well depth data was available but if not, the well depth was assumed to be 1.5 times intake water depth which was the median value for those facilities that had provided both water and well depth data. Other variables include saltwater versus freshwater, which primarily affected screen costs due to differences in material costs, and the presence of a canal or intake channel. Where a canal or intake channel was present, cost for the added fish return flume length was added.

Capital Cost Components:

The total estimated capital costs for modifying and/or adding traveling screens consists of the following cost components:

- Traveling Screens
- Screen Installation
- Fine Mesh Overlays
- Spray Water Pumps
- Fish Flume
- Added Fish Flume Length for Those with Canals

Exhibit 5-21 presents the cost components and the percent of total cost of each component for a single 10 feet wide 25 feet deep through-flow traveling screen. A 10 feet wide screen was selected as an example because it represents a commonly used standard screen size and the 25 feet depth was selected based on the median values from the detailed data. Dual-flow screens would present a similar cost mix as shown in Exhibit 5-21 but with slightly higher costs for the screen equipment component. Note that the proportions given are for facilities without canals. For those with canals, the fish flume component would be a higher proportion depending on the canal length.

Exhibit 5-21. Compliance Module Scenarios and Corresponding Cost Component Relative Proportions for 10 ft Wide and 25 ft Deep Screen Well

Compliance Action	Cost Component Included in EPA Cost Estimates	Existing Technology	
		Traveling Screens Without Fish Return	Traveling Screens With Fish Return
Module 2 - Add Fine Mesh Only (Scenario A)	New Screen Unit	NA	0%
	Screen Installation	NA	0%
	Add Fine Mesh Screen Overlay	NA	100%
	Add Spray Water Pumps	NA	0%
	Add Fish Flume	NA	0%

Exhibit 5-21. Compliance Module Scenarios and Corresponding Cost Component Relative Proportions for 10 ft Wide and 25 ft Deep Screen Well (continued)

Compliance Action	Cost Component Included in EPA Cost Estimates	Existing Technology	
		Traveling Screens Without Fish Return	Traveling Screens With Fish Return
Module 1 - Add Fish Handling Only (Scenario B)	New Screen Unit[1]	Freshwater 67% Saltwater 80%	NA
	Screen Installation	Freshwater 14% Saltwater 9%	NA
	Add Fine Mesh Screen Overlay[2]	0%	NA
	Add Spray Water Pumps	Freshwater 2% Saltwater 1%	NA
	Add Fish Flume	Freshwater 17% Saltwater 10%	NA
Module 2 - Add Fine Mesh With Fish Handling (Scenario C and Dual-Flow Traveling Screens)	New Screen Unit	Freshwater 63% Saltwater 74%	NA
	Add Fine Mesh Screen Overlay	Freshwater 6% Saltwater 7%	NA
	Add Spray Water Pumps	Freshwater 2% Saltwater 1%	NA
	Add Fish Flume	Freshwater 16% Saltwater 9%	NA

[1] Replace entire screen unit, includes one set of smooth top or fine mesh screen.
[2] Add fine mesh includes costs for a separate set of overlay fine mesh screen panels that can be placed in front of coarser mesh screens on a seasonal basis.
[3] Does not include initial installation labor for fine mesh overlays. Seasonal deployment and removal of fine mesh overlays is included in O&M costs.

Screen Equipment

As can be seen in Exhibit 5-21 the majority of the screen costs are for the screen units. Screen equipment costs were obtained from vendors, one set for freshwater only in 1999 and one set for freshwater and saltwater in 2002. EPA found that the 2002 costs for freshwater screens were about 10% to 30% less than the 1999 cost even after adjusting for inflation. The screen cost data were reported by the vendors as "budget" level estimates (i.e.,+30% to -15%). EPA chose the higher 1999 costs (adjusted to 2001) because they were most suited for application to the selected screen size scenarios and as a conservative (high cost side) approach. The ratio of saltwater to freshwater screens from the 2002 data was used to derive corresponding saltwater screen costs. Thus, the screen equipment costs for both freshwater and saltwater have an accuracy equivalent to budget level estimates and may be biased on the high side by 10% to 30%.

Screen Installation Costs

Screen installation costs are much more variable than the equipment costs and can increase by 30% if screens must be installed in sections due to overhead obstructions. Two vendors provided values that differed by about 50% but all noted that site-specific situations made estimating "typical" installation costs was difficult. The installation costs were adjusted for screen size and selected to span the range of costs cited. Thus, the installation costs should be considered as having the accuracy of a budget estimate.

Fine Mesh Overlays

Fine mesh overlays are calculated as a percent of screen costs. A vendor quoted that the cost would be 8 to 10% of the screen equipment costs and EPA chose to use a 10% factor resulting in a slight bias on the high side. Otherwise these costs should have the same accuracy as the cost of the screen equipment alone. The assumption of using fine mesh overlays rather than permanent fine mesh screens for scenario C would be a conservative assumption for locations that do not have seasonal debris problems. This assumption increases the confidence that the module would not underestimate costs where seasonal debris problems exist.

Spray Water Pump Costs

As show in Exhibit 5-13, the spray pump costs only contribute around 1% to 2% of the total costs and thus will not contribute significantly to variations in the data accuracy. However, as noted in the O&M discussion below the estimated volume of spray water has a significant effect on the O&M costs. Spray water pump costs are derived based on a vendor supplied water use factor per ft of total screen width. Only the additional volume needed for the low pressure fish spray component is costed for additional pumps. A range of 26.6 to 74.5 gpm/ft total flow was cited by vendors. Only one vendor gave a breakdown between the two requirements as 17.4 gpm for debris and 20.2 for the fish spray. EPA chose a 30 gpm rate for the fish spray as a conservative (high end) rate, which when compared to the single 20.2 gpm/ft example may bias the flow upward by nearly 50%. The pump equipment and installation costs are based on flow and engineering unit costs for similar equipment and thus should be viewed as having the accuracy of a budget estimate but biased towards the high side.

Fish Flume

The cost of fish return flumes will vary with flow volume and length, and other site-specific factors. All facilities that did not already have a fish return in-place received costs for a fish flume. The flumes are sized to return the entire flow generated (60 gpm/ ft screen width) which as noted above may be biased toward the high side. A screen vendor cited flume lengths of 75 feet to 150 feet and survey data for facilities without canals reported a length of 30 feet to 300 feet. EPA chose the high end of this range of 300 feet as a conservative estimate of a "typical" installation. Thus, the flume length chosen by EPA may be biased upward by up to 100%. EPA notes that in some tidal applications two return flumes are used to ensure that the debris is deposited downstream and this assumption ensures that such situations are accounted for.

For those facilities that reported the intake was at the end of a canal, an additional costs was added to account for the added distance needed to reach the main waterbody. This additional length was set equal to the canal length and was an additional cost above the 300 feet length. Note that the 300 feet length provides for placement of the debris discharge away from the intake. Flume costs include costs for PVC pipe and support pilings spaced at 10 ft. Costs for a 12 inch diameter PVC pipe were developed from RS Means data and then converted to a rate of $10.15/ inch dia.-ft length including site work and indirect costs. Flume diameter was calculated based on an assumed velocity when full of 1.5 feet per second. As such, the flume costs are based on engineering design assumptions that are conservative (high side) for the "typical" site to increase confidence that this component will not be underestimated. Therefore, the cost estimates should be viewed as having the accuracy of a budget estimate and may be biased towards the high side.

Module 2 Scenario A

The relative accuracy of these cost estimates should be equal to that of the screen equipment (+30% to -15%) and the cost factor (10%) which could be biased toward the high side by an additional 10% (the Agency used the 10% factor as opposed to the 9% midpoint between 8% and 10%).

Module 1 Scenario B

The screen equipment costs which have an estimated accuracy of +30% to -15% accounts for 67% to 80% and may be biased toward the high side by 10% to 30% for the example screen. The remaining components are considered as also having an accuracy of a budget estimate and also may be biased toward the high side for spray water pumps and flume length.

Module 2 Scenario C

The screen equipment costs which have an estimated accuracy of +30% to -15% accounts for 63% to 74% of the costs and may be biased toward the high side by 10% to 30% for the example screen. The remaining components are also considered as having an accuracy of a budget estimate and also may be biased toward the high side for spray water pumps and flume length.

Module 11 Scenario C (Dual-flow)

The capital costs for dual-flow screens were developed by multiplying the through-flow screen total costs by factors recommended by a vendor. Thus, the component proportions and relative accuracy should be similar to that for through-flow screens.

Traveling Screen O&M Costs

Baseline O&M Costs

O&M costs for facilities that have traveling screens in-place are calculated on a net basis. In other words a cost estimate is calculated for the existing intake screens and then subtracted from the compliance technology O&M cost estimate. As such, there is an additional O&M cost option for traveling screens without fish returns. In general, this option involves less operating time, no extra fish spray pumping and as a result labor, power, and parts replacement costs (less wear and tear) are lower. All assumption for this baseline option are based on vendor estimates of "typical" operations. In addition, the costs derived under Module 2 Scenario B also served as the basis for baseline O&M costs for facilities with existing traveling screens with fish returns.

Net cost calculations were limited to facilities where the compliance technology was an upgraded version of the traveling screen technology or where the existing traveling screen technology was being replaced in function and would no longer be required. An example is where fine mesh passive screens replaced traveling screens. An example where baseline costs were not deducted is the addition of fish barrier nets. The accuracy of the net O&M costs are therefore, a combination of the accuracies of the positive and negative components. When deviations of the module results from the actual costs of both components (baseline and compliance) have the same sign (+ or -), the differences will tend to cancel each other out somewhat. But when they have different signs, the accuracy of the net value will be reduced.

For facilities with fixed screens or other non-traveling type screen technologies, no baseline costs were deducted because there was no reliable way to estimate baseline O&M costs. This results in a bias toward the high side of net O&M costs for these facilities since even for fixed screens there would be certain amount of labor associated with periodically inspecting and cleaning the screens.

O&M Input Variables

The O&M costs use the same input variables, total screen width, well depth and saltwater versus freshwater as the capital costs (see discussion above).

O&M Cost Components

O&M costs consist of labor, power requirements, and parts replacement. Exhibit 5-22 presents the corresponding O&M cost component relative proportions for 10 feet wide and 25 feet deep screen well.

Exhibit 5-22. Compliance Module Scenarios and Corresponding O&M Cost Component Relative Proportions for 10 ft Wide and 25 ft Deep Screen Well

Compliance Action	Cost Component Included in EPA Cost Estimates	Existing Technology	
		Traveling Screens Without Fish Return	Traveling Screens With Fish Return
Module 2 - Add Fine Mesh Only(First Column) and Add Fine Mesh With Fish Handling(Second Column) (Scenarios A and C)*	Basic Labor	Freshwater 35% Saltwater 29%	Freshwater 35% Saltwater 29%
	Overlay Labor	Freshwater 15% Saltwater 12%	Freshwater 15% Saltwater 12%
	Motor Power	Freshwater 2% Saltwater 2%	Freshwater 2% Saltwater 2%
	Pump Power	Freshwater 30% Saltwater 26%	Freshwater 30% Saltwater 26%
	Parts	Freshwater 18% Saltwater 31%	Freshwater 18% Saltwater 31%
Module 1 - Add Fish Handling Only (Scenario B)	Basic Labor	Freshwater 41% Saltwater 33%	NA
	Overlay Labor	0%	NA
	Motor Power	Freshwater 2% Saltwater 2%	NA
	Pump Power	Freshwater36 % Saltwater 29%	NA
	Parts	Freshwater 21% Saltwater 35%	NA

* The O&M costs are assumed to be he same for compliance scenarios A and C but the net costs will be different for each since the baseline technologies are different.

Basic Labor

A vendor provided general guidelines for estimating basic labor requirements for traveling screens as averaging 200 hours and ranging from 100 to 300 hours per year per screen for coarse mesh screens without fish handling and double that for fine mesh screens with fish handling (Sunda 2002a, 2002b). If the range shown represented a single screen size then the accuracy would be roughly +50% to -50%, however a good portion of this variation in hours is related to intake size. Estimates for various screen sizes were scaled to span these ranges. Thus, the accuracy of the basic labor cost estimates should be considered as having the accuracy of a budget estimate because it included estimated hours. The hourly wage rate is fairly accurate as discussed under passive screens above.

Overlay labor

Overlay labor is based on recommended screen change-out times per screen panel. The number of screen panels is very accurate for each screen and so the accuracy of the labor estimate is associated with the accuracy of the estimated time for placing each screen overlay and whether the annual frequency estimate of once per year was correct. As such, it is reasonable to consider the overlay labor estimate as having an accuracy of a definitive estimate.

Motor and Pump Power

Power requirements for the motors comprises only 2% of the total and therefore will not be discussed. The spray water pump requirements, however, could be significant. Several aspects of the pump power requirements tend to bias these costs upward. The first as described in the pump capital costs above is that the flow rate chosen was somewhat biased toward the high side. Secondly,

the pump power requirements are based on the entire flow being pumped to the high pressure needed for debris removal. If the low pressure stream results from passing through a regulator from a high pressure pump then this is a valid assumption. However, if a separate set of low and high pressure pumps are used, then this assumption will result in an overestimation of the pump energy and therefore power requirements. As the flow requirements are based on engineering estimates, it is reasonable to consider the pump power estimate as having the accuracy of a budget estimate but potentially biased toward the high side.

Parts replacement

These costs are based entirely on proportions of the screen equipment costs using rough estimates provided by a vendor. As such, it is reasonable to consider the pump power estimate as having the accuracy of a budget estimate but potentially biased on the high side since it is based on a factor multiplied by the screen equipment costs.

Overall O&M Costs for Through-flow Screens

In general, the Agency views the best way to quantify the accuracy of the components as being on the order of a conceptual estimate with bias towards the high side for the components as noted.

Dual-flow Screens

The O&M costs for dual flow screens (Scenario C only) were calculated as a fixed proportion of through-flow screen costs reported by a vendor as the typical values they have observed. As this factor itself is a rough estimate, the dual-flow screen O&M estimates will reflect similar accuracies as the through-flow screens.

LARGER INTAKES

Cost Module Covered:

- Module #3: Add New Larger Intake Structure with Fine Mesh, Handling and Return

Larger Intake Capital Costs

Input Variables

In this case the independent variable was the estimated "compliance total screen width" which was calculated in a similar manner as the baseline total screen width used in the traveling screen cost estimates. As with the traveling screens, use of screen sizes, rather than flow alone, increases the confidence in the accuracy of the estimates. Differences in calculating the compliance screen width include using a through-screen velocity of 1.0 feet per second (instead of the actual velocity or data median of 1.5 feet per second that was used for the baseline) and a percent open area (POA) of 50% instead of 68% that was used for baseline total screen width. The 50% POA is consistent with use of fine mesh screens. In this case the independent variable may be biased toward the low side if facilities select a lower through-screen velocity than 1.0 feet per second. This same independent variable was used for estimating the capital and O&M costs for dual-flow traveling screens installed in the new larger intake.

Overall Accuracy

The new larger intake costs are based on a detailed engineering estimate of costs for a larger intake located just in front of the existing intake. A review of the construction components, component quantities and indirect costs does not indicate any items that may have been estimated in a way that would tend to bias the cost estimates either high or lower. Unit costs are based on costs reported in RS Means Costworks 2001. Considering the detailed nature of the estimation method, the cost estimate should be viewed as having the accuracy of a budget estimate.

Larger Intake O&M Costs

No separate O&M costs were derived for the structure itself since the majority of the O&M activities are covered in the O&M costs for the traveling screens to be installed in the new structure.

FISH BARRIER NETS

Cost Module Covered:

- Module #5: Add Fish Barrier Net

Barrier Net Capital Costs

Input Variables

In this case the independent variable was the design intake flow. A secondary variable was freshwater versus saltwater. Water depth was considered in the development of saltwater barrier nets but a single depth close to the median value reported by facilities was used in the application. Different support and anchor strategies were used in freshwater and saltwater. These different approaches to freshwater and saltwater applications increases the confidence in the cost estimates by accounting for differences in design due to the presence of tidal currents in saltwater environments. Research indicated that nets are designed on a site-specific basis and that limited engineering guidelines to follow exist. Therefore, the barrier net costs are based on design and cost data from two facilities with barrier nets that had similar net velocities. The estimates were not just simple scaled costs but rather an evaluation of each cost component was performed and then scaled for different sizes. Barrier net costs are primarily based on the required net size and support structures/equipment. Two facilities, one on a lake and another on an estuary, reported essentially the same velocity of 0.06 feet per second. Lacking more detailed engineering guidelines, use of actual reported net velocities was determined to be the best method to develop relatively accurate net costs.

Freshwater Barrier Nets (Scenario A)

Net costs are based on the unit costs in dollars/sq ft for both the installed net and a back-up replacement for the example facility. The freshwater unit costs include costs for shipping, floats and anchors. The freshwater facility cost data indicated that the unit costs used may be biased slightly toward the high side if shallower nets are used (e.g., 10 feet or less). The example facility had a net depth of 20 feet. The total reported installation cost was split into a fixed component of 20% (based on BPJ) and a variable dollar/sq ft component. While this module will provide a definitive estimate quality estimates of the net costs at facilities similar to the example facilities, the fact that there are limited guidelines indicates that actual designs may vary considerably tending to temper the accuracy of this module to an accuracy of a conceptual design estimate.

Saltwater Barrier Nets (Scenario B)

In this scenario, net costs are based on using two concentric nets, supported on pilings as is the case with the example facility. The costs for the nets are base on the costs cited by both the facility and its supplier. Costs for the pilings are based on engineering design using the 20 feet spacing at the example facility and RS Means unit costs for barge driven piles. Costs were derived for depths of 10 feet, 20 feet, and 30 feet. However, in developing the compliance cost estimates, only the 20 feet depth was used. In the case of this saltwater net design, shallower depths will tend to drive costs upward due to the requirement for more pilings. While this module will provide definitive estimate quality estimates of the net costs at facilities similar to the example facilities, the fact that there are no guidelines indicates that actual designs may vary considerably tending to temper the accuracy of this module to an accuracy of a conceptual design estimate.

Barrier Net O&M Costs

Input Variables

O&M costs use the same independent variables as capital costs. Duration of deployment was also considered.

Freshwater Barrier Nets

The O&M costs are based on reported labor requirements and net replacement rates. The period of deployment is also important. The example facility reported a deployment period of 120 but others reported longer periods. EPA chose to base the costs on a deployment period of 240 days as a conservative (high side) estimate. EPA scaled up the labor hours cited by the facility and added an additional net section replacement step. Costs for the example facility were developed and then converted to a straight line cost curve by assuming 20% of costs were fixed. While this module will provide a definitive estimate quality estimates of the net O&M costs at facilities similar to the example facilities, as with the O&M costs, the fact that there are no guidelines indicates that actual

operations may vary considerably tending to temper the accuracy of this module to an accuracy of a budget estimate with a potentially biased toward the high side.

EPA notes that other O&M costs reported in literature are often less than what results from the cost module. For example, 1985 O&M cost estimates for the JP Pulliam plant ($7,500/year, adjusted to 2002 dollars) calculate to $11,800 (compared to $57,000 for the example facility) for a design flow roughly half that of example facility. This suggests the scenario A estimates represent the high end of the range of freshwater barrier net O&M costs (biased upward as noted above). Other O&M estimates that also were lower, however, do not describe the cost components that are included and can not be used for comparison since they may not represent all cost components.

Saltwater Barrier Nets

The saltwater barrier net O&M costs are based on the net maintenance contractor costs plus replacement net costs. Nearly all of the O&M labor for Chalk Point facility is performed by a marine contractor who charges $1,400 per job to simultaneously remove the existing net and replace it with a cleaned net. The reported annual job frequency was used along with the reported net replacement rate. As with the capital costs, while this module will provide a accuracy of a definitive estimate at the example facility, the fact that actual designs may vary considerably indicates that the accuracy of this module can be considered as having the accuracy of a budget estimate

VELOCITY CAPS

Cost Module Covered:

- Module #8: Add Velocity Cap at Submerged Inlet

EPA identified only one vendor that supplied preconstructed velocity caps. This appears to be primarily due the fact that, for many installations, velocity caps are custom designed and constructed.

Velocity Cap Capital Costs

Input Variables

The primary input variable was design intake flow. Freshwater versus saltwater was an additional variable that affected equipment costs.

Capital Cost Components:

Capital costs consist of equipment, installation, and mobilization/demobilization. For higher flows, multiple heads are used with the costs including inlet piping modifications. The saltwater/freshwater differences are due to use of different materials. The vendor was very confident about the equipment, installation, and mobilization/demobilization costs as they had performed numerous recent jobs. The mobilization/demobilization costs were reported as a range of $15,000 to $30,000. This was applied such that the range spanned the range of flow rates costed.

The proportion of the total for equipment costs ranged from 39% for a 5,000 gpm freshwater intake to 71% for a 350,000 gpm freshwater intake and were roughly 7% less for saltwater. Due to the apparent limited number of prefabricated cap suppliers and the confidence expressed by the vendor the equipment portion should be considered as having an accuracy of a definitive estimate and the remainder having an accuracy of a budget estimate. This estimate of accuracy should be limited to the use of prefabricated velocity caps. As noted above many are custom designed built onsite and in those instances costs may vary considerably. This will tend to temper the accuracy of this module to an accuracy somewhere between a budget and a conceptual estimate when multiple methods of construction are considered.

Velocity Cap O&M Costs

Input Variables

The primary input variable was design intake flow. Freshwater versus saltwater was not considered as significant source of valiance in the O&M costs.

O&M Cost Components

Since this was a passive technology, O&M costs were limited to periodic inspection and cleaning by a dive team. The same per day dive team costs that were applied to the passive screen O&M costs are applied to the velocity cap O&M costs. As such, the dive team costs are considered as fairly accurate but the duration and frequency estimates are considered as less accurate resulting in an overall accuracy of a budget estimate.

AQUATIC FILTER BARRIERS

Cost Module Covered:

- Module #6: Add Aquatic Filter Barrier Net (Gunderboom)

Currently only one vendor (Gunderboom Inc.) is available to design install this technology. The technology has been demonstrated but is still somewhat in the developmental stage.

Aquatic Filter Barrier Capital Costs

Input Variables

Design intake flow was the primary variable.

Capital Costs

The cost data was provided for three flow values by the vendor in 1999 prior to any full scale installations. Three different capital costs representing low, average and high costs were provided. These costs have been adjusted for inflation. The average costs were selected to served as the basis for compliance costs for this module. No updated costs based on recent experience were made available. Given the lack of recent experience input the cost estimates should be considered as having an accuracy somewhere between a budget ands a conceptual estimate. Also note that additional filter fabric grades with different (mostly larger) pore sizes are now available. An increase in pore size can reduce the lateral forces acting on the barrier resulting in the ability to reduce the required barrier total effective area. This in turn can result in reduced costs.

The vendor recently provided a total capital cost estimate of 8 to 10 million dollars for full scale MLES™ system at the Arthur Kill Power Station in Staten Island, NY. The vendor is in the process of conducting a pilot study with an estimated cost of $750,000. The NYDEC reported the permitted cooling water flow rate for the Arthur Kill facility as 713 mgd or 495,000 gpm. Applying the cost equations results in a total capital cost of $8.7, $10.1 and $12.4 million dollars for low, average and high costs, respectively. These data indicate that the inflation adjusted cost for an average cost estimate in this application are within the accuracy range of a budget estimate. However, the cost estimates provided by Gunderboom are themselves estimates and may or may not accurately reflect project costs after completion. The vendor estimate for this project do however, indicate the vendors confidence in the module estimates at least in this flow range. The vendor had expressed a concern that for low flow applications the module costs may be too high. The range of module results (low and high) shown for the above example are consistent with budget estimate accuracy when compared to the average.

O&M Costs

Input Variables

Design intake flow was the primary variable.

O&M Costs

O&M costs are for the operation of the airburst system and fabric curtain maintenance. The cost estimates were obtained in a similar manner as the capital costs but in this case there was no recent corroboration of the original estimates. The range between the low, average, and high cost estimates indicate that the average O&M cost estimates should be considered as having an accuracy of a conceptual estimate and the cost estimates may be somewhat more accurate for higher flows.

5.0 FACILITY DOWNTIME ESTIMATES

In addition to the capital and annual operating and maintenance costs of the selected technology module, approximately 15% existing Phase III facilities will incur downtime costs. The basic approach to estimating downtime costs uses the same data and methodology used in the Phase II rulemaking (see the final Phase II Development Document). Downtime costs generally reflect decreased revenues due to lost production, or costs of supplemental power purchases incurred during the retrofit of existing cooling water intake structures. The length of downtime, when incurred, is a function of which technology is being retrofitted and the size of the intakes. Exhibit 5-23 provides this downtime in weeks. Facilities assigned technology modules 3, 4, 7, 12, or 14 were assessed downtime, except for four unique facilities as described below.

Exhibit 5-23. Weeks of Downtime Included in Costs of Technology Modules

Technology Module Description	Downtime in Weeks		
	DIF < 576 MGD	DIF between 576 MGD and 1152 MGD	DIF > 1152 MGD
New, larger intake with fine-mesh and fish handling and return system (module 3)	2 weeks	3 weeks	4 weeks
Addition of passive fine-mesh screen (modules 4 and 12)	9 weeks	10 weeks	11 weeks
Relocation to a submerged offshore location with passive fine-mesh screen (module 7)	9 weeks	10 weeks	10 weeks
Relocation of coastal to a submerged offshore location with passive fine-mesh screen (module 14)	9 weeks	10 weeks	11 weeks

Based on a review of the detailed technical surveys submitted by potential Phase III facilities, EPA has determined 7 facilities have more than a 50 MGD design intake flow and have multiple intakes. EPA examined flow diagrams and facility-level survey data describing the function of each intake, such as whether the intakes are dedicated intakes, or whether an intake has a small design intake flow and is labeled for non-routine use such as emergency back-up or fire suppression. EPA has concluded 4 of these facilities have multiple intakes where the intakes are not dedicated intakes. In other words, these four facilities could shut off any one intake and still meet their average intake flow without exceeding the total design intake flow of the remaining intakes. Furthermore, these facilities all have shoreline intakes (technology module 4), negating the need to maintain costly offshore equipment for the longer period of time necessary when conducting a retrofit one intake at a time. EPA assumes these four facilities with shoreline intakes could retrofit one intake at a time, thereby avoiding downtime costs. The retrofit costs for these four facilities still includes capital costs, equipment mobilization, labor, and contingency.

The average downtime costs for potential Phase III facilities is $10,650 per MGD of design intake flow. In Phase II, 18% of facilities incurred average downtime costs of $882 per MGD of design intake flow. The downtime cost (in dollars) varies for each individual facility; see the EA for more information.

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Chapter 6: Impingement Mortality and Entrainment Reduction Estimates

INTRODUCTION

In order to quantify the benefits derived from compliance with the proposed rule, estimates of the reduction in impingement mortality and entrainment for each facility must be calculated. This process is described in this chapter. A detailed example is included in Appendix 6A.

1.0 REQUIRED INFORMATION

The process of determining the estimated reduction in impingement mortality and entrainment as a result of the proposed rule (sometimes referred to as "benefits reduction") requires two components: 1) the results of the costing exercise and 2) a description of the regulatory options.

The costing exercise determines the costs for each facility to comply with the rule. This process is further described in the Economic and Benefit Analysis document. As a result of this exercise, specific performance standards are determined for each facility (based on the requirements of the rule) and a technology module is assigned to each facility (to meet those performance standards). Performance standards will either be "impingement mortality only" or "impingement mortality and entrainment," depending on what is required of the facility. One of 13 technology modules is then assigned to simulate the facility installing additional technology(ies) to meet the performance standards. If a facility is shown to already meet the performance standards, then no technology module is assigned.

The second piece of necessary information is a description of the regulatory options. In preparing the proposed rule, EPA analyzes several options for compliance. Under each option, a given facility may have different requirements. For more detail on the options considered by EPA for the proposed rule, see the preamble for today's rule.

2.0 ASSIGNING A REDUCTION

Once a compliance response has been determined for each facility, the benefit derived by installing a new technology can be assigned. The first step in calculating the benefits is to assign a reduction in impingement mortality and/or entrainment that is a direct result of compliance with the rule. As discussed in Chapter 4, impingement mortality and entrainment rates can be reduced by 80% and 60% respectively by installing new technology(ies). Once the impingement mortality and entrainment reduction has been determined, this information is used in calculating the benefits associated with a facility's compliance with the regulation. For details on the process of calculating the benefits associated with these reductions, see the Regional Benefit Assessment.

Assigning reductions in impingement mortality or entrainment to a facility depends on what reductions are required by the proposed rule and the technology module applied to the facility. In general, the process is to 1) determine what performance standards are required (impingement mortality only or impingement mortality and entrainment), 2) determine if the facility already meets either the impingement mortality or entrainment standards (via existing intake technologies), and 3) assign the appropriate reduction[1] of 80% or 0% (for impingement mortality) and 60% or 0% (for entrainment). For example, if a facility is required to meet impingement mortality standards and has no suitable technology to fulfill the requirements, a technology module will be assigned. The "new" technology will reduce the impingement mortality at the facility by the standard reduction of 80% (and possibly reduce entrainment as well).

On a larger scale, one can assign impingement mortality and entrainment reductions to the entire set of facilities in a few steps. This process is an exercise in sorting the data set by the appropriate data field and assigning a reduction based on what is required of the facility. Usually, the first data field by which to sort is the cost module that is applied to a facility. For facilities with no requirements, no compliance action is required by the facility and no benefit reductions (0% reduction for both impingement mortality and entrainment) are assigned to all of these facilities. Subsequent sort terms may include waterbody type, design intake flow, and the reduction requirements for a facility. For example, if all facilities with a design intake flow of less than 50 MGD located on a

[1] The I&E reductions assigned to a facility are a fixed value–80% for impingement mortality and/or 60% for entrainment. These values represent the lower end of the performance ranges (80 to 95% for impingement mortality and 60 to 80% for entrainment) established by EPA.

freshwater lake have only impingement mortality requirements, then these data fields can be used to identify all such facilities and the appropriate benefit reduction can be assigned to the entire set.

Again, the process is largely an exercise in sorting the data according to the data elements required to interpret and implement the regulatory option. Once the data is sorted, reductions are assigned accordingly with the reductions required from the costing exercise. Appendix A to this chapter contains a more detailed, step-by-step description of the entire process.

3.0 CONSIDERATIONS

The process of assigning impingement mortality and entrainment reductions carries several considerations, assumptions, and caveats.

1) A facility may qualify for "incidental benefits." If a facility has only impingement mortality compliance requirements but is assigned a cost module that corresponds to a technology that reduces both impingement mortality ***and*** entrainment, the incidental (or "extra") benefits are also assigned to the facility. Even though the reduction in entrainment is not explicitly required by the requirements for the given facility, site characteristics may dictate that a technology designed to reduce only impingement mortality may be impractical or less cost-efficient. In these cases, a technology designed to reduce both impingement mortality and entrainment may be assigned. Both the facility-level costs and benefits reflect this change.

2) Facilities that are to be regulated under best professional judgment (BPJ) under a given regulatory option are not assigned a reduction to impingement mortality or entrainment in this exercise, as there is no compliance action as a result of any national requirements. EPA does not, however, intend for these facilities to be exempt from any/all requirements as determined by the Director on a facility-specific basis.

3) EPA also conducted a sensitivity analysis by examining an adaptive management option. As stated above, any facility that is to be regulated under best professional judgment (BPJ) is not assigned a reduction in impingement mortality or entrainment. However, under the two adaptive management options, a facility regulated under BPJ is assigned a 5% or 15% reduction to both impingement mortality and entrainment reductions. EPA selected 5% and 15% reductions to reflect a reasonable estimate of the reductions attainable through optimization and proper operation and maintenance (O&M) of existing technologies by these facilities.

Under the co-proposed 50 MGD option, 262 facilities (of a total of 348 facilities) were assigned a reduction as a result of adaptive management (5% in one option, 15% in the second). When the 5% increase in the efficacy of operation and maintenance at these facilities is applied, the total national reduction in age 1 equivalent impingement and entrainment would increase by approximately 1.25%. For the 15% increase in efficacy, the reduction in age 1 equivalents would increase by approximately 3.8%.

Appendix 6A: Detailed Description of Impingement Mortality and Entrainment Reduction Estimates

INTRODUCTION

This appendix supplements Chapter 6 by providing a more detailed, step-by-step description of the process used to assign impingement mortality and entrainment reductions. This appendix uses a set of 10 fictional facilities with a variety of requirements, intake technologies, design intake flows (DIF), and waterbody types.

1.0 REQUIRED INFORMATION

1.1 Technology Costing Information

The technology costing exercise produces the first of the necessary components by determining what requirements are to be applied to each facility and assigning a technology module to meet those requirements. These results are used to determine both the facility-level costs and the facility-level benefits associated with compliance. These results are shown in Exhibit 6A-1 below.

Exhibit 6A-1. Results of Technology Costing

Facility ID	Waterbody Type	DIF (MGD)	Perf. Standards Required	Meets Imp. Standard?	Meets Ent. Standard?	No New Tech. Needed?	Tech. Cost Module	Incidental Benefit?	Imp. Reduction	Ent. Reduction
1	Freshwater River	10	I & E	TRUE	FALSE	FALSE	4	NO		
2	Freshwater River	8	I only	FALSE	TRUE	FALSE	1	NO		
3	Freshwater River	11	I only	TRUE	TRUE	TRUE	0	NO		
4	Estuary/ Tidal River	113	I & E	TRUE	TRUE	TRUE	0	NO		
5	Freshwater River	73	I & E	FALSE	FALSE	FALSE	2a	NO		
6	Freshwater River	126	I only	TRUE	TRUE	TRUE	0	NO		
7	Great Lakes	17	I & E	TRUE	FALSE	FALSE	3	NO		
8	Great Lakes	88	I only	TRUE	TRUE	TRUE	0	NO		
9	Lake/ Reservoir	8	I only	TRUE	TRUE	TRUE	0	NO		
10	Great Lakes	22	I only	FALSE	TRUE	FALSE	9	YES		

Description of the Data Fields

Facility ID: Unique identifier.
Waterbody Type: Type of waterbody upon which the facility is located.
Design Intake Flow: Design intake flow for the facility.
Performance Standards Required: Under the requirements of the proposed rule, what performance standards is the facility required to meet? Note that this is irrespective of what technologies may already be in place at a facility.
Meets Impingement Standard: Does the facility qualify as having met the requirements for impingement? This may be accomplished by existing technologies, closed-cycle cooling, or a low intake velocity (less than 0.5 feet per second).

Meets Entrainment Standard: Does the facility qualify as having met the requirements for entrainment? This may be accomplished by existing technologies or closed-cycle cooling.
No New Technology Needed: Based on the performance standards the facility is required to meet and the existing technologies, will the facility be required to install any new technologies to meet the standards?
Technology Cost Module: The technology module assigned by EPA to the facility in order to comply with the rule. (This does not necessarily reflect the technology the facility may ultimately install. See Chapter 5 in this Technical Development Document for more details.)
Incidental Benefit: If a facility has only impingement compliance requirements but is assigned a cost module that corresponds to a technology that reduces both impingement mortality *and* entrainment, the incidental (or "extra") benefits are also assigned to the facility. See section 6 in this Technical Development Document for more details.
Impingement Reduction: The reduction in impingement mortality assigned to a facility as a result of compliance with the proposed rule.
Entrainment Reduction: The reduction in entrainment assigned to a facility as a result of compliance with the proposed rule.

1.2 Regulatory Options Considered

The second component is a description of the regulatory options considered. Interpretation of these options will guide the process of assigning impingement mortality and entrainment reductions.

Option 1: Facilities with a design intake flow of 20 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this option, section 316(b) requirements Phase III facilities with a design intake flow of less than 20 MGD would be established on a case-by-case, best professional judgment, basis.

Option 2: Facilities with a design intake flow of 50 MGD or greater, as well as facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) when located on estuaries, oceans, or the Great Lakes would be subject to the performance standards and compliance alternatives proposed in today's rule. Facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) that withdraw from freshwater rivers and lakes would have to meet the performance standards for impingement only and not for entrainment. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 20 MGD would be established on a case-by-case, best professional judgment, basis.

Option 3: Facilities with a design intake flow of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule. Facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) would have to meet the performance standards for impingement only and not for entrainment. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 20 MGD would be established on a case-by-case, best professional judgment, basis.

Option 4: Facilities with a design intake flow of 50 MGD or greater, as well as facilities with a design intake flow between 20 and 50 MGD (20 MGD inclusive) when located on estuaries, oceans, or the Great Lakes would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Facilities that withdraw from freshwater rivers and lakes and all facilities with a design intake flow of less than 20 MGD would have requirements established on a case-by-case, best professional judgment, basis.

Option 5 (Co-proposed Option): Facilities with a design intake flow of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 50 MGD would be established on a case-by-case, best professional judgment, basis.

Option 6: Facilities with a design intake flow of greater than 2 MGD would be subject to the proposed performance standards and compliance alternatives. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of 2 MGD or less would be established on a case-by-case, best professional judgment, basis.

Option 7: Facilities with a design intake flow of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Facilities with a design intake flow between 30 and 50 MGD (30 MGD inclusive) would have to meet the performance standards for impingement only and not for entrainment. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 30 MGD would be established on a case-by-case, best professional judgment, basis.

Option 8 (Co-proposed Option): Facilities with a design intake flow of 200 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 200 MGD would be established on a case-by-case, best professional judgment, basis.

Option 9 (Co-proposed Option): Facilities with a design intake flow of 100 MGD or greater and located on oceans, estuaries, and the Great Lakes would be subject to the performance standards and compliance alternatives proposed in today's rule and discussed above. Under this regulatory option, section 316(b) requirements for Phase III facilities with a design intake flow of less than 100 MGD would be established on a case-by-case, best professional judgment, basis.

2.0 ASSIGNING A THRESHOLD

As described in Chapter 6, assigning the reductions is essentially an exercise in interpreting the compliance alternative and categorizing facilities by the appropriate data field. Several examples will be used to illustrate this process.

2.1 Facilities With No Requirements

Assigning a 0% reduction for both impingement mortality and entrainment to those facilities that are not required to add any new technologies is often the simplest first step. In this case, sort the data by the "No New Technology Needed" or the "Technology Cost Module" field and assign a 0% / 0% for each facility with a "TRUE" or a "0" as the assigned technology cost module. In other words, a facility with no new technology (a 0 module) is assigned no reduction for impingement mortality or entrainment. Section 2.2 will begin to address assigning reductions to facilities with non-zero requirements (those with no reductions in the table below).

Exhibit 6A-2. Assigning Zero Reductions

Facility ID	Waterbody Type	DIF (MGD)	Perf. Standards Required	Meets Imp. Standard?	Meets Ent. Standard?	No New Tech. Needed?	Tech. Cost Module	Incidental Benefit?	Imp. Reduction	Ent. Reduction
3	Freshwater River	11	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
4	Estuary/ Tidal River	113	I & E	TRUE	TRUE	TRUE	0	NO	0%	0%
6	Freshwater River	126	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
8	Great Lakes	88	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
9	Lake/ Reservoir	8	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
1	Freshwater River	10	I & E	TRUE	FALSE	FALSE	4	NO		
2	Freshwater River	8	I only	FALSE	TRUE	FALSE	1	NO		
5	Freshwater River	73	I & E	FALSE	FALSE	FALSE	2a	NO		
7	Great Lakes	17	I & E	TRUE	FALSE	FALSE	3	NO		
10	Great Lakes	22	I only	FALSE	TRUE	FALSE	9	YES		

2.2 Example of A Co-Proposed Threshold (Option 5)

The co-proposed 50 MGD option is relatively straightforward to interpret and assign impingement mortality and entrainment reductions. Beginning with the data from section 2.1 above, sort the remaining facilities by the design intake flow, as it is the primary criterion for the proposed option. Since only Facility 5 falls above the 50 MGD threshold, it is the only facility for which a reduction

will be assigned. Under the proposed rule, Facility 5 is required to meet both impingement mortality and entrainment requirements and it does not meet either standard. Therefore, it will install a new technology to meet both performance standards. As a result, impingement mortality and entrainment will be reduced by the introduction of this new technology and the standard reduction (80% / 60%) is assigned.

Facilities 2, 1, 7 and 10 fall below the 50 MGD threshold and would be regulated on a best professional judgment basis. Since these facilities may not install any new technologies to comply with the rule, it is assumed they will not be assigned a reduction.

Exhibit 6A-3. Assigning Reductions Under Option 5

Facility ID	Waterbody Type	DIF (MGD)	Perf. Standards Required	Meets Imp. Standard?	Meets Ent. Standard?	No New Tech. Needed?	Tech. Cost Module	Incidental Benefit?	Imp. Reduction	Ent. Reduction
3	Freshwater River	11	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
4	Estuary/ Tidal River	113	I & E	TRUE	TRUE	TRUE	0	NO	0%	0%
6	Freshwater River	126	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
8	Great Lakes	88	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
9	Lake/ Reservoir	8	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
2	Freshwater River	8	I only	FALSE	TRUE	FALSE	1	NO	0% (BPJ)	0% (BPJ)
1	Freshwater River	10	I & E	TRUE	FALSE	FALSE	4	NO	0% (BPJ)	0% (BPJ)
7	Great Lakes	17	I & E	TRUE	FALSE	FALSE	3	NO	0% (BPJ)	0% (BPJ)
10	Great Lakes	22	I only	FALSE	TRUE	FALSE	9	YES	0% (BPJ)	0% (BPJ)
5	Freshwater River	73	I & E	FALSE	FALSE	FALSE	2a	NO	80%	60%

The benefit reductions for the example co-proposed option are now complete.

2.2.1 *Adaptive Management*

As an illustration of the adaptive management sensitivity analysis noted in Chapter 6 of this Technical Development Document, the data from section 2.2 would appear as follows in a scenario where facilities regulated by best professional judgment are assigned a 5% reduction for impingement mortality and entrainment.

Exhibit 6A-4. Assigning Reductions Under the Proposed Option, with 5% Adaptive Management

Facility ID	Waterbody Type	DIF (MGD)	Perf. Standards Required	Meets Imp. Standard?	Meets Ent. Standard?	No New Tech. Needed?	Tech. Cost Module	Incidental Benefit?	Imp. Reduction	Ent. Reduction
3	Freshwater River	11	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
4	Estuary/ Tidal River	113	I & E	TRUE	TRUE	TRUE	0	NO	0%	0%
6	Freshwater River	126	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
8	Great Lakes	88	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
9	Lake/ Reservoir	8	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
2	Freshwater River	8	I only	FALSE	TRUE	FALSE	1	NO	5% (BPJ)	5% (BPJ)
1	Freshwater River	10	I & E	TRUE	FALSE	FALSE	4	NO	5% (BPJ)	5% (BPJ)
7	Great Lakes	17	I & E	TRUE	FALSE	FALSE	3	NO	5% (BPJ)	5% (BPJ)
10	Great Lakes	22	I only	FALSE	TRUE	FALSE	9	YES	5% (BPJ)	5% (BPJ)
5	Freshwater River	73	I & E	FALSE	FALSE	FALSE	2a	NO	80%	60%

2.3 Option 2

Option 2 (which is not one of today's co-proposed options) provides another, more complex example scenario. Beginning with the initial data set from section 1.1, identify the facilities with no reductions, as in section 2.1. The requirements for the remaining facilities is dependent upon two factors: design intake flow and waterbody type. Sort the data for the facilities with no reduction, assign those 0% reductions, and assign a reduction for Facility 5, as the benefits reductions for these facilities is the same as in the example in section 2.2.

It happens that the data is already sorted by waterbody type and then design intake flow, serving to group similar facilities together. Under Option 2, facilities located on freshwater rivers and having a design intake flow between 20 and 50 MGD are required to meet only impingement requirements. Facility 2 would be assigned an 80% reduction for impingement mortality, as it is required to meet the impingement standard and does not presently do so. Facility 1, on the other hand, does currently meet the impingement standard and therefore is assigned no reduction in impingement mortality. Both Facility 2 and 1are assigned 0% for an entrainment reduction as it is no longer required, even if the performance standards of the rule indicate otherwise. Option 2 relaxes those performance standards for these facilities.

Under Option 2, facilities located on one of the Great Lakes and having a design intake flow between 20 and 50 MGD are required to meet both impingement and entrainment requirements. Facility 7 already meets the impingement standard and is assigned only a 60% reduction for entrainment. Facility 10 already meets the entrainment standard and would normally be assigned an 80% / 0% reduction to reflect the addition of a technology to meet only the impingement requirements. However, due to site-specific characteristics, it is more efficient to install a technology that reduces both impingement mortality and entrainment. As a result, this facility is assigned an incidental benefit of a 60% reduction for entrainment.

Exhibit 6A-5. Assigning Reductions Under Option 2, Including Incidental Benefits

Facility ID	Waterbody Type	DIF (MGD)	Perf. Standards Required	Meets Imp. Standard?	Meets Ent. Standard?	No New Tech. Needed?	Tech. Cost Module	Incidental Benefit?	Imp. Reduction	Ent. Reduction
3	Freshwater River	11	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
4	Estuary/ Tidal River	113	I & E	TRUE	TRUE	TRUE	0	NO	0%	0%
6	Freshwater River	126	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
8	Great Lakes	88	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
9	Lake/ Reservoir	8	I only	TRUE	TRUE	TRUE	0	NO	0%	0%
2	Freshwater River	8	I only	FALSE	TRUE	FALSE	1	NO	80%	0%
1	Freshwater River	10	I & E	TRUE	FALSE	FALSE	4	NO	0%	0%
7	Great Lakes	17	I & E	TRUE	FALSE	FALSE	3	NO	0%	60%
10	Great Lakes	22	I only	FALSE	TRUE	FALSE	9	YES	80%	60%
5	Freshwater River	73	I & E	FALSE	FALSE	FALSE	2a	NO	80%	60%

2.4 Conclusion

The above examples illustrate the range of data manipulation involved in assigning impingement mortality and entrainment reductions. The reductions for the other options follow similar logic and require no further illustration.

Chapter 7: Cost-Cost Test

INTRODUCTION

This chapter presents the cost-cost test for alternative site-specific requirements. The first two sections present the requirements of the cost-cost test and the data needs to carry out the test. Section 3.0 presents the step-by-step instructions for carrying out the cost-cost test and the tabular data to be used with the cost-cost test. Section 4.0 presents the background information that supports the cost correction equations.

Note that the costs presented in this chapter reference costs developed for year 2002 dollars, which were used to develop Phase II facility costs. However, all costs for Phase III facilities presented in the preamble of today's proposed rule reflect costs that were adjusted to year 2003 dollars. Additionally, the applications of the cost-cost test discussed in this chapter also reflect similarities to the cost-cost test for Phase II.

1.0 SITE-SPECIFIC REQUIREMENTS - THE COST TO COST TEST

The proposed rule in § 125.103(a) (2) through (4) allows for a comparison between the projected costs of compliance of a facility (based on data specific to the facility) to the costs considered by the Agency for a facility like yours. A facility requesting a cost-cost determination must submit a Comprehensive Cost Evaluation Study and a Site Specific Technology Plan, the requirements of each can be found at § 125.104(b)(6)(i) and 125.104(b)(6)(iii), respectively. The Comprehensive Cost Evaluation Study must include engineering cost estimates in sufficient detail to document the costs of implementing design and construction technologies, operational measures, and/or restoration measures at the facility that would be needed to meet the applicable performance standards of the final rule; a demonstration that the documented costs significantly exceed the costs considered by EPA for a facility like yours in establishing the applicable performance standards; and engineering cost estimates in sufficient detail to document the costs of implementing alternative design and construction technologies, operational measures, and/or restoration measures in the facility's Site-Specific Technology Plan. If the facility's costs are significantly greater than the costs considered by the Agency for a facility like yours, then the Director may make a site specific determination of the best technology available for minimizing adverse environmental impact.

2.0 DETERMINING A FACILITY'S COSTS

To make the demonstration that compliance costs are significantly greater than those considered by EPA, the facility must first determine its actual compliance costs. To do this, the facility first should determine the costs for any new design and construction technologies, operational measures, and/or restoration measures that would be needed to comply with the requirements of § 125.103 (a)(2) through (4), which may include the following cost categories: the installed capital cost of the technologies or measures, the net operation and maintenance (O&M) costs for the technologies or measures (that is, the O&M costs for the final suite of technologies and measures once all new technologies and measures have been installed less the O&M costs of any existing technologies and measures), the net revenue losses (lost revenues minus saved variable costs) associated with net construction downtime (actual construction downtime minus that portion which would have been needed anyway for repair, overhaul or maintenance) and any pilot study costs associated with on-site verification and/or optimization of the technologies or measures.

Costs should be annualized using a 7 percent discount rate, with an amortization period of 10 years for capital costs and 30 years for pilot study costs and construction downtime net revenue losses. Annualized costs should be converted to 2002 dollars ($2002), using the engineering news record construction cost index (see Engineering News-Record. New York: McGraw Hill. Annual average value is 6538 for year 2002). Costs for permitting and post-construction monitoring should not be included in this estimate, as these are not included in the EPA-estimated costs against which they will be compared, as described below. Because existing facilities already incur monitoring and permitting costs, and these are largely independent of the specific performance standards adopted and technologies selected to meet them, it is both simpler and more appropriate to conduct the cost comparison required in this provision using direct compliance costs (capital, net O&M, net construction downtime, and pilot study) only. Adding permitting and monitoring costs to both sides of the comparison would complicate the methodology without substantially changing the results.

To calculate the costs that the Administrator considered for a like facility in establishing the applicable performance standards, the facility must follow the steps laid out below, based on the information in Exhibit 7-2 provided in section 3.0 of this chapter. Note that those facilities that claimed the flow data that they submitted to EPA, and which EPA used to calculate compliance costs, as confidential business information (CBI), are not listed in the table provided in Exhibit 7-2, unless the total calculated compliance costs were zero. If these facilities wish to request a site-specific determination of best technology available based on significantly greater

compliance costs, they will need to waive their claim of confidentiality prior to submitting the Comprehensive Cost Evaluation Study so that EPA can make the necessary flow data available to the facility, Director, and public.

Cost Categories Considered By The Agency

The installed **capital cost** of the technology (suite) represents the material, equipment, and labor costs of the technology and retrofit, the civil and site work costs, instrumentation and controls, electrical (installed), construction management, engineering and architectural fees, contingency, overhead and profit, non-316(b) related permits, metalwork, performance bond, and insurance. Once determined by the facility, the capital costs for comparison to the Agency's estimates must be amortized with a 7 percent discount factor and a 10 year amortization period. The dollar years of the capital costs must be expressed in 2002 average dollars. The Agency used the Engineering News-Record Construction Cost Index (McGraw-Hill, New York, NY) for estimating dollar year values. The capital costs are presented in pre-tax form for the cost to cost comparison.

The **net operation and maintenance costs** of the technology or technology suite is the projected operation and maintenance costs of the upgraded intake technology, post-construction and start-up, less the operation and maintenance costs of the cooling water intake structures(s) in-place at the facility prior to enacting the technology upgrade. The Agency considered the periodic replacement of parts, the periodic and intermittent maintenance of the technology (such as debris clearing, parts changeout, etc.), the periodic and intermittent inspection of the technology, the energy usage of screen motors and spray wash and fish return pumps, and management/technician labor. Additional factors may apply for special intakes located far offshore, such as diver inspections, or for net systems or wedgewire screens, such as energy and maintenance costs associated with self-cleaning airburst systems. The Agency notes that for the technologies considered for meeting the requirements of the final rule that cooling water intake flows did not change from baseline to the technology upgrade. As a result the operation and maintenance of the main cooling water intake pumps would typically not be considered a component of a net operation and maintenance cost for the purposes of the cost to cost test. Some facilities may choose to comply with the requirements of the rule by adopting strategic flow reduction activities. As such, reduced O&M costs associated with reduced intake flows for strategic plant operation should not be factored into the compliance comparison of costs, as the Agency did not account for these savings in its cost estimates. Similarly, if dredging of canals or screen areas was a typical portion of the maintenance activities of the site at baseline, then the net operation and maintenance costs for the purposes of the cost to cost test may not include these costs. The Agency represented O&M costs on an annual basis. The O&M costs are presented in pre-tax form for the cost to cost comparison.

The Agency determined the cost of the technology connection outage **downtime** as the revenue loss during the downtime less the variable expenses that would normally be incurred during that period. The duration of the connection outage should be the total construction outage less any concurrent outages due to planned maintenance. The Agency notes that with the flexible compliance scheduling allowed with the final rule that facilities will have opportunities to plan construction schedules to take advantage of concurrent downtime periods (such as period inspections and maintenance outages). The following formulas were used to calculate the net loss due to downtime:

$$\textit{Cost of Connection Outage} = \textit{Revenue Loss} - \textit{Variable Production Costs}$$

where

$$\textit{Variable Production Cost} = \textit{Fuel Cost} + \textit{Variable Operating} \Lambda \textit{Maintenance Cost.}$$

The Agency amortized net construction downtime costs using a discount rate of 7 percent and an amortization period of 30 years. The downtime costs are presented in pre-tax form for the cost to cost comparison.

The technology **pilot study** costs associated with site verification of the technology estimated by the Agency included the total capital and total operation and maintenance costs associated with a technology pilot study. Because pilot studies, by their nature, are short term activities, the Agency represented the total cost of the study as a one-time capital cost, even though the actual study may be extend out over a half-year to two-years; the total cost of the study was represented as a single one-time cost. Therefore, facilities enacting pilot studies should represent the total costs of the pilot study in a similar manner. Similar to a construction project lasting several months to years, some minor correction for dollar years may be necessary. The Agency amortized total capital costs using a discount rate of 7 percent and an amortization period of 30 years. The pilot study costs are presented in pre-tax form for the cost to cost comparison.

Site-specific Technology Plan

The Site-Specific Technology Plan is developed based on the results of the Comprehensive Cost Evaluation Study and must contain the following information:

- A narrative description of the design and operation of all existing and proposed design and construction technologies, operational measures, and/or restoration measures that you have selected;
- An engineering estimate of the efficacy of the proposed and/or implemented design and construction technologies or operational measures, and/or restoration measures. This estimate must include a site-specific evaluation of the suitability of the technologies or operational measures for reducing impingement mortality and/or entrainment (as applicable) of all life stages of fish and shellfish based on representative studies (e.g., studies that have been conducted at cooling water intake structures located in the same waterbody type with similar biological characteristics) and, if applicable, site-specific technology prototype or pilot studies. If restoration measures will be used, you must provide a Restoration Plan (see § 125.104 (b)(5));
- A demonstration that the proposed and/or implemented design and construction technologies, operational measures, and/or restoration measures achieve an efficacy that is as close as practicable to the applicable performance standards of § 125.103(b) without resulting in costs significantly greater than either the costs considered by the Administrator for a facility like yours in establishing the applicable performance standards, or as appropriate, the benefits of complying with the applicable performance standards at your facility; and,
- Design and engineering calculations, drawings, and estimates prepared by a qualified professional to support the elements of the Plan.

3.0 COST TO COST TEST

The data in Exhibit 7-2 is keyed to survey ID number. Exhibit 7-3 presents a crosswalk between survey ID number and facility name. Facilities should also be able to determine their ID number from the survey they submitted to EPA during the rule development process.

Step 1: Determine which technology EPA modeled as the most appropriate compliance technology for your facility. To do this, use the code in column 12 of Exhibit 7-2 to look up the modeled technology in Exhibit 7-1 below.

Exhibit 7-1. Technology Codes and Descriptions

Technology Code	Technology Description
1	Addition of fish handling and return system to an existing traveling screen system
2	Addition of fine-mesh screens to an existing traveling screen system
3	Addition of a new, larger intake with fine-mesh and fish handling and return system in front of an existing intake system
4	Addition of passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 1.75 mm
5	Addition of a fish net barrier system
6	Addition of an aquatic filter barrier system
7	Relocation of an existing intake to a submerged offshore location with passive fine-mesh screen inlet with mesh width of 1.75 mm
8	Addition of a velocity cap inlet to an existing offshore intake
9	Addition of passive fine-mesh screen to an existing offshore intake with mesh width of 1.75 mm
11	Addition of dual-entry, single-exit traveling screens (with fine- mesh) to a shoreline intake system
12	Addition of passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 0.76 mm
13	Addition of passive fine-mesh screen to an existing offshore intake with mesh width of 0.76 mm
14	Relocation of an existing intake to a submerged offshore location with passive fine-mesh screen inlet with mesh width of 0.76 mm

Step 2: Using EPA's costing equations, calculate the annualized capital and net operation and maintenance costs for a facility with your design flow using this technology. To do this, you should use the following formula, which is derived from the results of EPA's costing equations (see section 4.0 of this chapter for more discussion) for a facility like yours using the selected technology:

$$y_f = y_{epa} + m * (x_f - x_{epa}),$$

where:

y_f = annualized capital and net O&M costs using actual facility design intake flow,
x_f = actual facility design intake flow (in gallons per minute),
x_{epa} = EPA assumed facility design intake flow (in gallons per minute) (column 3),
y_{epa} = Annualized capital and net O&M costs using EPA design intake flow (column 7), and
m = design flow adjustment slope (column 13).

EPA has provided some additional information in Exhibit 7-2, beyond that which is needed to perform the calculations, to facilitate comparison of the results obtained using formula 1 to the detailed costing equations presented in Chapter 1 of this document, for those who wish to do so. EPA does not expect facilities or permit writers to do this, and has in fact provided the simplified formula to preclude the need for doing so, but is providing the additional information to increase transparency. Thus, for informational purposes, the total capital cost (not annualized), baseline O&M cost, and post construction O&M cost from which the annualized capital and net O&M costs using EPA design intake flow (y_{epa} in column 7) are derived are listed separately in columns 4 through 6. To calculate y_{epa}, EPA annualized the total capital cost using a 7 percent discount rate and 10 year amortization period, and added the result to the difference between the post construction O&M costs and the baseline O&M costs.

Note that some entries in Exhibit 7-2 have "n/a" indicated for the EPA assumed design intake flow in column 2. These are facilities for which EPA projected that they would already meet otherwise applicable performance standards based on existing technologies and measures. EPA projected zero compliance costs for these facilities, irrespective of design intake flow, so no flow adjustment is needed. These facilities should use $0 as their value for the costs considered by EPA for a like facility in establishing the applicable performance standards. EPA recognizes that these facilities will still incur permitting and monitoring costs, but these are not included in the cost comparison for the reasons stated above.

Step 3: Determine the annualized net revenue loss associated with net construction downtime that EPA modeled for the facility to install the technology and the annualized pilot study costs that EPA modeled for the facility to test and optimize the technology. The sum of these two figures is listed in column 10. For informational purposes, the total (not annualized) net revenue losses from construction downtime, and total (not annualized) pilot study costs are listed separately in columns 8 and 9. These two figures were annualized using a 7% discount rate and 30 year amortization period and the results added together to get the annualized facility downtime and pilot study costs in column 10.

Step 4: Add the annualized capital and O&M costs using actual facility design intake flow (y_f from step 2), and the annualized facility downtime and pilot study costs (column 10 from step 3) to get the preliminary costs considered by EPA for a facility like yours.

Step 5: Determine which performance standards in 125.103(b)(1) and (2) (i.e., impingement mortality only, or impingement mortality and entrainment) are applicable to your facility, and compare these to the performance standards on which EPA's cost estimates are based, listed in column 11. If the applicable performance standards and those on which EPA's cost estimates are based are the same, then the preliminary costs considered by EPA for a facility like yours are the final costs considered by EPA for a facility like yours. If only the impingement mortality performance standards are applicable to your facility, but EPA based its cost estimates on impingement mortality and entrainment performance standards, then you should divide the preliminary costs by a factor of 2.148 to get the final costs. If impingement mortality and entrainment performance standards are applicable to your facility, but EPA based its cost estimates on impingement mortality performance standards only, then you should multiply the preliminary costs by 2.148 to get the final costs. See section 4.0 of this chapter for more discussion of the performance standard correction factor.

Survey IDs

The survey ID for a facility was that assigned to the recipients of either the short technical questionnaire (STQ) or the detailed questionnaire (DQ). The Agency assigned short technical questionnaire recipients questionnaire IDs in the form of "AUT0001", where the "AUT" prefix was constant and the four number suffix varies for each facility. The Agency assigned detailed questionnaire recipient questionnaire IDs dependent on the type of recipient. Utilities received IDs in the form of "DUT1000", where the "DUT" prefix was constant and the four number suffix varied in the "1000" range for each recipient. Nonutilities received IDs in the form of "DNU2000", where the "DNU" prefix was constant and the four number suffix varied in the "2000" range for each recipient.

Municipality operated facilities received IDs in the form of "DMU3000", where the "DMU" prefix was constant and the four number suffix varied in the "3000" range for each recipient.

Exhibit 7-2 presents costs for individual cooling water intake structures only for the case of detailed questionnaire recipients. For short technical questionnaire recipients, the Agency necessarily estimated costs on the facility-level by assuming that the entire set of intakes at the facility would have the intake characteristics reported at the facility level. Short technical questionnaire recipients would make the potential corrections to EPA's estimated costs at the facility-level only (as outlined in Steps 2, 3, and 4 below).

In completing the questionnaire, the detailed questionnaire respondents assigned each cooling water intake structure at their plant a designating number or name (through part 2, question 1a). The Agency has included these reported intake descriptors in Exhibit 7-2 to allow the detailed questionnaire recipients to identify individual intake structures. Even though the cost to cost test is evaluated on the facility level, detailed questionnaire recipients would make potential corrections to EPA's estimated capital and O&M costs as outlined in Step 2 for each cooling water intake structure and then aggregate at the facility-level.

If a facility within the scope of the rule completed and returned a questionnaire but is not included in Exhibit 7-1, then the facility may have claimed cooling water intake flow information pertaining to their facility to be confidential business information (CBI). If these facilities wish to request a site-specific determination of best technology available based on significantly greater compliance costs, they will need to waive their claim of confidentiality prior to submitting the Comprehensive Cost Evaluation Study so that EPA can make the necessary flow data available to the facility, Director, and public.

Because the Agency has based its list of facilities projected to be within the scope of the rule on information collected through a survey that is subject to some degree of uncertainty, there could be a small set of facilities that are subject to this rule that may not be included in Exhibit 7-2. Exhibit 7-2 is the Agency's best estimate of the facilities that it projects to fall within the scope of the final rule (less those claiming flow information as CBI). However, Exhibit 7-2 is not a definitive list of the inscope population of facilities for the final rule. Therefore, a complying facility may discover when attempting to conduct a cost to cost test that the Agency did not include costs for the particular facility in Exhibit 7-2. This is not to say that the Agency has not considered costs for the facility, as the Agency scaled its national costs to represent weighted a population of facilities not receiving the survey. In the case of a facility not included in Exhibit 7-2, the method for determining the representative costs that EPA considered for a similar facility should be conducted by assessing the projected annual capital cost + net annual O&M cost of the intake technology determined by a facility like that facility. Figures 7-1 through 7-13 provide estimated equations for calculating annual capital cost + net annual O&M cost for each technology module considered by the Agency. In addition, the facility should find in Exhibit 7-2 facilities with the same cost-correction equation slope (m) and could utilize the median annualized facility-level downtime and pilot study costs for that technology in the comparison.

Exhibit 7-2. Costs Considered by EPA in Establishing Performance Standards ($2002)

[Note: Exhibits 7-2 and 7-3 are taken from Phase II and serve as placeholders only.]

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (Y_{epa})
AUT0001		401,881	$ 322,884	$ 699,866	$ 795,393	$ 141,498
AUT0002		549,533	$ 5,750,259	$ 68,489	$ 104,063	$ 854,282
AUT0004		239,107	$ 528,427	$ 30,725	$ 104,458	$ 148,969
AUT0011		453,758	$ 967,675	$ 55,545	$ 193,660	$ 275,890
AUT0012		2,018,917	$ 48,835,329	$ 360,813	$ 989,876	$ 7,582,115
AUT0014		572,383	$ 2,732,729	$ 91,057	$ 110,893	$ 408,915
AUT0015		1,296,872	$ 510,784	$ -	$ 134,070	$ 206,794
AUT0016		301,127	$ 41,613	$ -	$ 28,195	$ 34,120
AUT0019		848,784	$ 11,094,343	$ 271,045	$ 994,876	$ 2,303,416
AUT0020		207,514	$ 1,517,779	$ 34,859	$ 42,089	$ 223,327

Exhibit 7-3. Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0001	Cane Run
AUT0002	Chesapeake
AUT0004	Hennepin
AUT0010	Bowen
AUT0011	Shawville
AUT0012	Diablo Canyon Nuclear
AUT0013	Montville
AUT0014	Williams
AUT0015	Northport
AUT0016	Cholla

4.0 COST CORRECTION

Derivation of the cost correction equation and technology module slopes.

Rather than providing the detailed costing equations that EPA used to calculate annualized capital and net O&M costs for facilities to use each of the modeled technologies, EPA has provided the simplified formula (equation 1), which collapses the results of those equations for the particular facility and technology into a single result (y_{epa}) and then allows the facility to adjust this result to reflect its actual design intake flow, using a technology specific slope for a facility like yours that is derived from the costing equations. This allows facilities to perform the flow adjustment in a straightforward and transparent manner. The Agency analyzed each of the cooling water intake structures (facilities) predicted to implement each technology module with respect to its annual capital plus net O&M costs, normalized by design intake flow. The Agency then performed a best-fit for each technology, as presented in Figures 7-1 through 7-13.

Derivation of the correction factor for impingement mortality and/or entrainment requirements.

In calculating compliance costs, EPA projected what performance standards would be applicable to the facility based on available data. However, because of both variability and uncertainty in the underlying parameters that determine which performance standards apply (e.g., capacity utilization rate, mean annual flow), it is possible that in some cases the performance standards that EPA projected are not correct. The adjustment factor of 2.148 was determined by taking the ratio of median compliance costs for facilities to meet impingement mortality and entrainment performance standards over median compliance costs for facilities to meet impingement mortality performance standards only. While using this adjustment factor will not necessarily yield the exact compliance costs that EPA would have calculated had it had current information, EPA believes the results are reasonable for determining whether a facility's actual compliance costs are "significantly greater than" the costs considered by EPA for a like facility in establishing the applicable performance standards. EPA believes it is preferable to provide a simple and transparent methodology for making this adjustment that yields reasonably accurate results, rather than a much more complex methodology that would be difficult to use and understand (for the facility, permit writer, and public), even if the more complex methodology would yield slightly more accurate results. DCN 6-3588 in the confidential business information docket provides the calculations upon which the correction factor is based.

Figure 7-1. Module 1: Add fish handling and return system to traveling screens

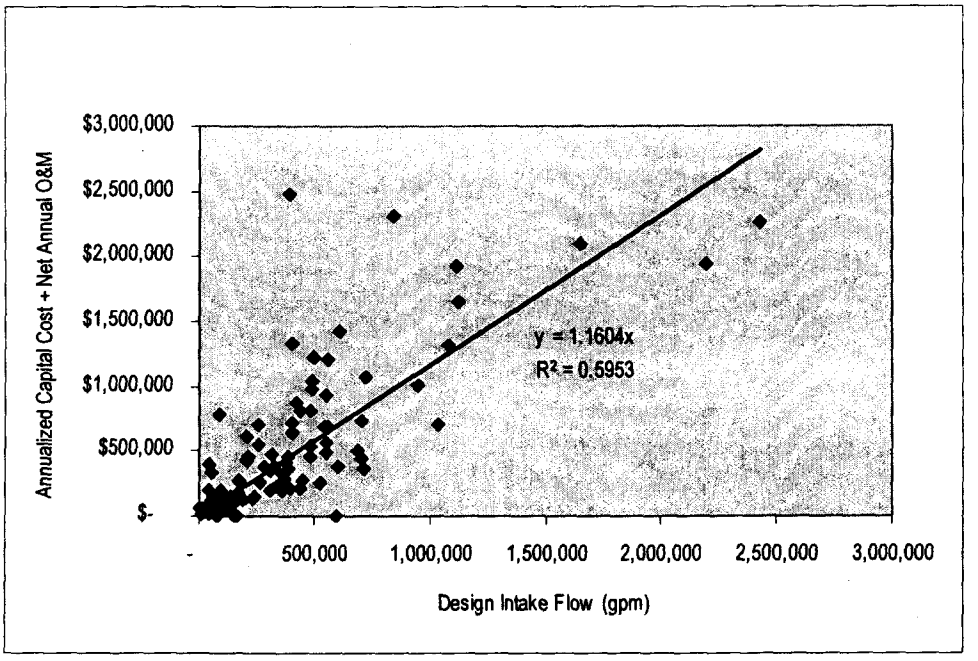


Figure 7-2. Module 2: Add fine-mesh screens to traveling screens

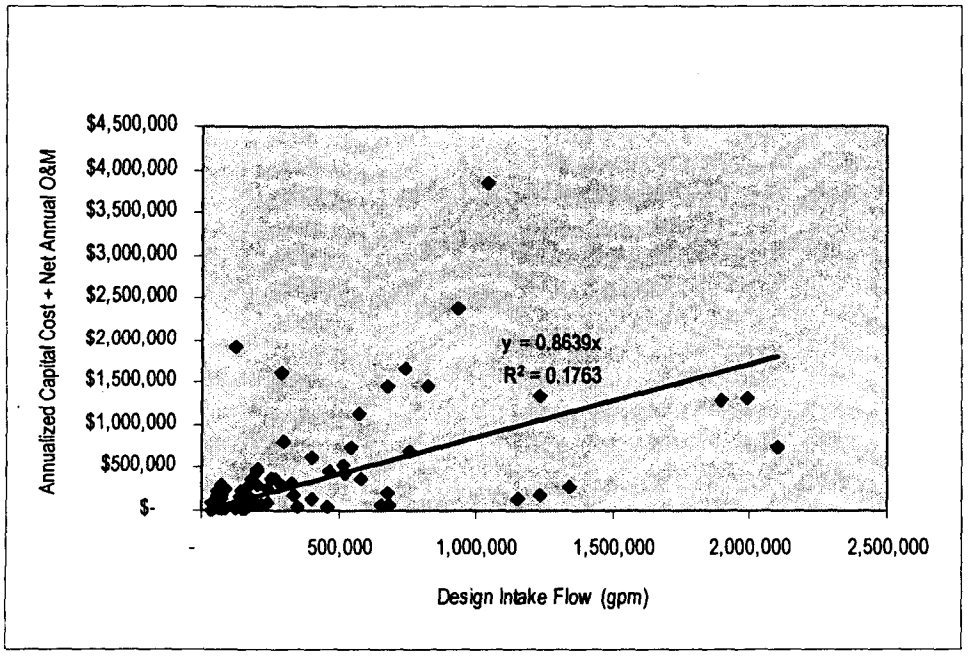


Figure 7-3. Module 3: Add new, larger intake in front of existing intake

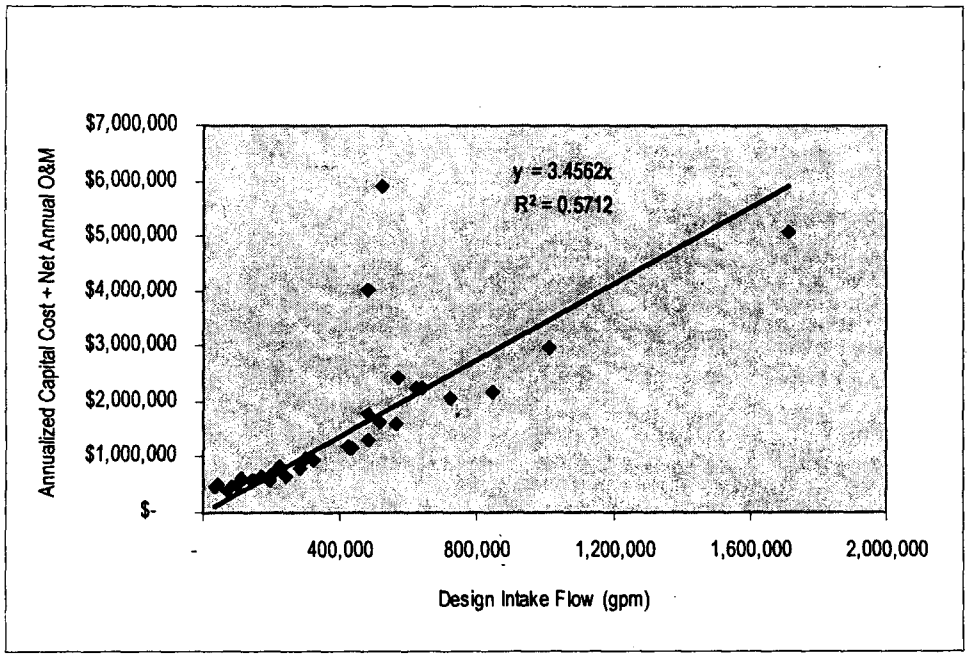


Figure 7-4. Module 4: Add passive fine-mesh screen near shoreline w/ 1.75 mm mesh

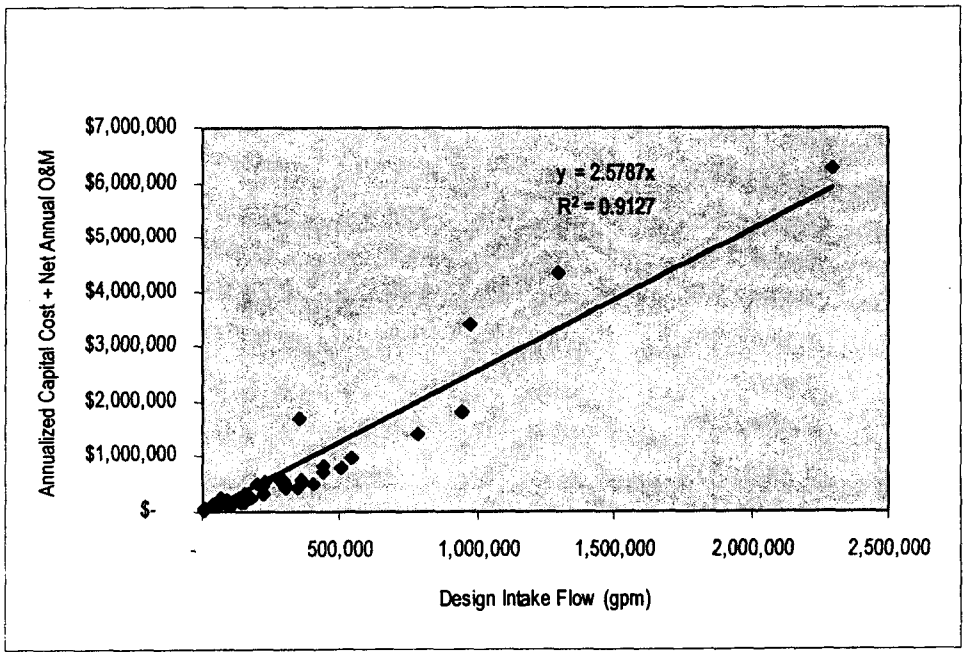


Figure 7-5. Module 5: Add fish net barrier system

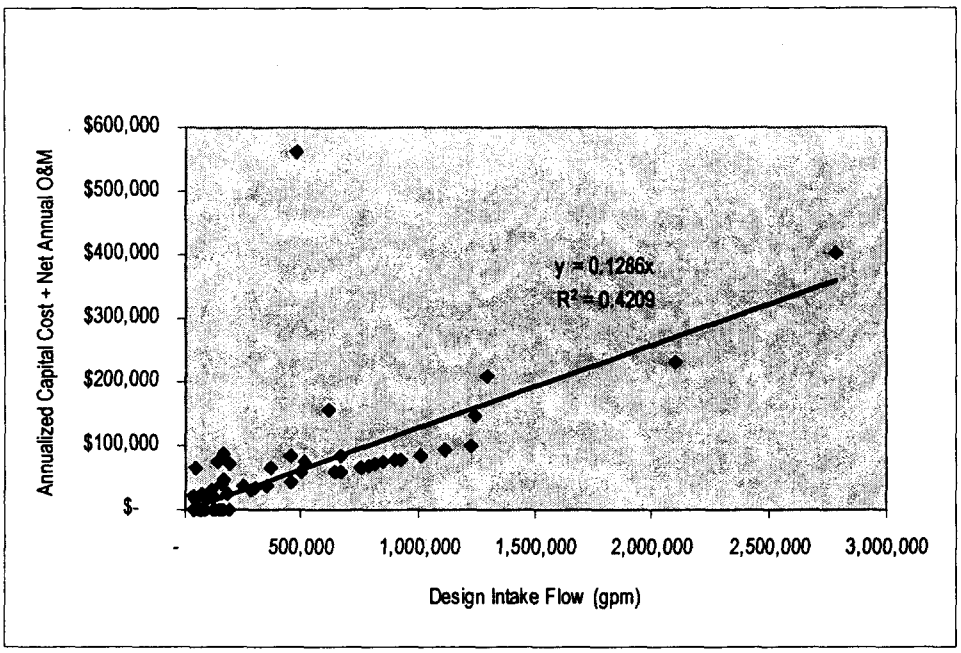


Figure 7-6. Module 6: Add aquatic filter barrier system

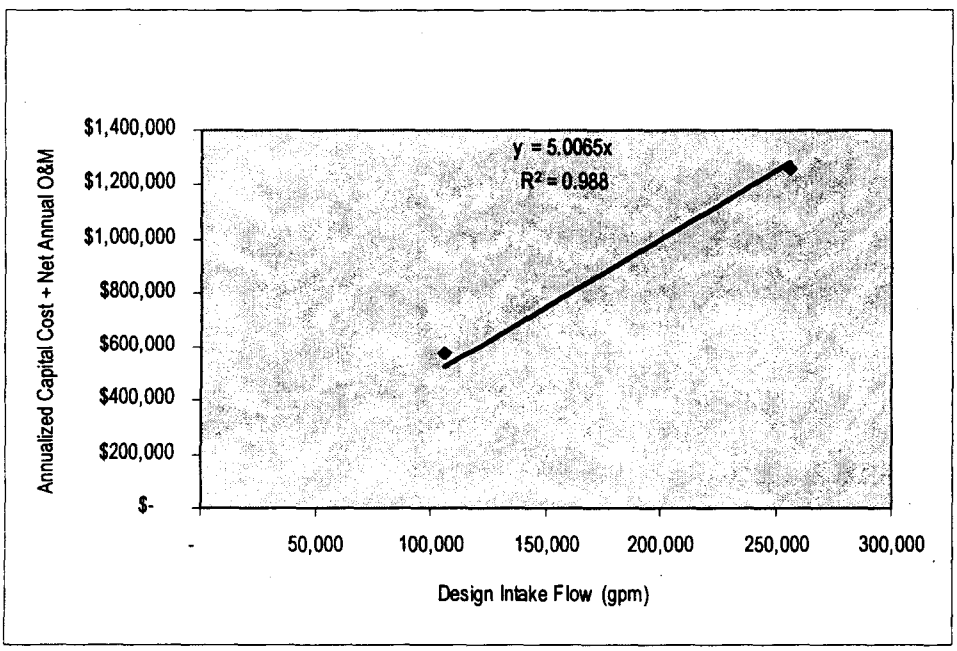


Figure 7-7. Module 7: Relocate to submerged offshore w/passive fine-mesh screen inlet & 1.75 mm mesh

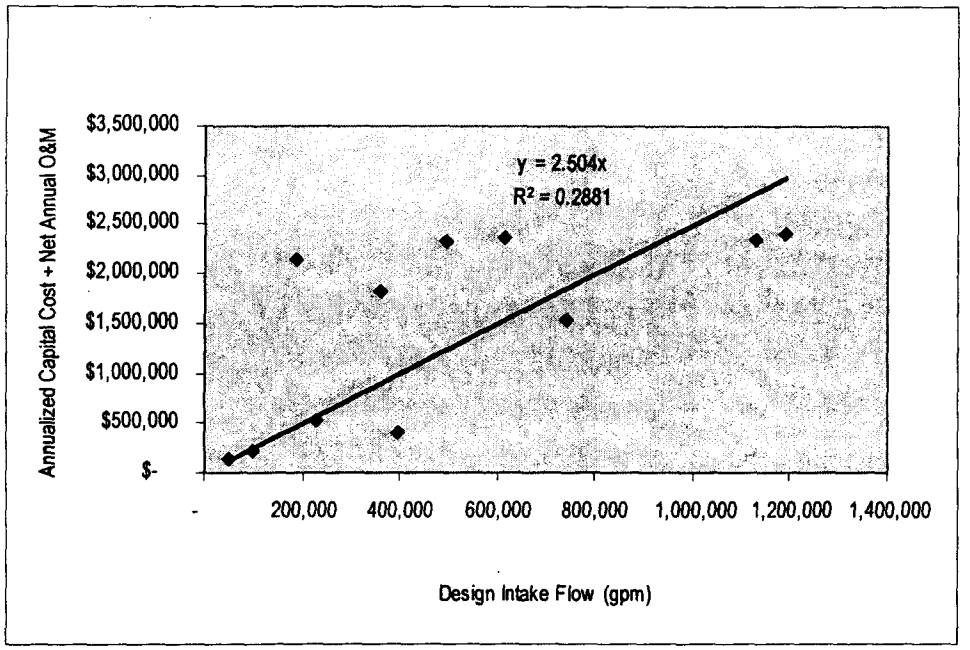


Figure 7-8. Module 8: Add velocity cap inlet to offshore intake

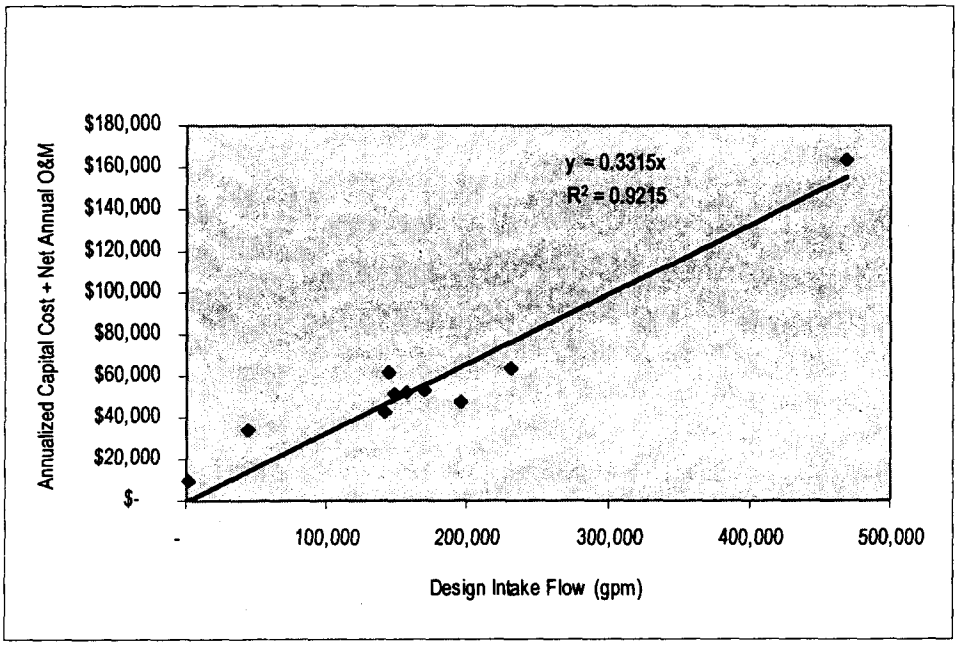


Figure 7-9. Module 9: Add passive fine-mesh screen to offshore intake w/ 1.75 mm mesh

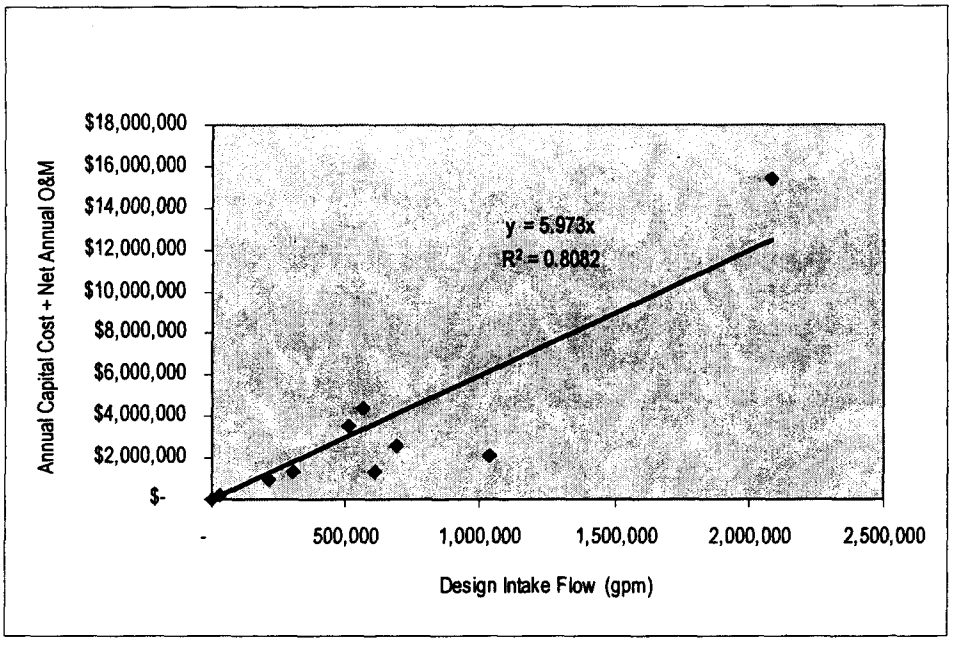


Figure 7-10. Module 11: Add dual-entry, single-exit traveling screens (with fine-mesh)

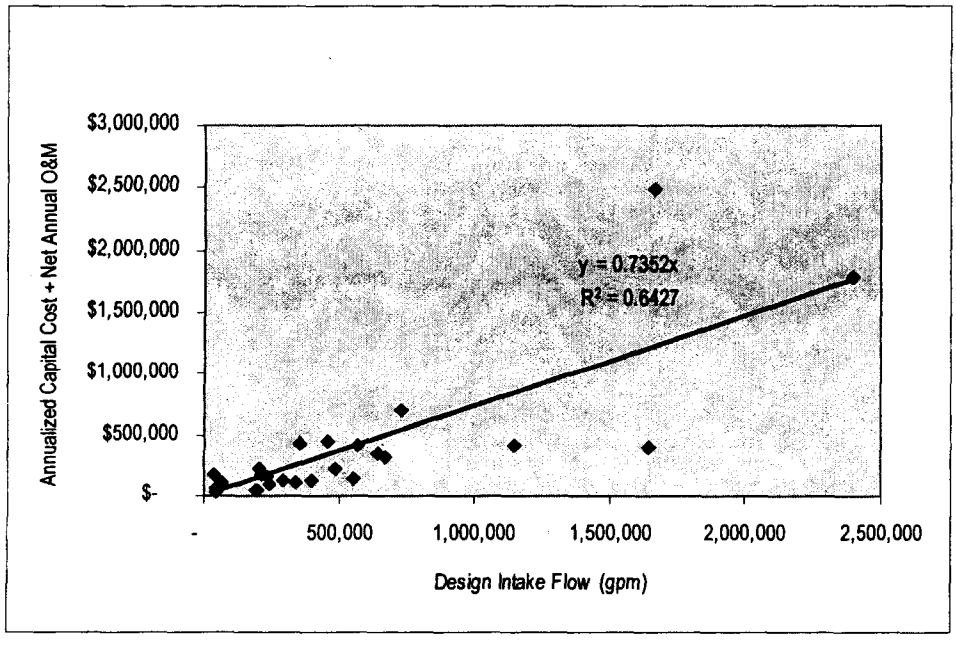


Figure 7-11. Module 12: Add passive fine-mesh screen near shoreline w/ 0.76 mm mesh

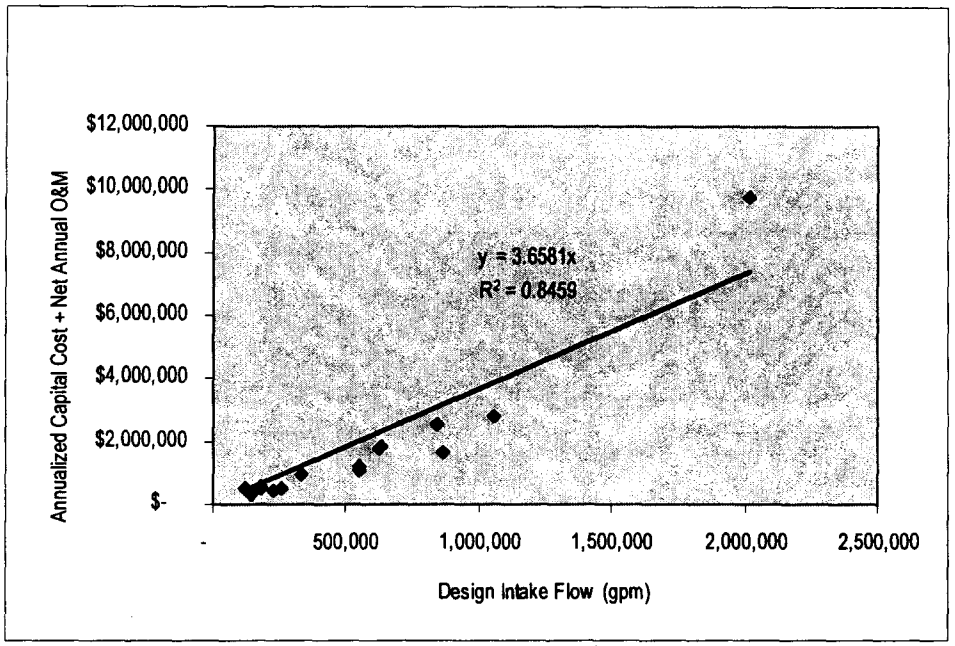


Figure 7-12. Module 13: Add passive fine-mesh screen to offshore intake w/ 0.76 mm mesh

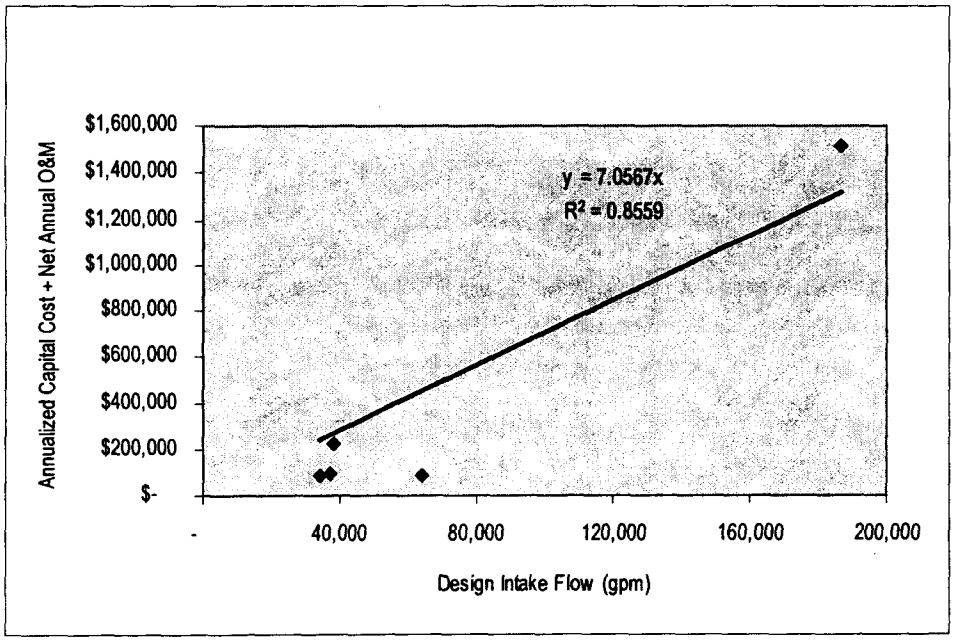
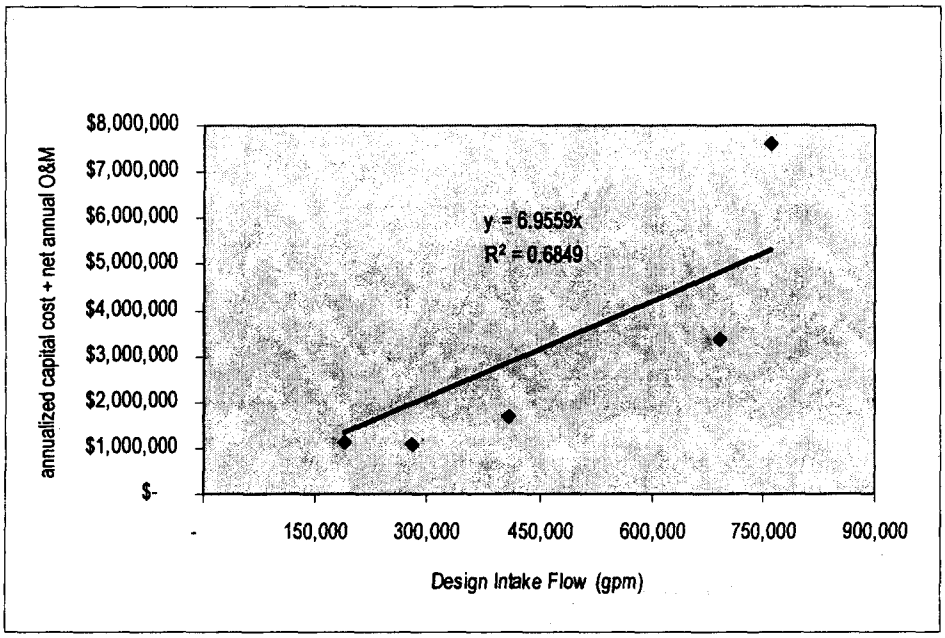


Figure 7-13. *Module 14: Relocate to submerged offshore w/ passive fine-mesh screen inlet & 0.76 mm mesh*



Chapter 8: Efficacy of Cooling Water Intake Structure Technologies

INTRODUCTION

This chapter presents the data compiled by the Agency on the performance of the range of technologies currently used to minimize impingement mortality and entrainment (I&E) at existing manufacturing facilities and offshore oil and gas extraction facilities nationwide.

Although uniform national requirements under the proposed rule would only apply to manufacturing facilities, based on the co-proposed thresholds, the technologies described for Phase III facilities are the same as those used by Phase II electricity generation facilities to meet section 316(b) requirements. EPA considers the types of intakes and the technologies available to address impingement and entrainment at Phase II facilities to be consistent with the intakes and technologies at Phase III existing facilities.

I. EXISTING MANUFACTURING FACILITIES

1.0 DATA COLLECTION OVERVIEW

To support the section 316(b) proposed rule for existing facilities, the Agency compiled data on the performance of the range of technologies currently used to minimize impingement and entrainment (I&E) at power plants nationwide. The goal of this data collection and analysis effort was to determine whether specific technologies could be shown to provide a consistent level of proven performance. The information compiled was used to compare specific regulatory options and their associated costs and benefits, as well as provide stakeholders with a comprehensive summary of previous studies designed to assess the efficacy of the various technologies. It provided the supporting information for the rule and alternative regulatory options considered during the development process and final action by the Administrator.

Throughout this chapter, *baseline technology performance* refers to the performance of conventional, wide-mesh traveling screens that are not intended to prevent impingement and/or entrainment. The term *alternative technologies* generally refer to those technologies, other than closed-cycle recirculating cooling systems, that can be used to minimize impingement and/or entrainment. Overall, the Agency has found that performance and applicability vary to some degree based on site-specific and seasonal conditions. The Agency has also determined, however, that alternative technologies can be used effectively on a widespread basis if properly designed, operated, and maintained.

1.1 Scope of Data Collection Efforts

The Agency has compiled readily available information on the nationwide performance of I&E-reduction technologies. This information has been obtained through the following:

- Literature searches and associated collection of relevant documents on facility-specific performance.
- Contacts with governmental (e.g., Tennessee Valley Authority (TVA)) and non-governmental entities (e.g., Electric Power Research Institute (EPRI)) that have undertaken national or regional data collection efforts/performance studies.
- Meetings with and visits to the offices of EPA regional and State agency staff as well as site visits to operating power plants.

It is important to recognize that the Agency did not use a systematic approach to data collection; that is, the Agency did not obtain all the facility performance data available nor did it obtain the same amount and detail of information for every facility. The Agency is not aware of such an evaluation ever being performed nationally. The most recent national data compilation was conducted by EPRI in 2000; see *Fish Protection at Cooling Water Intakes, Status Report*. The findings of that report are cited extensively in the following subsections. EPRI's analysis, however, was primarily a literature collection and review effort and was not intended to be an exhaustive compilation and analysis of all available data. Through this evaluation, EPA worked to build on the EPRI review by reviewing primary study documents cited by EPRI as well as through the collection and reviewing of additional data.

1.2 Technology Database

In an effort to document and further assess the performance of various technologies and operational measures designed to minimize the impacts of cooling water withdrawals, EPA compiled a database of documents to allow analyses of the efficacy of a specific technology or suite of technologies. The data collected and entered into this database came from materials ranging from brief journal articles to the more intensive analyses found in historical section 316(b) demonstration reports and technology evaluations. In preparing this database, EPA assembled as much documentation as possible within the available timeframe to support future Agency decisions. It should be noted that the data may be of varying quality. EPA did not validate all database entries. However, EPA did evaluate the general quality and thoroughness of the study. Information entered into the database includes some notation of the limitations the individual studies might have for use in further analyses (e.g., no biological data or conclusions).

EPA's intent in assembling this information was fourfold. First, the Agency sought to develop a categorized database containing a comprehensive collection of available literature regarding technology performance. The database is intended to allow, to the extent possible, a rigorous compilation of data supporting the determination that the proposed performance standards are considered best technology available. Second, EPA used the data to demonstrate that the technologies chosen as compliance technologies for costing purposes are reasonable and can meet the performance standards. Third, the availability of a user-friendly database will allow EPA, state permit writers, and the public to more easily evaluate potential compliance options and facility compliance with performance standards. Fourth, EPA attempted to evaluate the technology efficacy data against objective criteria to assess the general quality and thoroughness of each study. This evaluation might assist in further analysis of conclusions made using the data.

Basic information from each document was recorded in the database (e.g., type of technology evaluated, facility at which it was tested). In addition to basic document information, the database contains two types of information: (1) general facility information and (2) detailed study information.

For those documents that refer to a specific facility (or facilities), basic technical information was included to enable EPA to classify facilities according to general categories. EPA collected locational data (e.g., waterbody type, name, state), as well as basic cooling water intake structure configuration information. Each technology evaluated in the study is also recorded, along with specific details regarding its design and operation. Major categories of technologies include modified traveling screens, wedgewire screens, fine-mesh screens, velocity caps, barrier nets, and behavioral barriers. (Data identifying the technologies present at a facility, as well as the configuration of the intake structure, refer to the configuration when the study was conducted and do not necessarily reflect the present facility configuration).

Information on the type of study, along with any study results, is recorded in the second part of the database. EPA identifies whether the study evaluates the technology with respect to impingement mortality reduction (or avoidance), entrainment survival, or entrainment exclusion (or avoidance). Some studies address more than one area of concern, and that is noted. EPA records basic biological data used to evaluate the technology, if such data are provided. These data include target or commercially/recreationally valuable species, species type, life history stage, size, sample size, and raw numbers of impinged and/or entrained organisms. Finally, EPA records any overall conclusions reached by the study, usually presented as a percentage reduction or increase, depending on the area of focus. Including this information for each document allows EPA and others to readily locate and compare documents addressing similar technologies. Each document is reviewed according to five areas of data quality where possible: (1) applicability and utility, (2) soundness, (3) clarity and completeness, (4) uncertainty and variability, and (5) evaluation and review. Because the compiled literature comes from many different sources and was developed under widely varying standards, EPA reviewed all documents in the database against all five criteria.

To date, EPA has collected 153 documents for inclusion in the database. The Agency did not exclude from the database any document that addressed technology performance in relation to impingement mortality and entrainment, regardless of the overall quality of the data.

1.3 Data Limitations

Because EPA did not undertake a systematic data collection effort with consistent data collection procedures, there is significant variability in the information available from different data sources. This variability leads to the following data limitations:

- Some facility data include all the major species and associated life stages present at an individual facility, whereas others include only data for selected species and/or life stages. The identification of important species can be a valid method for determining the overall effectiveness of a technology if the criteria used for selection are valid. In some studies, target species are identified but no reason for their selection is given.

- Many of the data were collected in the 1970s and early 1980s when existing facilities were required to complete their initial 316(b) demonstrations. In addition, the focus of these studies was not the effectiveness of a particular technology but rather the overall performance of a facility in terms of rates of impingement and entrainment.

- Some facility data includes only initial survival results, whereas other facilities have 48- to 96-hour survival data. These longer-term survival data are relevant because some technologies can exhibit significant latent mortality after initial survival.

- Analytical methods and collection procedures, including quality assurance/quality control protocols, are not always present or discussed in summary documentation. Where possible, EPA has reviewed study methods and parameters to determine qualifications, if any, that must be applied to the final results.

- Some data come from laboratory and pilot-scale testing rather than full-scale evaluations. Laboratory studies offer unique opportunities to control and alter the various inputs to the study but might not be able to mimic the real-world variables that could be present at an actual site. Although EPA recognizes the value of laboratory studies and does not discount their results, *in situ* evaluations remain the preferred method for gauging the effectiveness of a technology.

- Survival rates calculated in individual studies can vary as to their true meaning. In some instances, the survival rate for a given species (initial or latent) has been corrected to account for the mortality rate observed in a control group. Other studies explicitly note that no control groups have been used. These data are important because overall mortality, especially for younger and more fragile species, can be adversely affected by the collection and observation process–factors that would not affect mortality under unobserved conditions.

EPA recognizes that the practicality or effectiveness of alternative technologies might not be uniform under all conditions. The chemical and physical nature of the waterbody, facility intake requirements, climatic conditions, and biology of the area all affect feasibility and performance. Despite the above limitations, however, EPA has concluded that significant general performance expectations can be inferred for the range of technologies and that one or more technologies (or groups of technologies) can provide significant impingement mortality and/or entrainment protection at most sites. In addition, in EPA's view many of the technologies have the potential for even greater applicability and higher performance when facilities optimize their use.

The remainder of this chapter is organized by groups of technologies. A brief description of conventional, once-through traveling screens is provided for comparison purposes. Fact sheets describing each technology, available performance data, and design requirements and limitations are provided in Attachment A. It is important to note that this chapter does not provide descriptions of all potential cooling water intake structure (CWIS) technologies. (ASCE 1982 generally provides such an all-inclusive discussion.) Instead, EPA has focused on those technologies that have shown significant promise at the laboratory, pilot-scale, or full-scale levels in consistently minimizing impingement mortality and/or entrainment. In addition, this chapter does not identify every facility where alternative technologies have been used but rather only those where some measure of performance in comparison to conventional screens has been made. The chapter concludes with a brief discussion of how the location of intakes (as well as the timing of water withdrawals) can also be used to limit potential impingement mortality and/or entrainment effects. Habitat restoration projects are an additional means to comply with this rule. Such projects, however, have not had widespread application at existing facilities. Because the nature, feasibility, and likely effectiveness of such projects would be highly site-specific, EPA has not attempted to quantify their expected performance level in this document.

1.4 Conventional Traveling Screens

For impingement control technologies, performance is compared to conventional (unmodified) traveling screens, the baseline technology. These screens are the most commonly used intake technology at older existing facilities, and their operational performance is well established. In general, these technologies are designed to prevent debris from entering the cooling water system, not to minimize I&E. The most common intake designs include front-end trash racks (usually consisting of fixed bars) to prevent large debris from entering the system. The traveling screens are equipped with screen panels mounted on an endless belt that rotates through the water vertically. Most conventional screens have 3/8-inch mesh that prevents smaller debris from clogging the condenser tubes. The screen wash is typically high-pressure (80 to 120 pounds per square inch (psi)). Screens are rotated and washed intermittently, and fish that are impinged often die because they are trapped on the stationary screens for extended periods. The high-pressure wash also frequently kills fish, or they are re-impinged on the screens. Approximately 89 percent of all existing facilities within the scope of this rule use conventional traveling screens.

1.5 Closed-cycle Wet Cooling System Performance

Although flow reduction serves the purpose of reducing both impingement and entrainment, flow reduction requirements function foremost as a reliable entrainment reduction technology. Throughout this chapter, EPA compares the performance of entrainment-reducing technologies to that of recirculating wet cooling towers. To evaluate the feasibility of regulatory options with flow reduction requirements and to allow comparison of costs and benefits of alternatives, EPA determined the likely range in flow reductions between wet, closed-cycle cooling systems and once through systems. In closed-cycle systems, certain chemicals will concentrate as they continue to be recirculated through the tower. Excess buildup of such chemicals, especially total dissolved solids, affects the tower's performance. Therefore, some water (blowdown) must be discharged and make-up water added periodically to the system. An additional question that EPA has considered is the feasibility of constructing salt-water make-up cooling towers. For the development of the New Facility 316(b) rule, EPA contacted Marley Cooling Tower (Marley), which is one of the largest cooling tower manufacturers in the world. Marley provided a list of facilities (Marley 2001) that have installed cooling towers that use marine or otherwise high total dissolved solids/brackish make-up water. It is important to recognize the facilities listed represent only a selected group of facilities for which Marley has constructed cooling towers worldwide.

2.0 ALTERNATIVE TECHNOLOGIES

2.1 Modified Traveling Screens and Fish Handling and Return Systems

Technology Overview

Conventional traveling screens can be modified so that fish impinged on the screens can be removed with minimal stress and mortality. Ristroph screens have water-filled lifting buckets that collect the impinged organisms and transport them to a fish return system. The buckets are designed such that they will hold approximately 2 inches of water once they have cleared the surface of the water during the normal rotation of the traveling screens. The fish bucket holds the fish in water until the screen rises to a point at which the fish are spilled onto a bypass, trough, or other protected area (Mussalli, Taft, and Hoffman 1978). Fish baskets are another modification of a conventional traveling screen and may be used in conjunction with fish buckets. Fish baskets are separate framed screen panels attached to vertical traveling screens. An essential feature of modified traveling screens is continuous operation during periods when fish are being impinged. Conventional traveling screens typically operate intermittently. (EPRI 2000, 1989; Fritz 1980). Removed fish are typically returned to the source waterbody by sluiceway or pipeline. ASCE (1982) provides guidance on the design and operation of fish return systems.

Technology Performance

A wide range of facilities nationwide have used modified screens and fish handling and return systems to minimize impingement mortality. Although many factors influence the overall performance of a given technology, modified screens with a fish return capability have been deployed with success under varying waterbody conditions. In recent years, some researchers, primarily Fletcher (1996), have evaluated the factors that affect the success of these systems and described how they can be optimized for specific applications. Fletcher cited the following as key design factors:

- Shaping fish buckets or baskets to minimize hydrodynamic turbulence within the bucket or basket.
- Using smooth-woven screen mesh to minimize fish descaling.
- Using fish rails to keep fish from escaping the buckets or baskets.
- Performing fish removal prior to high-pressure washing for debris removal.
- Optimizing the location of spray systems to provide a more gentle fish transfer to sloughs.
- Ensuring proper sizing and design of return troughs, sluiceways, and pipes to minimize harm.

2.1.1 Example Studies

Although uniform national requirements under the proposed rule would only apply to manufacturing facilities, based on the co-proposed thresholds, the technologies described for Phase III facilities are the same as those used by Phase II electricity generation facilities to meet section 316(b) requirements. EPA considers the types of intakes and the technologies available to address impingement and entrainment at Phase II facilities to be consistent with the intakes and technologies at Phase III existing facilities.

Salem Generating Station

Salem Generating Station, on the Delaware Bay estuary in New Jersey, converted 6 of its 12 conventional traveling screen assemblies to a modified design that incorporated improved fish buckets constructed of a lighter composite material (which improved screen

rotation efficiency), smooth-woven mesh material, an improved spray wash system (both low- and high-pressure), and flap seals to improve the delivery of impinged fish from the fish buckets to the fish return trough.

The initial study period consisted of 19 separate collection events during mid-summer 1996. The configuration of the facility at the time of the study (half of the screens had been modified) allowed for a direct comparison of the effectiveness of the modified and unmodified screens on impingement mortality rates. The limited sampling timeframe enabled the analysis of only the species present in numbers sufficient to support any statistical conclusions. 1,082 juvenile weakfish were collected from the unmodified screens while 1,559 were collected from the modified structure. Analysts held each sample group separately for 48 hours to assess overall mortality due to impingement on the screens. Results showed that use of the modified screens had increased overall survival by as much as 20 percent over the use of the unmodified screens. Approximately 58 percent of the weakfish impinged on the unmodified screens survived, whereas the new screens had a survival rate approaching 80 percent. Both rates were based on 48-hour survival and not adjusted for the mortality of control samples.

Water temperature and fish length are two independent factors cited in the study as affecting overall survival. Researchers noted that survival rates decreased somewhat as the water temperature increased, possibly as a result of lower levels of dissolved oxygen. Survival rates decreased to a low of 56 percent for the modified screens when the water temperature reached its maximum of 80°F. At the same temperature, the survival rate on the unmodified screens were 35 percent. Differences in survival rates were also attributable to the size of the fish impinged. In general, small fish (< 50 mm) fared better on both the modified and unmodified screens than large fish (> 50 mm). The survival rates of the two size categories did not differ significantly for the modified screens (85 percent survival for small, 82 percent for large), although a more pronounced difference was evident on the unmodified screens (74 percent survival for small, 58 percent for large).

Salem Generating Station conducted a second series of impingement sampling from 1997 to 1998. By that time all screen assemblies had been modified to include fish buckets and a fish return system as described above. Additional modifications to the system sought to enhance the chances of survival of fish impinged against the screens. One modification altered the fish return slide to reduce the stress on fish being delivered to the collection pool. Flap seals were improved to better seal gaps between the fish return and debris trough, thus preventing debris from affecting returning fish. Researchers used a smaller mesh screen in the collection pools during the 1997-1998 sampling events than had been used during the 1995 studies. The study notes that the larger mesh used in 1995 might have enabled smaller fish to escape the collection pool. Since smaller fish typically have a higher mortality rate due to physical stress than larger fish, the actual mortality rates may have been greater than those found in the 1995 study.

The second impingement survival study analyzed samples collected from October through December 1997 and April through September 1998. Samples were collected twice per week and analyzed for survival at 24- and 48-hour intervals. Six principal species were identified as constituting the majority of the impinged fish during the sampling periods: weakfish, white perch, bay anchovy, Atlantic croaker, spot, and *Alosa* spp. Fish were sorted by species and size, classified by their condition, and placed in holding tanks.

For most species, survival rates varied noticeably depending on the season. For white perch, survival was above 90 percent throughout the sample period (as high as 98 percent in December). Survival rates for weakfish varied from a low of 18 percent in July to a high of 88 percent in September. Although the number of weakfish collected in September was approximately one-fifth of the number collected in July, a possible explanation for the variation in survival rates is the modifications to the collection system described above, which were implemented during the study period. Similarly, bay anchovy fared worst during the warmer months, dropping to a 20 percent survival rate in July while achieving a 72 percent rate during November. Rates for Atlantic croaker varied from 58 percent in April to 98 percent in November. Spot were collected in only one month (November) and had a survival rate of 93 percent. The survival rate for the *Alosa* spp. (alewife, blueback herring, and American shad) remained relatively consistent, ranging from 82 percent in April to 78 percent in November.

For all species in the study, with the exception of weakfish, survival rates improved markedly with the use of the modified screen system when compared to data from 1978-1982, when the unmodified system was still in use.

Mystic Station

Mystic Station, on the Mystic River in Massachusetts, converted one of its two conventional traveling screen assemblies to a modified system incorporating fish collection buckets and a return system in 1981 to enable a side-by-side comparison of impingement survival. Fish buckets were attached to each of the screen panels. Low-pressure spray (10 psi) nozzles were installed to remove fish from the buckets and into the collection trough. The screen system was modified to include a two-speed motor with a four-speed transmission to enable various rotation speeds for the traveling screens.

The goal of the study was to determine the optimal screen rotation speed and rotation interval that could achieve the greatest survival rate without affecting the screen performance. The study analyzes 2-, 4- and 8-hour rotation intervals as well as continuous rotation.

Samples were collected from October 7, 1980 to April 27, 1981. Fish collected from the screens were sorted several times per week, classified, and placed into holding tanks for 96 hours to observe latent mortality.

Results from the study indicated that impingement of the various species was highly seasonal in nature. Data from Unit 7 during the sample period indicate that in terms of both biomass and raw numbers, the majority of fish are present in the vicinity, and thus susceptible to impingement, during the fall and early winter. Almost 50 percent of the *Alosa* spp. were collected during one week in November, while 75 percent of the smelt were collected in a 5-week period in late fall. Likewise, nearly 60 percent of the winter flounder were collected in January. These data suggest that optimal rotation speeds and intervals, whatever they might be, might not be necessary throughout the year.

Continuous rotation of the screens, regardless of speed, resulted in a virtual elimination of impingement mortality for winter flounder. For all other species, survival generally increased with screen speed and rotation interval, with the best 96-hour survival rate (50 percent) occurring at a continuous rotation at 15 feet per second. The overall survival rate is affected by the high latent mortality of *Alosa* spp. in the sample. The study speculates that the overall survival rates would be markedly higher under actual (unobserved) operating conditions, given the high initial survival for large *Alosa* spp. Fragile species such as *Alosa* can be adversely affected by the stresses of collection and monitoring and might exhibit an abnormally higher mortality rate as a result.

Indian Point Unit 2

Indian Point is located on the eastern shore of the Hudson River in New York. In 1985, the facility modified the intake for Unit 2 to include a fish lifting trough fitted to the face of the screen panels. Two low-pressure (10 psi) spray nozzles removed collected fish into a separate fish return sluiceway. A high-pressure spray flushed other debris into a debris trough. The new screen also incorporated a variable speed transmission, enabling the rotation of the screen panels at speeds of up to 20 feet per minute. For the study period, screens were continuously rotated at a speed of 10 feet per minute.

The sampling period lasted from August 15, 1985 to December 7, 1985. Fish were collected from both the fish trough and the debris trough, though survival rates are presented for the fish collected from the fish trough only. The number of fish collected from the debris trough was approximately 45 percent of the total collected from the fish trough; the survival rate of these fish is unknown. Control groups were not used to monitor the mortality associated with natural environmental factors such as salinity, temperature, and dissolved oxygen. Collected fish were held in observation tanks for 96 hours to determine a latent survival rate.

White perch composed the majority (71 percent) of the overall sample population. Survival rates ranged from 63 percent in November to 90 percent in August. It should be noted that during the month with the greatest abundance (December), the survival rate was 67 percent. This generally represents the overall survival rate for this species because 75 percent of white perch collected during the sample period were collected during December. Weakfish were the next most abundant species, with an overall survival rate of 94 percent. A statistically significant number of weakfish were collected only during the month of August. Atlantic tomcod and blueback herring were reported to have survival rates of 73 percent and 65 percent, respectively. Additional species present in small numbers had widely varying survival rates, from a low of 27 percent for alewife to a high of over 95 percent for bluegill and hogchoker.

A facility-wide performance level is not presented for Indian Point, but a general inference can be obtained from the survival rates of the predominant species. A concern is raised, however, by the exclusion of fish collected from the debris trough. Their significant number might affect the overall mortality of each species. Because the fish in the debris trough have been subjected to high-pressure spray washes as well as any large debris removed from the screens, mortality rates for these fish are likely to be higher, thereby reducing the overall effectiveness of the technology as deployed. The experiences of other facilities suggest that modifications to the system might be able to increase the efficiency of moving impinged fish to the fish trough. In general, species survival appeared greater during late summer than in early winter. Samples were collected during one 5-month period. It is not known from the study how the technology would perform in other seasons.

Roseton Generating Station

Roseton Generating Station is located on the eastern shore of the Hudson River in New York. In 1990, the facility replaced two of eight conventional traveling screens with dual-flow screens that included water-retaining fish buckets, a low-pressure (10 psi) spray system, smooth-woven mesh screen panels, and a separate fish return trough. The dual-flow screens were also equipped with variable speed motors to achieve faster rotational speeds. For the study period, screens were continuously rotated at a speed of 10.2 feet per minute.

Impingement samples were collected during two periods in 1990: May 9 to August 30 and September 30 to November 29. A total of 529 paired samples were collected for the first period and 246 paired samples for the second period. Initial mortality was recorded at the Roseton facility. Collected samples were not held on site but rather transported to the fish laboratory at Danskammer Point, where

they were observed for latent mortality. Latent mortality observations were made at 48- and 96-hour intervals. A control study using a mark-recapture method was conducted simultaneously to measure the influence, if any, that water quality factors and collection and handling procedures might have had on overall mortality rates. Based on the results of this study, the post-impingement survival rates did not need to be adjusted for a deviation from the control mortality.

Blueback herring, bay anchovy, American shad, and alewife composed the majority of the sample population in both sampling periods. Latent survival rates ranged from 0 percent to 6 percent during the summer and were somewhat worse during the fall. The other two predominant species, white perch and striped bass, fared better, having survival rates as high as 53 percent. Other species that composed less than 2 percent of the sample population survived at considerably higher rates (98 percent for hogchoker).

It is unclear why the more fragile species (alewife, blueback herring, American shad, and bay anchovy) had such high mortality rates. The study notes that debris had been collecting in the fish return trough and was disrupting the flow of water and fish to the collection tanks. Water flow was increased through the trough to prevent accumulation of debris. No information is presented to indicate the effect of this modification. Also noted is the effect of temperature on initial survival. An overall initial survival rate of 90 percent was achieved when the ambient water temperature was 54°F. Survival rates decreased markedly as water temperature increased, and the lowest initial survival rate (6 percent) was recorded at the highest temperature.

Surry Power Station

Surry Power Station is located on the James River in Virginia. Each of the two units has 3/8-inch mesh Ristroph screens with a fish return trough. A combined spray system removes impinged organisms and debris from the screens. Spray nozzle pressures range from 15 to 20 psi. During the first several months of testing, the system was modified to improve fish transfer to the sluiceway and increase the likelihood of post-impingement survival. A flap seal was added to prevent fish from falling between the screen and return trough during screen washing. Water volume in the return trough was increased to facilitate the transfer of fish to the river, and a velocity-reduction system was added to the trough to reduce the speed of water and fish entering the sample collecting pools.

Samples were collected daily during a 6-month period from May to November 1975. Initial mortality was observed and recorded after a 15-minute period during which the water and fish in the collection pools were allowed to settle. The average survival rate for the 58 different species collected was 93 percent, although how this average was calculated was not noted. Bay anchovy and the *Alosa* spp. constituted the majority of the sample population and generally had the lowest initial survival rates at 83 percent. The study does not indicate whether control samples were used and whether mortality rates were adjusted accordingly. A noticeable deficiency of the study is the lack of latent mortality analysis. Consideration of latent mortality, which could be high for the fragile species typically impinged at Surry Power Station, might significantly reduce the overall impingement survival rate.

Arthur Kill Station

The Arthur Kill Station is located on the Arthur Kill estuary in New York. To fulfill the terms of a consent order, Consolidated Edison modified two of the station's dual-flow intake screens to include smooth mesh panels, fish-retention buckets, flap seals to prevent fish from falling between screen panels, a low-pressure spray wash system (10 psi), and a separate fish return sluiceway. One of the modified screens had mesh of 1/8-inch by 1/2-inch while the other had 1/4-inch by 1/2-inch while the six unmodified screens all had 1/8-inch by 1/8-inch mesh. Screens were continuously rotated at 20 feet per minute during the sampling events.

The sampling period lasted from September 1991 to September 1992. Weekly samples were collected simultaneously from all screens, with the exception of 2 weeks when the facility was shut down. Each screen sample was held separately in a collection tank where initial mortality was observed. A 24-hour survival rate was calculated based on the percentage of fish alive after 24 hours versus the total number collected. Because a control study was not performed, final survival rates have not been adjusted for any water quality or collection factors. The study did not evaluate latent survival beyond the 24-hour period.

Atlantic herring, blueback herring and bay anchovy typically composed the majority (> 90 percent) of impinged species during the course of the study period. Bay anchovy alone accounted for more than 72 percent of the sample population. Overall performance numbers for the modified screens are greatly influenced by the survival rates for these three species. In general, the unmodified screens demonstrated a substantially lower impingement survival rate when compared to the modified screens. The average 24-hour survival for fish impinged on the unmodified screens was 15 percent. Fish impinged on the larger mesh (1/4") and smaller mesh (1/8") modified screens had survival average 24-hour survival rates of 92 percent and 79 percent, respectively. Most species with low survival rates on the unmodified screens showed a marked improvement on the modified screens. Bay anchovy showed a 24-hour survival rate increase from 1 percent on the unmodified screens to 50 percent on the modified screens.

The study period at the Arthur Kill station offered a unique opportunity to conduct a side-by-side evaluation of modified and unmodified intake structures. The results for 24-hour post-impingement survival clearly show a marked improvement for all species that had fared poorly on the conventional screens. The study notes that lower survival rates for fragile species such as Atlantic herring might have been adversely affected by the collection tanks and protocols. Larger holding tanks appeared to improve the survival of these species, suggesting that the reported survival rates may underrepresent the rate that would be achieved under normal (unobserved) conditions, though by how much is unclear.

Dunkirk Steam Station

Dunkirk Steam Station is located on the southern shore of Lake Erie in New York. In 1998 a modified dual-flow traveling screen system was installed on Unit 1 for an impingement mortality reduction study. The new system incorporated an improved fish bucket design to minimize turbulence caused by flow through the screen face, as well as a nose cone on the upstream wall of the screen assembly. The nose cone was installed to reduce the flow and velocity variations that had been observed across the screen face.

Samples were collected during the winter months of 1998/1999 and evaluated for 24-hour survival. Four species (emerald shiner, juvenile gizzard shad, rainbow smelt, and spottail shiner) compose nearly 95 percent of the sample population during this period. All species exhibited high 24-hour survival rates; rainbow smelt fared worst at 83 percent. The other three species had survival rates of better than 94 percent. Other species were collected during the sampling period but were not present in numbers significant enough to warrant a statistical analysis.

The results presented above represent one season of impingement sampling. Species not in abundance during cooler months might be affected differently by the intake structure. Sampling continued beyond the winter months, but EPA has not yet been reviewed by EPA.

Kintigh Station

Kintigh Station is located on the southern shore of Lake Ontario in New York. The facility operates an offshore intake in the lake with traveling screens and a fiberglass fish return trough. Fish are removed from the screens and deposited in the return trough by a low-pressure spray wash (10 psi). It is noted that the facility also operates with an offshore velocity cap. This does not directly affect the survival rate of fish impinged against the screen but might alter the distribution of species subject to impingement on the screen.

Samples were collected seasonally and held for observation at multiple intervals up to 96 hours. Most species exhibited a high variability in their rate of survival depending on the season. Rainbow smelt had a 96-hour survival rate of 95 percent in the spring and a 22 percent rate in the fall. (The rate was 1.5 percent in summer but the number of samples was small.) Alewife composed the largest number among the species in the sample population. Survival rates were generally poor (0 percent to 19 percent) for spring and summer sampling before the system was modified 1989. After the screen assembly had been modified to minimize stress associated with removal from the screen and return to the waterbody, alewife survival rates increased to 45 percent. Survival rates were not adjusted for possible influence from handling and observation stresses because no control study was performed.

Calvert Cliffs Nuclear Power Plant

Calvert Cliffs Nuclear Power Plant is located on the eastern shore of the Chesapeake Bay in Maryland. The facility used to have conventional traveling screens on its intake screen assemblies. Screens were rotated for 10 minutes every hour or when triggered by a set pressure differential across the screen surface. A spray wash system removed impinged fish and debris into a discharge trough. The original screens have since been converted to a dual-flow design. The data discussed in the 1975-1981 study period are related to the older conventional screen systems.

Sampling periods were determined to account for the varying conditions that might exist due to tides and time of day. Impingement and survival rates were estimated monthly based on the number and weights of the individual species in the sample collection. No control studies accompanied the impingement survival evaluation although total impingement data and estimated mortalities were provided for comparative purposes. Latent survival rates were not evaluated for this study; only initial survival was included.

Five species typically constituted over 90 percent of the sample population in the study years. Spot, Atlantic menhaden, Atlantic silverside, bay anchovy, and hogchoker had composite initial survival rates of 84, 52, 54, 68 and 99 percent, respectively. Other species generally had survival rates greater than 75 percent, but these data are less significant to the facility-wide survival rate given their low percentage of the overall sample population (< 8 percent). Overall, the facility showed an initial survival rate of 73 percent for all species.

It is notable that the volume of impingement data collected by Calvert Cliffs NPP (over 21 years) has enabled the facility to anticipate possible large impingement events by monitoring fluctuations in the thermal and salinity stratification of the surrounding portion of the Chesapeake Bay. When possible, operational changes during these periods (typically mid to late summer) might allow the facility to reduce cooling water intake volume, thereby reducing the potential for impingement losses. The facility has also studied ways to maintain adequate dissolved oxygen levels in the intake canal to assist fish viability and better enable post-impingement survival and escape.

Huntley Steam Station

Huntley Steam Station is located on the Niagara River in New York. The facility recently replaced four older conventional traveling screens with modified Ristroph screens on Units 67 and 68. The modified screens are fitted with smoothly woven coarse mesh panels on a rotating belt. A fish collection basket is attached to the screen face of each screen panel. Bucket contents are removed by low-pressure spray nozzles into a fish return trough. High-pressure sprays remove remaining fish and debris into a separate debris trough. The study does not contain the rotation interval of the screen or the screen speed at the time of the study.

Samples were collected over five nights in January 1999 from the modified-screen fish return troughs. All collected fish were sorted according to initial mortality. Four targeted species (rainbow smelt, emerald shiner, gizzard shad, and alewife) were sorted according to species and size and held to evaluate 24-hour survival rates. Together, the target species accounted for less than 50 percent of all fish impinged on the screens. (An additional 6,364 fish were not held for latent survival evaluation.) Of the target species, rainbow smelt and emerald shiners composed the greatest percentage with 57 and 37 percent, respectively.

Overall, the 24-hour survival rate for rainbow smelt was 84 percent; some variation was evident for juveniles (74 percent) and adults (94 percent). Emerald shiner were present in the same general life stage and had a 24-hour survival rate of 98 percent. Gizzard shad, both juvenile and adult, fared poorly, with an overall survival of 5 percent for juveniles and 0 percent for adults. Alewife were not present in large numbers ($n = 30$) and had an overall survival rate of 0 percent.

The study notes the low survival rates for alewife and gizzard shad and posits the low water temperature as the principal factor. At the Huntley facility, both species are near the northern extreme of their natural ranges and are more susceptible to stresses associated with extremes in water conditions. The water temperatures at the time of collection were among the coldest of the year. Laboratory evaluations conducted on these species at the same temperatures showed high degrees of impairment that would likely adversely affect post-impingement survival. A control evaluation was performed to determine whether mortality rates from the screens would need to be adjusted for waterbody or collection and handling factors. No discrepancies were observed, and therefore no corrections were made to the final results. Also of note in the study is the inclusion of a spray wash collection efficiency evaluation. The spray wash and fish return system were evaluated to determine the proportion of impinged fish that were removed from the buckets and deposited in the fish trough instead of the debris trough. All species had suitable removal efficiencies.

2.1.2 Summary

Studies conducted at steam electric power generating facilities over the past three decades have built a sizable record demonstrating the performance potential for modified traveling screens that include some form of fish return. Comprehensive studies, such as those cited above, have shown that modified screens can achieve an increase in the post-impingement survival of aquatic organisms that come under the influence of cooling water intake structures. Hardier species, as might be expected, have exhibited survival rates as high as 100 percent. More fragile species, which are typically smaller and more numerous in the source waterbody, understandably have lower survival rates. Data indicates, however, that with fine tuning, modified screen systems can increase survival rates for even the most susceptible species and bring them closer to the performance standards established under the final rule.

2.2 Cylindrical Wedgewire Screens

Technology Overview

Wedgewire screens are designed to reduce entrainment and impingement by physical exclusion and by exploitation of hydrodynamics and the natural flushing action of currents present in the source waterbody. Physical exclusion occurs when the mesh size of the screen is smaller than the organisms susceptible to entrainment. Screen mesh sizes range from 0.5 to 10 mm, with the most common slot sizes in the 1.0 to 2.0 mm range. Hydrodynamic exclusion results from maintenance of a low through-slot velocity, which, because of the screen's cylindrical configuration, is quickly dissipated. This allows organisms to escape the flow field (Weisberd et al. 1984). The name of these screens arises from the triangular or wedge-shaped cross section of the wire that makes up the screen. The screen is composed of wedgewire loops welded at the apex of their triangular cross section to supporting axial rods presenting the base

of the cross section to the incoming flow (Pagano et al. 1977). Wedgewire screens are also referred to as profile screens, Johnson screens, or "vee wire".

General understanding of the efficacy of cylindrical wedgewire screens holds that in order to achieve the optimal reduction in impingement mortality and entrainment, certain conditions must be met. First, the slot size must be small enough to physically prevent the entrainment of the organisms identified as warranting protection. Larger slot sizes might be feasible in areas where eggs, larvae, and some classes of juveniles are not present in significant numbers. Second, a low through-slot velocity must be maintained to minimize the hydraulic zone of influence surrounding the screen assembly. A general rule of thumb holds that a lower through-slot velocity, when combined with other optimal factors, will achieve significant reductions in entrainment and impingement mortality. Third, a sufficient ambient current must be present in the source waterbody to aid organisms in bypassing the structure and to remove other debris from the screen face. A constant current also aids the automated cleaning systems that are now common to cylindrical wedgewire screen assemblies.

2.2.1 Example Studies

Although uniform national requirements under the proposed rule would only apply to manufacturing facilities, based on the co-proposed thresholds, the technologies described for Phase III facilities are the same as those used by Phase II electricity generation facilities to meet section 316(b) requirements. EPA considers the types of intakes and the technologies available to address impingement and entrainment at Phase II facilities to be consistent with the intakes and technologies at Phase III existing facilities.

Laboratory Evaluation (EPRI 2003)

EPRI recently published (May 2003) the results of a laboratory evaluation of wedgewire screens under controlled conditions in the Alden Research Laboratory Fish Testing Facility. A principal aim of the study was to identify the important factors that influence the relative rates of impingement and entrainment associated with wedgewire screens. The study evaluated characteristics such as slot size, through-slot velocity, and the velocity of ambient currents that could best carry organisms and debris past the screen. When each of the characteristics was optimized, wedgewire screen use became increasingly effective as an impingement reduction technology; in certain circumstances it could be used to reduce the entrainment of eggs and larvae. EPRI notes that large reductions in impingement and entrainment might occur even when all characteristics are not optimized. Localized conditions unique to a particular facility, which were not represented in laboratory testing, might also enable successful deployment. The study cautions that the available data are not sufficient to determine the biological and engineering factors that would need to be optimized, and in what manner, for future applications of wedgewire screens.

Slot sizes of 0.5, 1.0, and 2.0 mm were each evaluated at two different through-slot velocities (0.15 and 0.30 m/s) and three different channel velocities (0.08, 0.15, and 0.30 m/s) to determine the impingement and entrainment rates of fish eggs and larvae. Screen porosities increase from 24.7 percent for the 0.5 mm screens to 56.8 percent for 2.0 mm screens. The study evaluated eight species (striped bass, winter flounder, yellow perch, rainbow smelt, common carp, white sucker, alewife, and bluegill) because of their presence in a variety of waterbody types and their history of entrainment and impingement at many facilities. Larvae were studied for all species except alewife, while eggs were studied for striped bass, white sucker, and alewife. (Surrogate, or artificial, eggs of a similar size and buoyancy substituted for live striped bass eggs.)

Individual tests followed a rigorous protocol to count and label all fish eggs and larvae prior to their introduction into the testing facility. Approach and through-screen velocities in the flume were verified, and the collection nets used to recapture organisms that bypassed the structure or were entrained were cleaned and secured. Fish and eggs were released at a point upstream of the wedgewire screen selected to deliver the organisms at the centerline of the screens, which maximized the exposure of the eggs and larvae to the influence of the screen. The number of entrained organisms was estimated by counting all eggs and larvae captured on the entrainment collection net. Impinged organisms were counted by way of a plexiglass window and video camera setup.

In addition to the evaluations conducted with biological samples, Alden Laboratories developed a Computational Fluid Dynamics (CFD) model to evaluate the hydrodynamic characteristics associated with wedgewire screens. The CFD model analyzed the effects of approach velocity and through-screen velocities on the velocity distributions around the screen assemblies. Using the data gathered from the CFD evaluation, engineers were able to approximate the "zone of influence" around the wedgewire screen assembly under different flow conditions and estimate any influence on flow patterns exerted by multiple screen assemblies located in close proximity to each other.

The results of both the biological evaluation and the CFD model evaluation support many of the conclusions reached by other wedgewire screen studies, as well as in situ anecdotal evidence. In general, the lower impingement rates were achieved with larger slot sizes (1.0 to 2.0 mm), lower through-screen velocities, and higher channel velocities. Similarly, the lowest entrainment rates were

seen with low through-screen velocities and higher channel velocities, although the lowest entrainment rates were achieved with smaller slot sizes (0.5 mm). Overall impingement reductions reached as high as 100 percent under optimal conditions, and entrainment reductions approached 90 percent. It should be noted that the highest reductions for impingement and entrainment were not achieved under the same conditions. Results from the biological evaluation generally agree with the predictions from the CFD model: the higher channel velocities, when coupled with lower through-screen velocities, would result in the highest rate of protection for the target organisms.

JH Campbell

JH Campbell is located on Lake Michigan in Michigan, with the intake for Unit 3 located approximately 1,000 meters from shore at a depth of 10.7 meters. The cylindrical intake structure has 9.5-mm mesh wedgewire screens and withdraws approximately 400 MGD. Raw impingement data are not available, and EPA is not aware of a comprehensive study evaluating the impingement reduction associated with the wedgewire screen system. Comparative analyses using the impingement rates at the two other intake structures (on shore intakes with conventional traveling screens) have shown that impingement of emerald shiner, gizzard shad, smelt, yellow perch, and alewife associated with the wedgewire screen intake has been effectively reduced to insignificant levels. Maintenance issues have not been shown to be problematic at JH Campbell because of the far offshore location in deep water and the periodic manual cleaning using water jets to reduce biofouling. Entrainment has not been shown to be of concern at the intake structure because of the low abundance of entrainable organisms in the immediate vicinity of the wedgewire screens.

Eddystone Generating Station

Eddystone Generating Station is located on the tidal portion of the Delaware River in Pennsylvania. Units 1 and 2 were retrofitted to include wide-mesh wedgewire screens and currently withdraw approximately 500 MGD from the Delaware River. Pre-deployment data showed that over 3 million fish were impinged on the unmodified intake structures during a single 20-month period. An automatic air burst system has been installed to prevent biofouling and debris clogging from affecting the performance of the screens. EPA has not been able to obtain biological data for the Eddystone wedgewire screens but EPRI indicates that fish impingement has been eliminate.

2.2.2 Other Facilities

Other plants with lower intake flows have installed wedgewire screens, but there are limited biological performance data for these facilities. The Logan Generating Station in New Jersey withdraws 19 MGD from the Delaware River through a 1-mm wedgewire screen. Entrainment data show 90 percent less entrainment of larvae and eggs than conventional screens. No impingement data are available. Unit 1 at the Cope Generating Station in South Carolina is a closed-cycle unit that withdraws about 6 MGD through a 2-mm wedgewire screen; however, no biological data are available. Performance data are also unavailable for the Jeffrey Energy Center, which withdraws about 56 MGD through a 10-mm screen from the Kansas River in Kansas. The system at the Jeffrey Plant has operated since 1982 with no operational difficulties. Finally, the American Electric Power Corporation has installed wedgewire screens at the Big Sandy (2 MGD) and Mountaineer (22 MGD) facilities, which withdraw water from the Big Sandy and Ohio rivers, respectively. Again, no biological test data are available for these facilities.

Wedgewire screens have been considered or tested for several other large facilities. In situ testing of 1- and 2-mm wedgewire screens was performed in the St. John River for the Seminole Generating Station Units 1 and 2 in Florida in the late 1970s. This testing showed virtually no impingement and 99 and 62 percent reductions in larvae entrainment for the 1-mm and 2-mm screens, respectively, over conventional screen (9.5-mm) systems. In 1982 and 1983 the State of Maryland conducted testing 1-, 2-, and 3-mm wedgewire screens at the Chalk Point Generating Station, which withdraws water from the Patuxent River in Maryland. The 1-mm wedgewire screens were found to reduce entrainment by 80 percent. No impingement data were available. Some biofouling and clogging were observed during the tests. In the late 1970s, Delmarva Power and Light conducted laboratory testing of fine-mesh wedgewire screens for the proposed 1,540 MW Summit Power Plant. This testing showed that entrainment of fish eggs (including striped bass eggs) could effectively be prevented with slot widths of 1 mm or less, while impingement mortality was expected to be less than 5 percent. Actual field testing in the brackish water of the proposed intake canal required the screens to be removed and cleaned as often as once every 3 weeks.

Applicability to Large-Capacity Facilities

EPA believes that cylindrical wedgewire screens can be successfully employed by large intake facilities under certain circumstances. Although many of the current installations of this technology have been at smaller-capacity facilities, EPA does not believe that the increased capacity demand of a large intake facility, in and of itself, is a barrier to deployment of this technology. Large water withdrawals can be accommodated by multiple screen assemblies in the source waterbody. The limiting factor for a larger facility may be the availability of sufficient accessible space near the facility itself because additional screen assemblies obviously consume more

space on the waterbody floor and might interfere with navigation or other uses of the waterbody. Consideration of the impacts in terms of space and placement must be evaluated before selecting wedgewire screens for deployment.

Applicability in High-Debris Waterbodies
As with any intake structure, the presence of large debris poses a risk of damage to the structure if not properly managed. Cylindrical wedgewire screens, because of their need to be submerged in the water current away from shore, might be more susceptible to debris interaction than other onshore technologies. Vendor engineers indicated that large debris has been a concern at several of their existing installations, but the risk associated with it has been effectively minimized by selecting the optimal site and constructing debris diversion structures. Significant damage to a wedgewire screen is most likely to occur from fast-moving submerged debris. Because wedgewire screens do not need to be sited in the area with the fastest current, a less damage-prone area closer to shore or in a cove or constructed embayment can be selected, provided it maintains a minimum ambient current around the screen assembly. If placement in the main channel is unavoidable, deflecting structures can be employed to prevent free-floating debris from contacting the screen assembly. Typical installations of cylindrical wedgewire place them roughly parallel to the direction of the current, exposing only the upstream nose to direct impacts with debris traveling downstream. EPA has noted several installations where debris-deflecting nose cones have been installed to effectively eliminate the damage risk associated with large debris.

Apart from the damage that large debris can cause, smaller debris, such as household trash or organic matter, can build up on the screen surface, altering the through-slot velocity of the screen face and increasing the risk of entrainment and/or impingement of target organisms. Again, selection of the optimal location in the waterbody might be able to reduce the collection of debris on the structure. Ideally, cylindrical wedgewire is located away from areas with high submerged aquatic vegetation (SAV) and out of known debris channels. Proper placement alone may achieve the desired effect, although technological solutions also exist to physically remove small debris and silt. Automated air-burst systems can be built into the screen assembly and set to deliver a short burst of air from inside and below the structure. Debris is removed from the screen face by the air burst and carried downstream and away from the influence of the intake structure. Improvements to the air burst system have eliminated the timed cleaning cycle and replaced it with one tied to a pressure differential monitoring system.

Applicability in High Navigation Waterbodies
Wedgewire screens are more likely to be placed closer to navigation channels than other onshore technologies, thereby increasing the possibility of damage to the structure itself or to a passing commercial ship or recreational boat. Because cylindrical wedgewire screens need to be submerged at all times during operation, they are typically installed closer to the waterbody floor than the surface. In a waterbody of sufficient depth, direct contact with recreational watercraft or small commercial vessels is unlikely. EPA notes that other submerged structures (e.g., pipes, transmission lines) operate in many different waterbodies and are properly delineated with acceptable navigational markers to prevent accidents associated with trawling, dropping anchor, and similar activities. Such precautions would likely be taken for a submerged wedgewire screen as well.

2.2.3 Summary

Cylindrical wedgewire screens have been effectively used to mitigate impingement and, under certain conditions, entrainment impacts at many different types of facilities over the past three decades. Although not yet widely used at steam electric power plants, the limited data for Eddystone and Campbell indicate that wide mesh screens, in particular, can be used to minimize impingement. Successful use of the wedgewire screens at Eddystone, as well as at Logan in the Delaware River (high debris flows), suggests that the screens can have widespread applicability. This is especially true for facilities that have relatively low intake flow requirements (closed-cycle systems). Nevertheless, the lack of more representative full-scale plant data makes it impossible to conclusively say that wedgewire screens can be used in all environmental conditions. For example, there are no full-scale data available specifically for marine environments where biofouling and clogging are significant concerns. Technological advances have been made to address such concerns. Automated cleaning systems can now be built into screen assemblies to reduce the disruptions debris buildup can cause. Likewise, vendors have been experimenting with different screen materials and coatings to reduce the on-screen growth of vegetation and other organisms (zebra mussels).

Fine-mesh wedgewire screens (0.5 - 1 mm) also have the *potential* for use to control both impingement and entrainment. EPA is not aware of the installation of any fine-mesh wedgewire screens at any power plants with high intake flows (> 100 MGD). However, such screens have been used at some power plants with lower intake flow requirements (25 to 50 MGD), which would be comparable to a very large power plant with a closed-cycle cooling system. With the exception of Logan, EPA has not identified any full-scale performance data for these systems. They could be even more susceptible to clogging than wide-mesh wedgewire screens (especially in marine environments). It is unclear whether clogging would simply necessitate more intensive maintenance or preclude their day-to-day use at many sites. Their successful application at Logan and Cope and the historical test data from Florida, Maryland, and Delaware at least suggest promise for addressing both fish impingement and entrainment of eggs and larvae. However, based on the

fine-mesh screen experience at Big Bend Units 3 and 4, it is clear that frequent maintenance would be required. Therefore, relatively deep water sufficient to accommodate the large number of screen units would preferably be close to shore (readily accessible). Manual cleaning needs might be reduced or eliminated through use of an automated flushing (e.g., microburst) system.

2.3 Fine-mesh Screens

Technology Overview
Fine-mesh screens are typically mounted on conventional traveling screens and are used to exclude eggs, larvae, and juvenile forms of fish from intakes. These screens rely on gentle impingement of organisms on the screen surface. Successful use of fine-mesh screens is contingent on the application of satisfactory handling and return systems to allow the safe return of impinged organisms to the aquatic environment (Pagano et al. 1977; Sharma 1978). Fine-mesh screens generally include those with mesh sizes of 5 mm or less.

Technology Performance
Similar to fine-mesh wedgewire screens, fine-mesh traveling screens with fish return systems show promise for control of both impingement and entrainment. However, they have not been installed, maintained, and optimized at many facilities.

2.3.1 Example Facilities

Although uniform national requirements under the proposed rule would only apply to manufacturing facilities, based on the co-proposed thresholds, the technologies described for Phase III facilities are the same as those used by Phase II electricity generation facilities to meet section 316(b) requirements. EPA considers the types of intakes and the technologies available to address impingement and entrainment at Phase II facilities to be consistent with the intakes and technologies at Phase III existing facilities.

Big Bend
The most significant example of long-term use of fine-mesh screens has been at the Big Bend Power Plant in the Tampa Bay area. The facility has an intake canal with 0.5-mm mesh Ristroph screens that are used seasonally on the intakes for Units 3 and 4. During the mid-1980s when the screens were initially installed, their efficiency in reducing I&E mortality was highly variable. The operator, Florida Power & Light (FPL) evaluated different approach velocities and screen rotational speeds. In addition, FPL recognized that frequent maintenance (manual cleaning) was necessary to avoid biofouling. By 1988, system performance had improved greatly. The system's efficiency in screening fish eggs (primarily drums and bay anchovy) exceeded 95 percent, with 80 percent latent survival for drum and 93 percent for bay anchovy. For larvae (primarily drums, bay anchovies, blennies, and gobies), screening efficiency was 86 percent, with 65 percent latent survival for drums and 66 percent for bay anchovy. (Note that latent survival in control samples was also approximately 60 percent). Although more recent data are generally not available, the screens continue to operate successfully at Big Bend in an estuarine environment with proper maintenance.

2.3.2 Other Facilities

Although egg and larvae entrainment performance data are not available, fine-mesh (0.5-mm) Passavant screens (single entry/double exit) have been used successfully in a marine environment at the Barney Davis Station in Corpus Christi, Texas. Impingement data for this facility show an overall 86 percent initial survival rate for bay anchovy, menhaden, Atlantic croaker, killfish, spot, silverside, and shrimp.

Additional full-scale performance data for fine-mesh screens at large power stations are generally not available. However, some data are available from limited use or study at several sites and from laboratory and pilot-scale tests. Seasonal use of fine mesh on two of four screens at the Brunswick Power Plant in North Carolina has shown 84 percent reduction in entrainment compared to the conventional screen systems. Similar results were obtained during pilot testing of 1-mm screens at the Chalk Point Generating Station in Maryland. At the Kintigh Generating Station in New Jersey, pilot testing indicated that 1-mm screens provided 2 to 35 times the reduction in entrainment over conventional 9.5-mm screens. Finally, Tennessee Valley Authority (TVA) pilot-scale studies performed in the 1970s showed reductions in striped bass larvae entrainment of up to 99 percent for a 0.5-mm screen and 75 and 70 percent for 0.97-mm and 1.3-mm screens, respectively. A full-scale test by TVA at the John Sevier Plant showed less than half as many larvae entrained with a 0.5-mm screen than with 1- and 2-mm screens combined.

2.3.3 Summary

Despite the lack of full-scale data, the experiences at Big Bend (as well as Brunswick) show that fine-mesh screens can reduce entrainment by 80 percent or more. This reduction is contingent on optimized operation and intensive maintenance to avoid biofouling and clogging, especially in marine environments. It might also be appropriate to use removable fine mesh that is installed only during periods of egg and larval abundance, thereby reducing the potential for clogging and wear and tear on the systems.

2.4 Fish Net Barriers

Technology Overview
Fish net barriers are wide-mesh nets that are placed in front of the entrance to intake structures. The size of the mesh needed is a function of the species present at a particular site and varies from 4 mm to 32 mm (EPRI 2000). The mesh must be sized to prevent fish from passing through the net, which could cause them to be gilled. Relatively low velocities are maintained because the area through which the water can flow is usually large. Fish net barriers have been used at numerous facilities and lend themselves to intakes where the seasonal migration of fish and other organisms requires fish diversion facilities at only specific times of the year.

Technology Performance
Barrier nets can provide a high degree of impingement reduction by preventing large fish from entering the vicinity of the intake structure. Because of typically wide openings, they do not reduce entrainment of eggs and larvae. A number of barrier net systems have been used or studied at large power plants.

2.4.1 Example Studies

Although uniform national requirements under the proposed rule would only apply to manufacturing facilities, based on the co-proposed thresholds, the technologies described for Phase III facilities are the same as those used by Phase II electricity generation facilities to meet section 316(b) requirements. EPA considers the types of intakes and the technologies available to address impingement and entrainment at Phase II facilities to be consistent with the intakes and technologies at Phase III existing facilities.

JP Pulliam Station
The JP Pulliam Station is located on the Fox River in Wisconsin. Two separate nets with 6-mm mesh are deployed on opposite sides of a steel grid supporting structure. The operation of a dual net system facilitates the cleaning and maintenance of the nets without affecting the overall performance of the system. Under normal operations, nets are rotated at least two times per week to facilitate cleaning and repair. The nets are typically deployed when the ambient temperature of the intake canal exceeds 37°F. This usually occurs between April 1 and December 1.

Studies undertaken during the first 2 years after deployment showed an overall net deterrence rate of 36 percent for targeted species (noted as commercially or recreationally important, or forage species). Improvements to the system in subsequent years consisted of a new bulkhead to ensure a better seal along the vertical edge of the net and additional riprap along the base of the net to maintain the integrity of the seal along the bottom of the net. The improvements resulted in a deterrence rate of 98 percent for some species; no species performed at less than 85 percent. The overall effectiveness for game species was better than 90 percent while forage species were deterred at a rate of 97 percent or better.

JR Whiting Plant
The JR Whiting Plant is located on Maumee Bay of Lake Erie in Michigan. A 3/8-inch mesh barrier net was deployed in 1980 as part of a best technology available determination by the Michigan Water Resources Commission. Estimates of impingement reductions were based on counts of fish impinged on the traveling screens inside the barrier net. Counts in years after the deployment were compared to data from the year immediately prior to the installation of the net when over 17 million fish were impinged. Four years after deployment, annual impingement totals had fallen by 98 percent.

Bowline Point
Bowline Point is located on the Hudson River in New York. A 150-foot long, 0.95-cm mesh net has been deployed in a V-shaped configuration around the intake pump house. The area of the river in which the intake is located has currents that are relatively stagnant, thus limiting the stresses to which the net might be subjected. Relatively low through-net velocities (0.5 feet per second) have been maintained across a large portion of the net because of low debris loadings. Debris loads directly affecting the net were reduced by including a debris boom outside the main net. An air bubbler was also added to the system to reduce the buildup of ice during cold months.

The facility has attempted to evaluate the reduction in the rate of impingement by conducting various studies of the fish populations inside and outside the barrier net. Initial data were used to compare impingement rates from before and after deployment of the net and showed a deterrence of 91 percent for targeted species (white perch, striped bass, rainbow smelt, alewife, blueback herring, and American shad). In 1982 a population estimate determined that approximately 230,000 striped bass were present in the embayment outside the net area. A temporary mesh net was deployed across the embayment to prevent fish from leaving the area. A 9-day study found that only 1.6 percent of the estimated 230,000 fish were ultimately impinged on the traveling screens. A mark-recapture study that released individual fish inside and outside the barrier net showed similar results, with more than 99 percent of fish inside the net impinged and less than 3 percent of fish outside the net impinged. Gill net capture studies sought to estimate the relative population densities of fish species inside and outside the net. The results agreed with those of previous studies, showing that the net was maintaining a relatively low density of fish inside the net as compared to the outside.

2.4.2 Summary

Barrier nets have clearly proven effective for controlling *impingement* (i.e., more than 80 percent reductions over conventional screens without nets) in areas with limited debris flows. Experience has shown that high debris flows can cause significant damage to net systems. Biofouling can also be a concern but it can be addressed through frequent maintenance. In addition, barrier nets are also often used only seasonally where the source waterbody is subject to freezing. Fine-mesh barrier nets show some promise for entrainment control but would likely require even more intensive maintenance. In some cases, the use of barrier nets might be further limited by the physical constraints and other uses of the waterbody.

2.5 Aquatic Microfiltration Barriers

Technology Overview

Aquatic microfiltration barrier systems are barriers that employ a filter fabric designed to allow water to pass into a cooling water intake structure but exclude aquatic organisms. These systems are designed to be placed some distance from the cooling water intake structure within the source waterbody and act as a filter for the water that enters the cooling water system. These systems can be floating, flexible, or fixed. Because these systems usually have such a large surface area, the velocities maintained at the face of the permeable curtain are very low. One company, Gunderboom, Inc., has a patented full-water-depth filter curtain composed of polyethylene or polypropylene fabric that is suspended by flotation billets at the surface of the water and anchored to the substrate below. The curtain fabric is manufactured as a matting of minute unwoven fibers with an apparent opening size of 20 microns. Gunderboom systems also employ an automated "air burst" system to periodically shake the material and pass air bubbles through the curtain system to clean off of sediment buildup and release any other material back into the water column.

Technology Performance

EPA has determined that microfiltration barriers, including the Gunderboom, show significant *promise* for minimizing entrainment. EPA acknowledges, however, that the Gunderboom technology is currently "experimental in nature." At this juncture, the only power plant where the Gunderboom has been used at a full-scale level is the Lovett Generating Station along the Hudson River in New York, where pilot testing began in the mid-1990s. Initial testing at that facility showed significant potential for reducing entrainment. Entrainment reductions of up to 82 percent were observed for eggs and larvae, and these levels were maintained for extended month-to-month periods during1999 through 2001. At Lovett, some operational difficulties have affected long-term performance. These difficulties, including tearing, overtopping, and plugging/clogging, have been addressed, to a large extent, through subsequent design modifications. Gunderboom, Inc. specifically has designed and installed a microburst cleaning system to remove particulates. Each of the challenges encountered at Lovett could be of significantly greater concern at marine sites with higher wave action and debris flows. Gunderboom systems have been otherwise deployed in marine conditions to prevent migration of particulates and bacteria. They have been used successfully in areas with waves up to 5 feet. The Gunderboom system is being tested for potential use at the Contra Costa Plant along the San Joaquin River in Northern California.

An additional question related to the utility of the Gunderboom and other microfiltration systems is sizing and the physical limitations and other uses of the source waterbody. With a 20-micron mesh, 100,000 and 200,000 gpm intakes would require filter systems 500 and 1,000 feet long (assuming a 20-foot depth). In some locations, this may preclude the successful deployment of the system because of space limitations or conflicts with other waterbody uses.

2.6 Louver Systems

Technology Overview
Louver systems consist of series of vertical panels placed at 90 degree angles to the direction of water flow (Hadderingh 1979). The placement of the louver panels provides both changes in both the flow direction and velocity, which fish tend to avoid. The angles and flow velocities of the louvers create a current parallel to the face of the louvers that carries fish away from the intake and into a fish bypass system for return to the source waterbody.

Technology Performance
Louver systems can reduce impingement losses based on fishes' abilities to recognize and swim away from the barriers. Their performance, i.e., guidance efficiency, is highly dependant on the length and swimming abilities of the resident species. Because eggs and early stages of larvae cannot swim away, they are not affected by the diversions and there is no associated reduction in entrainment.

Although louver systems have been tested at a number of laboratory and pilot-scale facilities, they have not been used at many full-scale facilities. The only large power plant facility where a louver system has been used is San Onofre Units 2 and 3 (2,200 MW combined) in Southern California. The operator initially tested both louver and wide mesh, angled traveling screens during the 1970s. Louvers were subsequently selected for full-scale use at the intakes for the two units. In 1984 a total of 196,978 fish entered the louver system with 188,583 returned to the waterbody and 8,395 impinged. In 1985, 407,755 entered the louver system; 306,200 were returned and 101,555 impinged. Therefore, the guidance efficiencies in 1984 and 1985 were 96 and 75 percent, respectively. However, 96-hour survival rates for some species, i.e., anchovies and croakers, was 50 percent or less. The facility has also encountered some difficulties with predator species congregating in the vicinity of the outlet from the fish return system. Louvers were originally considered for use at San Onofre because of 1970s pilot testing at the Redondo Beach Station in California, where maximum guidance efficiencies of 96 to 100 percent were observed.

EPRI (2000) indicated that louver systems could provide 80-95 percent diversion efficiency for a wide variety of species under a range of site conditions. These findings are generally consistent with the American Society of Civil Engineers' (ASCE) findings from the late 1970s, which showed that almost all systems had diversion efficiencies exceeding 60 percent with many more than 90 percent. As indicated above, much of the EPRI and ASCE data come from pilot/laboratory tests and hydroelectric facilities where louver use has been more widespread than at steam electric facilities. Louvers were specifically tested by the Northeast Utilities Service Company in the Holyoke Canal on the Connecticut River for juvenile clupeids (American shad and blueback herring). The overall guidance efficiency was found to be 75 to 90 percent. In the 1970s Alden Research Laboratory observed similar results for Hudson River species, including alewife and smelt. At the Tracy Fish Collection Facility along the San Joaquin River in California, testing was performed from 1993 and 1995 to determine the guidance efficiency of a system with primary and secondary louvers. The results for green and white sturgeon, American shad, splittail, white catfish, delta smelt, chinook salmon, and striped bass showed mean diversion efficiencies ranging from 63 percent (splittail) to 89 percent (white catfish). Also in the 1990s, an experimental louver bypass system was tested at the USGS Conte Anadromous Fish Research Center in Massachusetts. This testing showed guidance efficiencies for Connecticut River species of 97 percent for a "wide array" of louvers and 100 percent for a "narrow array." Finally, at the T.W. Sullivan Hydroelectric Plant along the Williamette River in Oregon, the louver system is estimated to be 92 percent effective in diverting spring chinook, 82 percent for all Chinook, and 85 percent for steelhead. The system has been optimized to reduce fish injuries such that the average injury occurrence is only 0.44 percent.

Overall, the above data indicate that louvers can be highly effective (more than 70 percent) in diverting fish from potential impingement. Latent mortality is a concern, especially where fragile species are present. Similar to modified screens with fish return systems, operators must optimize louver system design to minimize fish injury and mortality.

2.7 Angled and Modular Inclined Screens

Technology Overview
Angled traveling screens use standard through-flow traveling screens in which the screens are set at an angle to the incoming flow. Angling the screens improves the fish protection effectiveness because the fish tend to avoid the screen face and move toward the end of the screen line, assisted by a component of the inflow velocity. A fish bypass facility with independently induced flow must be provided (Richards 1977). Modular inclined screens (MISs) are a specific variation on angled traveling screens, in which each module in the intake consists of trash racks, dewatering stop logs, an inclined screen set at a 10 to 20 degree angle to the flow, and a fish bypass (EPRI 1999).

Technology Performance

Angled traveling screens with fish bypass and return systems work similarly to louver systems. They also provide only potential reductions in impingement mortality because eggs and larvae will not generally detect the factors that influence diversion. Like louver systems, they were tested extensively at the laboratory and pilot scales, especially during the 1970s and early 1980s. Testing of angled screens (45 degrees to the flow) in the 1970s at San Onofre showed poor to good guidance (0 to 70 percent) for northern anchovies and moderate to good guidance (60 to 90 percent) for other species. Latent survival varied by species: fragile species had only 25 percent survival, while hardy species showed greater than 65 percent survival. The intake for Unit 6 at the Oswego Steam plant along Lake Ontario in New York has traveling screens angled at 25 degrees. Testing during 1981 through 1984 showed a combined diversion efficiency of 78 percent for all species, ranging from 53 percent for mottled sculpin to 95 percent for gizzard shad. Latent survival testing results ranged from 22 percent for alewife to nearly 94 percent for mottled sculpin.

Additional testing of angled traveling screens was performed in the late 1970s and early 1980s for power plants on Lake Ontario and along the Hudson River. This testing showed that a screen angled at 25 degrees was 100 percent effective in diverting 1- to 6- inch-long Lake Ontario fish. Similar results were observed for Hudson River species (striped bass, white perch, and Atlantic tomcod). One-week mortality tests for these species showed 96 percent survival. Angled traveling screens with a fish return system have been used on the intake from Brayton Point Unit 4. Studies that evaluated the angled screens from 1984 through 1986 showed a diversion efficiency of 76 percent with a latent survival of 63 percent. Much higher results were observed excluding bay anchovy.

Finally, 1981 full-scale studies of an angled screen system at the Danskammer Station along the Hudson River in New York showed diversion efficiencies of 95 to 100 percent with a mean of 99 percent. Diversion efficiency combined with latent survival yielded a total effectiveness of 84 percent. Species included bay anchovy, blueback herring, white perch, spottail shiner, alewife, Atlantic tomcod, pumpkinseed, and American shad.

During the late 1970s and early 1980s, Alden Research Laboratories conducted a range of tests on a variety of angled screen designs. Alden specifically performed screen diversion tests for three northeastern utilities. In initial studies for Niagara Mohawk, diversion efficiencies were found to be nearly 100 percent for alewife and smolt. Followup tests for Niagara Mohawk confirmed 100 percent diversion efficiency for alewife with mortalities only 4 percent higher than those in control samples. Subsequent tests by Alden for Consolidated Edison, Inc. using striped bass, white perch, and tomcod also found nearly 100 percent diversion efficiency with a 25 degree angled screen. The 1-week mean mortality was only 3 percent. Alden performed further tests during 1978 to 1990 to determine the effectiveness of fine-mesh, angled screens.

In 1978, tests were performed with striped bass larvae using both 1.5- and 2.5-mm mesh and different screen materials and approach velocity. Diversion efficiency was found to clearly be a function of larvae length. Synthetic materials were also found to be more effective than metal screens. Subsequent testing using only synthetic materials found that 1-mm screens can provide post larvae diversion efficiencies of greater than 80 percent. The tests found, however, that latent mortality for diverted species was also high. Finally, EPRI tested MIS in a laboratory in the early 1990s. Most fish had diversion efficiencies of 47 to 88 percent. Diversion efficiencies of greater than 98 percent were observed for channel catfish, golden shiner, brown trout, Coho and Chinook salmon, trout fry and juveniles, and Atlantic salmon smolts. Lower diversion efficiency and higher mortality were found for American shad and blueback herring, but the mortalities were comparable to control mortalities. Based on the laboratory data, an MIS system was pilot-tested at a Niagara Mohawk hydroelectric facility on the Hudson River. This testing showed diversion efficiencies and survival rates approaching 100 percent for golden shiners and rainbow trout. High diversion and survival were also observed for largemouth and smallmouth bass, yellow perch, and bluegill. Lower diversion efficiency and survival were found for herring.

In October 2002, EPRI published the results of a combined louver/angled screen assembly study that evaluated the diversion efficiencies of various configurations of the system. In 1999, fish guidance efficiency was evaluated with two bar rack configurations (25- and 50-mm spacings) and one louver configuration (50-mm clearance), with each angled at 45 degrees to the approach flow. In 2000, the same species were evaluated with the 50-mm bar racks and louvers angled at 15 degrees to the approach flow. Diversion efficiencies were evaluated at various approach velocities ranging from 0.3 to 0.9 m/s.

Guidance efficiency was lowest, generally lower than 50 percent, for the 45 degree louver/bar rack array, with efficiencies distributed along a bell shaped curve according to approach velocity. For the 45 degree array, diversion efficiency was best at 0.6 m/s, with most species approaching 50 percent. All species except one (lake sturgeon) experienced higher diversion efficiencies with the louver/bar rack array set at 15 degrees to the approach flow. With the exception of lake sturgeon, species were diverted at 70 percent or better at most approach velocities.

Similar to louvers, angled screens show potential to minimize impingement by greater than 80 to 90 percent. More widespread full-scale use is necessary to determine optimal design specifications and verify that they can be used on a widespread basis.

2.8 Velocity Caps

Technology Description
A velocity cap is a device that is placed over a vertical inlet at an offshore intake. This cover converts vertical flow into horizontal flow at the entrance to the intake. The device works on the premise that fish will avoid rapid changes in horizontal flow but are less able to detect and avoid vertical velocity vectors. Velocity caps have been installed at many offshore intakes and have usually been successful in minimizing impingement.

Technology Performance
Velocity caps can reduce the number of fish drawn into intakes based on the concept that they tend to avoid rapid changes in horizontal flow. They do not provide reductions in entrainment of eggs and larvae, which cannot distinguish flow characteristics. As noted in ASCE (1981), velocity caps are often used in conjunction with other fish protection devices, such as screens with fish returns. Therefore, there are somewhat limited data on their performance when used alone. Facilities that have velocity caps include the following:

- Oswego Steam Units 5 and 6 in New York (combined with angled screens on Unit 6).
- San Onofre Units 2 and 3 in California (combined with louver system).
- El Segundo Station in California
- Huntington Beach Station in California
- Edgewater Power Plant Unit 5 in Wisconsin (combined with 9.5-mm wedgewire screen)
- Nanticoke Power Plant in Ontario, Canada
- Nine Mile Point in New York
- Redondo Beach Station in California
- Kintigh Generation Station in New York (combined with modified traveling screens)
- Seabrook Power Plant in New Hampshire
- St. Lucie Power Plant in Florida
- Palisades Nuclear Plant in Michigan

At the Huntington Beach and Segundo stations in California, velocity caps have been found to provide 80 to 90 percent reductions in fish entrapment. At Seabrook, the velocity cap on the offshore intake has minimized the number of pelagic fish entrained except for pollock. Finally, two facilities in England each have velocity caps on one of two intakes. At the Sizewell Power Station, intake B has a velocity cap, which reduces impingement about 50 percent compared to intake A. Similarly, at the Dungeness Power Station, intake B has a velocity cap, which reduces impingement about by 62 percent compared to intake A.

2.9 Porous Dikes and Leaky Dams

Technology Overview
Porous dikes, also known as leaky dams or dikes, are filters that resemble a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel that permits free passage of water. The dike acts as both a physical and a behavioral barrier to aquatic organisms. Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish. The major problems associated with porous dikes come from clogging by debris and silt, ice buildup, and colonization by fish and plant life.

Technology Performance
Porous dike technologies work on the premise that aquatic organisms will not pass through physical barriers in front of an intake. They also operate with low approach velocity, further increasing the potential for avoidance. They will not, however, prevent entrainment by nonmotile larvae and eggs. Much of the research on porous dikes and leaky dams was performed in the 1970s. This work was generally performed in a laboratory or on a pilot level, and the Agency is not aware of any full-scale porous dike or leaky dam systems currently used at power plants in the United States. Examples of early study results include:

- Studies of porous dike and leaky dam systems by Wisconsin Electric Power at Lake Michigan plants showed generally lower I&E rates than those for other nearby onshore intakes.

- Laboratory work by Ketschke showed that porous dikes could be a physical barrier to juvenile and adult fish and a physical or behavioral barrier to some larvae. All larvae except winter flounder showed some avoidance of the rock dike.

- Testing at the Brayton Point Station showed that densities of bay anchovy larvae downstream of the dam were reduced by 94 to 99 percent. For winter flounder, downstream densities were lower by 23 to 87 percent.

Entrainment avoidance for juvenile and adult finfish was observed to be nearly 100 percent. As indicated in the above examples, porous dikes and leaky dams show *potential* for use in limiting the passage of adult and juvenile fish and, to some degree, motile larvae. However, the lack of more recent, full-scale performance data makes it difficult to predict their widespread applicability and specific levels of performance.

2.10 Behavioral Systems

Technology Overview
Behavioral devices are designed to enhance fish avoidance of intake structures or to promote attraction to fish diversion or bypass systems. Specific technologies that have been considered include:

- Light Barriers: Light barriers consist of controlled application of strobe lights or mercury vapor lights to lure fish away from the cooling water intake structure or deflect natural migration patterns. This technology is based on research that shows that some fish species avoid light; however, it is also known that some species are attracted by light.

- Sound Barriers: Sound barriers are noncontact barriers that rely on mechanical or electronic equipment that generates various sound patterns to elicit avoidance responses in fish. Acoustic barriers are used to deter fish from entering cooling water intake structures. The most widely used acoustical barrier is a pneumatic air gun or "popper."

- Air bubble barriers: Air bubble barriers consist of an air header with jets arranged to provide a continuous curtain of air bubbles over a cross sectional area. The general purpose of air bubble barriers is to repel fish that might attempt to approach the face of a CWIS.

Technology Performance
Many studies have been conducted and reports prepared on the application of behavioral devices to control I&E, see, for example, EPRI 2000. For the most part, these studies have been inconclusive or have shown no significant reduction in impingement or entrainment. As a result, the full-scale application of behavioral devices has been limited. Where data are available, performance appears to be highly dependent on the types and sizes of species and environmental conditions. One exception might be the use of sound systems to divert alewife. In tests at the Pickering Station in Ontario, poppers were found to be effective in reducing alewife I&E by 73 percent in 1985 and 76 percent in 1986. No impingement reductions were observed for rainbow smelt and gizzard shad. Testing of sound systems in 1993 at the James A. Fitzpatrick Station in New York showed similar results, i.e., 85 percent reductions in alewife I&E through use of a high-frequency sound system. At the Arthur Kill Station, pilot- and full-scale high-frequency sound tests showed comparable results for alewife to those for Fitzpatrick and Pickering. Impingement of gizzard shad was also three times lower than that without the system. No deterrence was observed for American shad or bay anchovy using the full-scale system. In contrast, sound provided little or no deterrence for any species at the Roseton Station in New York. Overall, the Agency expects that behavioral systems would be used in conjunction with other technologies to reduce I&E and perhaps targeted toward an individual species (e.g., alewife).

2.11 Other Technology Alternatives

Use of variable speed pumps can provide for greater system efficiency and have reduced flow requirements (and associated entrainment) by 10 to 30 percent. EPA Region 4 estimated that use of variable speed pumps at the Canaveral and Indian River stations in the Indian River estuary would reduce entrainment by 20 percent. Presumably, such pumps could be used in conjunction with other technologies to meet the performance standards.

Perforated pipes draw water through perforations or elongated slots in a cylindrical section placed in the waterway. Early designs of this technology were not efficient, velocity distribution was poor; and the pipes were specifically designed to screen out detritus, not to protect fish (ASCE 1982). Inner sleeves were subsequently added to perforated pipes to equalize the velocities entering the outer perforations. These systems have historically been used at locations requiring small amounts of make-up water; experience at steam electric plants is very limited (Sharma 1978). Perforated pipes are used on the intakes for the Amos and Mountaineer stations along the Ohio River, but I&E performance data for these facilities are unavailable. In general, EPA projects that perforated pipe system performance should be comparable to that of wide mesh wedgewire screens (e.g., at Eddystone Units 1 and 2 and Campbell Unit 3).

At the Pittsburg Plant in California, impingement survival was studied for continuously rotated screens versus intermittent rotation. Ninety-six-hour survival for young-of-year white perch was 19 to 32 percent for intermittent screen rotation versus 26 to 56 percent for continuous rotation. Striped bass latent survival increased from 26 to 62 percent when continuous rotation was used. Similar studies were also performed at Moss Landing Units 6 and 7, where no increased survival was observed for hardy and very fragile species; there was, however, a substantial increase in impingement survival for surfperch and rockfish.

Facilities might be able to use recycled cooling water to reduce their intake flow needs. The Brayton Point Station has a "piggyback" system in which the entire intake requirements for Unit 4 can be met by recycled cooling water from Units 1 through 3. The system has been used sporadically since 1993, and it reduces the make-up water needs (and thereby entrainment) by 29 percent.

2.12 Intake Location

Beyond design alternatives for CWISs, an operator might be able to relocate CWISs offshore or in others areas that minimize I&E (compared to conventional onshore locations). In conjunction with offshore inlet technologies such as cylindrical wedgewire t-screens or velocity caps, the relocated offshore intake could be quite effective at reducing impingement and/or entrainment effects. However, the action of relocating at existing facilities is costly due to significant civil engineering works. It is well known that there are certain areas within every waterbody with increased biological productivity, and therefore where the potential for I&E of organisms is higher.

In large lakes and reservoirs, the littoral zone (the shore zone areas where light penetrates to the bottom) serves as the principal spawning and nursery area for most species of freshwater fish and is considered one of the most productive areas of the waterbody. Fish of this zone typically follow a spawning strategy wherein eggs are deposited in prepared nests, on the bottom, or are attached to submerged substrates where they incubate and hatch. As the larvae mature, some species disperse to the open water regions, whereas many others complete their life cycle in the littoral zone. Clearly, the impact potential for intakes located in the littoral zone of lakes and reservoirs is high. The profundal zone of lakes and reservoirs is the deeper, colder area of the waterbody. Rooted plants are absent because of insufficient light, and for the same reason, primary productivity is minimal. A well-oxygenated profundal zone can support benthic macroinvertebrates and cold-water fish; however, most of the fish species seek shallower areas to spawn (either in littoral areas or in adjacent streams and rivers). Use of the deepest open water region of a lake or reservoir (e.g., within the profundal zone) as a source of cooling water typically offers lower I&E impact potential than use of littoral zone waters.

As with lakes and reservoirs, rivers are managed for numerous benefits, which include sustainable and robust fisheries. Unlike lakes and reservoirs, the hydrodynamics of rivers typically result in a mixed water column and overall unidirectional flow. There are many similarities in the reproductive strategies of shoreline fish populations in rivers and the reproductive strategies of fish within the littoral zone of lakes and reservoirs. Planktonic movement of eggs, larvae, post larvae, and early juvenile organisms along the shore zone is generally limited to relatively short distances. As a result, the shore zone placement of CWISs in rivers might potentially impact local spawning populations of fish. The impact potential associated with entrainment might be diminished if the main source of cooling water is recruited from near the bottom strata of the open water channel region of the river. With such an intake configuration, entrainment of shore zone eggs and larvae, as well as the near-surface drift community of ichthyoplankton, is minimized. Impacts could also be minimized by controlling the timing and frequency of withdrawals from rivers. In temperate regions, the number of entrainable or impingeable organisms of rivers increases during spring and summer (when many riverine fishes reproduce). The number of eggs and larvae peak at that time, whereas entrainment potential during the remainder of the year can be minimal.

In estuaries, species distribution and abundance are determined by a number of physical and chemical attributes, including geographic location, estuary origin (or type), salinity, temperature, oxygen, circulation (currents), and substrate. These factors, in conjunction with the degree of vertical and horizontal stratification (mixing) in the estuary, help dictate the spatial distribution and movement of estuarine organisms. With local knowledge of these characteristics, however, the entrainment effects of a CWIS could be minimized by adjusting the intake design to areas (e.g., depths) least likely to affect concentrated numbers and species of organisms.

In oceans, nearshore coastal waters are typically the most biologically productive areas. The euphotic zone (zone light available for photosynthesis) typically does not extend beyond the first 100 meters (328 feet) of depth. Therefore, inshore waters are generally more productive due to photosynthetic activity and due to the input from estuaries and runoff of nutrients from land.

There are only limited published data quantifying the locational differences in I&E rates at individual power plants. Some information, however, is available for selected sites. For example,

- For the St. Lucie plant in Florida, EPA Region 4 permitted the use of a once through cooling system instead of closed-cycle cooling by locating the outfall 1,200 feet offshore (with a velocity cap) in the Atlantic Ocean. This approach avoided impacts on the biologically sensitive Indian River estuary.

- In *Entrainment of Fish Larvae and Eggs on the Great Lakes, with Special Reference to the D.C. Cook Nuclear Plant, Southeastern Lake Michigan* (1976), researchers noted that larval abundance is greatest within the area from the 12.2-m (40-ft) contour to shore in Lake Michigan and that the abundance of larvae tends to decrease as one proceeds deeper and farther offshore. This finding led to the suggestion of locating CWISs in deep waters.

- During biological studies near the Fort Calhoun Power Station along the Missouri River, results of transect studies indicated significantly higher fish larvae densities along the cutting bank of the river, adjacent to the station's intake structure. Densities were generally were lowest in the middle of the channel.

II. Offshore Oil and Gas Extraction Facilities

INTRODUCTION

To identify suitable technologies to minimize impingement mortality and entrainment of fish in typical seawater intake structures for offshore oil and gas extraction facilities, the Agency evaluated currently known technologies and other possible technologies. Known technologies include standard screens, velocity caps and barrier nets. Other technologies identified include acoustic barriers, air curtains and electric barriers. Technologies such as acoustic or electric barriers may be particularly valuable to limit impingement on difficult to modify systems, such as sea chests. This evaluation also includes technologies for anti bio-fouling systems. Current anti bio-fouling technology includes chemical injection at the intake, air sparging of screens and the use of Cu-Ni alloys on the intake screen surfaces.

An alternative technology must prove to be practical before progressing it as a viable alternative to current technology. The primary criteria for a practical/acceptable alternative configuration/technology is that it is successfully implemented at one or more facilities, including other manufacturing industries with a similar seawater intake structure, anywhere around the world.

In addition to identifying appropriate fish barrier technologies, this section characterize typical seawater intake structures used by offshore oil and gas extraction facilities.

1.0 AVAILABLE TECHNOLOGIES

1.1 Known Technologies

Known technologies evaluated include standard screens, velocity caps, and barrier nets as discussed in the previous section. Each technology is discussed below with respect to its potential use with offshore oil and gas extraction facilities.

1.1.1 Passive Intake Screens

Passive intake screens covers the whole range of static screens that act as a physical barrier to fish entrainment. These barriers include:

- Simple mesh over an open pipe end (caisson or simple intake pipe) with a suitably low face velocity to prevent impingement,
- Grill or mesh spanning an opening (as used on sea chest) with a suitably low face velocity to prevent impingement, and
- Cylindrical and wedgewire T-screens designed for the purpose of protecting fish stocks (suitable for caissons or simple intake pipes but not sea chests). Passive intake screens are very commonly used throughout industry and are readily available.

Fine mesh wedgewire screens (0.5-1mm) have been identified as having potential to prevent both entrainment and impingement. (See the Phase I Technical Development Document (EPA-821-R-01-036), DCN 3-0002). The main drawback practical with this fish barrier solution is that the screens are prone to blockages as a result of bio-fouling. Since this type of equipment is so common, an investigation into anti bio-fouling technology is presented below.

The use of a passive intake screen on a sea chest (as used by some mobile offshore drilling units (MODUs)) may be prone to impingement issues. This is because the size of the opening of a sea chest into the ocean is essentially fixed. To increase the size of a sea chest would be very costly due to significant works at a dry dock. A passive screen that has a suitably low face velocity may therefore have to protrude outside the hull of the vessel. This would have a negative impact on the hydrodynamics of the vessel and create a catch point under the waterline. Alternatively, the passive screen may be used in conjunction with another technology such as an acoustic or electro barrier to reduce impingement. Due to the success of passive intake screens at many installations around the world, this type of technology is a suitable fish barrier for use/retrofit on offshore oil and gas extraction facilities.

1.1.2 Velocity Caps

A velocity cap is a device that is placed over vertical inlets at offshore intakes. This cover converts vertical flow into horizontal flow at the entrance into the intake. The device works on the premise that fish will avoid rapid changes in horizontal flow. In general, velocity caps have been installed at many offshore intakes and have been successful in minimizing impingement. Velocity caps can reduce fish drawn into intakes based on the concept that they tend to avoid horizontal flow. They do not provide reductions in entrainment of eggs and larvae, which cannot distinguish flow characteristics. As noted in ASCE (1982), velocity caps are often used in conjunction with other fish protection devices. Therefore, there is somewhat limited data on their performance when used alone.

In the case of offshore oil and gas extraction facilities, velocity caps may be used in conjunction with a passive intake screen (as described above). However, the bio-fouling drawback of a passive intake screen would also be present. Other possible barriers to use in conjunction with a velocity cap may include the "other" technologies noted below (such as acoustic barriers). Velocity caps, when used in conjunction with another barrier may be a suitable fish barrier technology for offshore oil and gas extraction facilities that use a simple pipe intake or a caisson. The use of a velocity cap on a sea chest (as used by some MODUs) is unlikely to be a practical technology. This is because the size of the opening of a sea chest into the ocean is essentially fixed. To increase the size of a sea chest would very costly due to significant works at a dry dock. A velocity cap over the inlet would therefore have to protrude outside the hull of the vessel. This would have a negative impact on the hydrodynamics of the vessel and create a catch point under the waterline.

1.1.3 Barrier Nets

Barrier nets are typically utilized in locations where impingement is a problem. In these situations, a net is used to keep relatively large fish away from an intake screen. Fish net barriers are wide-mesh nets, which are placed in front of the entrance to intake structures. The size of the mesh needed is a function of the species that are present at a particular site and vary from 4 mm to 32 mm. A number of barrier net systems have been used/studied at large onshore power plants. Barrier nets have clearly proven effective for controlling impingement (i.e., 80+ percent reductions over conventional screens without nets) in areas with limited debris flows. Experience has shown that high debris flows can cause significant damage to net systems.

Bio-fouling can also be a concern but this can be addressed through frequent maintenance. Barrier nets are also often only used seasonally, where the source water body is subject to freezing. Fine-mesh barrier nets show some promise for entrainment control but would likely require even more intensive maintenance. In some cases, the use of barrier nets may be further limited by the physical constraints and other uses of the water body. Barrier nets are not suitable for use on MODUs since the net would be a major hindrance to the operation of the vessel. Fixed platforms may potentially use barrier nets to reduce impingement problems. The configuration that may be practical is to set the nets up in removable panels around the intake. At this stage, an example of this type of paneled net configuration is not available.

1.1.4 Perforated Intake Pipe

A perforated pipe arrangement draws water through perforations or elongated slots in a cylindrical section placed in the water body. Early designs of this technology were not efficient, velocity distribution was poor, and they were specifically designed to screen out debris and not for the protection of aquatic organisms. Perforated caissons or simple pipes have been used on some fixed platforms. For example: Marathon South Pass (Block 86) use a 20" inner diameter simple pipe with bottom at 59' below water level. The lower 8' pipe section is slotted with bottom open, slots are 1"W x 4"L, slots spaced 3" apart along circumference and 8" apart vertically.

Since impingement and entrainment performance data for perforated pipe arrangements are unavailable, the use of this technology is questionable. In general, EPA projects that perforated pipe system performance should be comparable to wide-mesh wedgewire screens (e.g., at Eddystone Units 1 and 2 and Campbell Unit 3).

1.1.5 Traveling Screens (Includes Angular and Modular Screens)

Traveling screens are generally used on onshore facilities that incorporate large stilling and pump pits. The traveling screen installation requires a significant amount of specifically designed structure to be included in the intake design. Retrofitting a structure to accept a traveling screen on offshore oil and gas extraction facilities would be impractical and extremely costly. Furthermore, the maintenance of a sub-sea traveling screen retrofitted to an existing structure would also be impractical and very costly. The design of traveling intake screens is not suited to offshore oil and gas extraction facilities. As such, this technology has been deemed to be unsuitable for these facilities.

1.1.6 Porous Dikes and Leaky Dams

Porous dikes, also known as leaky dams or dikes, are filters resembling a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel that permits free passage of water. The dike acts both as a physical and behavioral barrier to aquatic organisms. Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish. The major problems associated with porous dikes come from clogging by debris and silt, ice build-up, and by colonization of fish and plant life. Clearly the construction of a fixed major civil installation such as a porous dam or leaky dike is not possible for MODUs. The use of this type of equipment on fixed platforms may also be rejected due to the fact that if one were constructed in the middle of the ocean it would be extremely impractical and costly and result in the death or dislocation of a large number of marine wildlife. As such, this technology has been deemed to be unsuitable for the facilities evaluated here.

2.0 OTHER TECHNOLOGIES

Other technologies reviewed include acoustic barriers, air curtains, electro fish barriers, intake location, keel cooling, and strobe lights and illumination. Each technology is discussed below with respect to its potential use in minimizing impingement and entrainment at offshore oil and gas extraction facilities.

2.1 Acoustic Barriers

Although there is simplicity in the concept of an acoustic fish deterrent, it is apparent that the use of sound for fish repulsion is not a simple task. The use of sound has been established as an effective means of repelling many species of fish. The major problems with acoustic barriers are that some sounds repel some fish yet have no effect or attract others, and fish may, over time, become desensitized to a sound that would otherwise scare them away. There have been a number of studies undertaken on specific fish entrainment issues at specific locations. However, from a commercial perspective, supply of acoustic barrier equipment is not commonly available. Fish Guidance Systems Limited (FGS) from Southampton in the United Kingdom design and manufacture a range of acoustic barriers for large industrial water intakes.

For fish to be repelled by a sound, a number of criteria must be met (derived from www.fish-guide.com):
- The fish must be able to detect the frequencies used to compose the deterrent signal.
- The sound signal composition must be of a type that is repellent to fish (some sounds attract, others have no effect);
- The level of the sound must be high enough to elicit a reaction, taking account of background noise.

The issue of background noise is important, especially where acoustic systems are deployed near underwater machinery such as pumps and turbines. In such cases, it may be necessary to measure the underwater noise spectra under typical operating conditions.

Underwater noise may be repellent to fish if:
- Noise of any type having frequencies that lie within the fish hearing range is emitted at very high audio levels (but this is very expensive and may impact other biota);
- The characteristics of the noise have any special biological meaning to the fish (e.g., mimicking the approach of a predator);
- The noise is designed by experimentation to cause particularly strong avoidance.

The biological approach may offer good possibilities for individual species, but the empirical approach has yielded a number of signal types that are effective against a wide range of species. The signal types that have proved most effective in all applications are based on artificially generated waveforms that rapidly cycle in amplitude and frequency content, thus reducing habituation. A human equivalent would be being made to stand near to a wailing police or ambulance siren. It simply gets uncomfortable, so you move away. In practice, considerable attention needs to be given to the design and specification of a system to ensure it achieves high fish deflection efficiencies. Key variables include the type of fish, background noise, hydraulic conditions (eg. intake velocities, attraction flow to the fish pass) and acoustic design. Acoustic systems may be designed primarily either to block or to deflect fish movement.

Deflection is usually the best course of action, as the fish are moved swiftly from the source of danger (e.g., water intake) into a safe flow. Blocking can be more difficult if the fish are not moved away from the area, as the risk of habituation to the sound signals becomes increased. This can be overcome to some extent by changing the signal pattern at intervals but acoustic deterrents are essentially a mild form of stimulus less effective than electric barriers purely for blocking. For this reason it is advised that a well-designed and suitably placed bypass facility be provided.

Sound projectors are electro-mechanical devices and regular maintenance of them is required to ensure optimum performance. This involves removing the underwater units to replace perished seals and to check moving components. Also, it is desirable to raise and

clean the units occasionally to remove any build-up of silt or fouling. It is necessary to provide a deployment system to bring sound projectors to the surface for maintenance, without the need to use divers.

As it is difficult to check the performance of submerged equipment, diagnostic units can be attached to the control electronics to monitor performance of the sound projectors.

2.1.1 Example Installations

It must be noted that the examples of Acoustic Barriers did not include any facilities that fall into the category of offshore oil and gas extraction facilities. However, the following installations share similarities with fixed offshore structures. The use of this equipment on sea chests or mobile equipment may be possible but is not proven by example.

Doel Power Station - SPA System

Doel nuclear power station operated by Electrabel responded to concerns expressed by environmental regulators and fishermen to reduce the numbers of fish that were being drawn into their cooling water intake each year. The main species being affected were herring and sprat (clupeid family).

In 1997, a SPA fish deterrent system was designed and installed on the offshore intake. In total, 20 large FGS Mk II 30-600 sound projectors were installed to create a repellent sound field close to the water intake openings causing passing fish to veer away. A multiple signal generator was used to avoid resident species habituating to any one sound signal. To allow servicing of the fish deterrent system while the station is still operating, a deployment frame has been installed to lower sound projectors into their optimum position and to allow them to be raised for routine inspections and maintenance.

The acoustic installation has subsequently undergone a number of evaluation trials by researchers from Belgium's Leuven University. Independent trials have shown a reduction in the target species by 98%. In addition, the catch of other non-target species has been reduced with the overall reduction being 81%.

Foss Flood Relief Pumping Station SPA System

The Environment Agency responded to a fish kill at the River Foss Flood Alleviation Pumping Scheme in York (UK). The scheme consists of a barrier gate to prevent floodwater from the River Ouse flowing up the River Foss. Water flowing down the Foss is pumped from the upstream side of the floodgate by eight vertical, axial flow propeller pumps, and discharged below the gate. Fish damage was attributable to contact with moving machinery and rapid pressure changes during passage through the pumps.

In 1994, an acoustic fish deflection system was installed to deflect fish away from pumps prior to and during operation. As the pump inlets formed a popular shelter for resident fish, the acoustic system was designed to start operating 15 minutes prior to the pumps operating. The SPA installation also provided important protection to resident fish while the pumps were operating by creating a gradient of deterrent sound, increasing towards the intake openings. The installation comprised six FGS Mk I Model 30-600 sound projectors.

A series of independent trials were performed to test the effectiveness of an acoustic fish deterrent system in 1994. Coarse fish representing 12 species were captured during the trial. The most abundant species were bleak, dace, chub, perch and common bream. Prior to the trial, it was previously considered that the sudden commencement of pumping accounted for a larger proportion of the fish entrained through the pumps, as the enclosed environment of the pump channels provided a potential refuge for fish. It was found that the majority of fish were drawn into the Foss Basin during pumping. The acoustic system was found to reduce overall fish entrainment by 80% with the system deflecting fish in the pumpwells and outside the Foss Basin during operation.

Other Installations

- Central Hidroelectrica de Allones, Spain: Four 15-100 Sound Projector Array system supplied to deflect fish away from a head race channel entrance. (August 2000)
- Blackdyke Water Transfer Pumping Station, UK: Eight 15-100 Sound Projector Array system supplied to deflect fish out of pumping station chambers, prior to and during water transfers. (July 2000)
- Great Yarmouth CCGT, UK: Eight 30-600 Sound Projector Array system supplied for cooling water system to new CCGT power station. (July 2000)

- Shoreham CCGT, UK: Six 30-600 Sound Projector Array system supplied for cooling water intake to new CCGT power station. (June 2000)

- Drinking Water Abstraction, River Stour, UK: Six 15-100 Sound Projector Array system supplied for drinking water abstraction. (April 2000)

2.1.2 Acoustic Barrier Conclusions

Acoustic barriers have proven to be effective as fish impingement and entrainment barriers. Since there is no fine mesh covering the intake, this type of barrier is not prone to issues with bio-fouling.

This type of equipment is commercially available and has been proven effective at a number of locations.

The typical application of this technology has been onshore-based intake structures rather than offshore oil and gas extraction facilities. The transfer of this technology to offshore oil and gas extraction facility intake structures may be possible with further development. It is particularly interesting for fitting to sea chest intake structures.

2.2 Air Curtains

Air curtains are simply a screen of bubbles used to guide fish away from an intake structure. Air bubbles have proven to have some effect for herding and guiding fish or as a barrier to their normal activity (Bibko *et al.* 1973). However, the effectiveness of air bubble curtains at water intakes varies greatly (NEST 1996). Northeast Science and Technology (NEST) undertook a detailed study into the effectiveness of many different types of technology for preventing lake Sturgeon impingement and entrainment for the Little Long Generating Station Facilities (NEST 1996). This facility is located in Northeastern Ontario on the Mattagami River and represents one of the last refuges for lake Sturgeon.

Overall, air curtains on their own do not effectively deter fish or substantially reduce impingement (Zweiacker *et al.* 1977; Lieberman and Muessig 1978; Patrick *et al.* 1988: NEST 1996). Factors that reduce the effectiveness of an air curtain include:

- water temperature (Bibko *et al.* 1973),
- fish crowding (Smith 1961),
- the presence of predators (Smith 1961), and
- levels of light (Alevras 1973).

The effectiveness of an air curtain may be improved when used in combination with acoustic deterrents. When a pneumatic popper is used in combination with an air curtain, there is an improved overall effectiveness. This same effect is not observed with use of strobe lights (Patrick *et al.* 1988). Supply of air curtain and acoustic barrier equipment is not commonly available. Fish Guidance Systems Limited (FGS) from Southampton in the United Kingdom design and manufacture a device that utilizes both a bubble curtain and an acoustic deterrent for large industrial water intakes.

The BAFF is used to divert fish from a major flow, e.g., entering a turbine, into the minor flow of a fish pass channel. It may be regarded as analogous to a conventional angled fish screen. It uses an air bubble curtain to contain a sound signal that is generated pneumatically. Effectively, this creates a "wall of sound" (an evanescent sound field) field that can be used to guide fish around river structures by deflection into fish passes.

Physically, the BAFF comprises a pneumatic sound transducer coupled to a bubble-sheet generator, causing sound waves to propagate within the rising curtain of bubbles. The sound is contained within the bubble curtain as a result of refraction, since the velocity of sound in a bubble-water mixture differs from that in either water or air alone. The sound level inside the bubble curtain may be as high as 170 dB re 1mPa, typically decaying to 5% of this value within 0.5-1 m from the bubble sheet. It can be deployed in much the same way as a standard bubble curtain, but its effectiveness as a fish barrier is greatly enhanced by the addition of a repellent sound signal. The characteristics of the sound signals are similar to those used in SPA systems, i.e., within the 20-500 Hz frequency range and using frequency or amplitude sweeps.

FGS acoustic BAFF systems comprise the following components:

- BAFF Unit: The BAFF system comprises of modular sections, each 2.4 m long, which are linked together to form the required length. The acoustic signal is entrapped in the bubbles by a driver unit and the resulting 'wall of sound' produces an uninterrupted guidance system.
- Air Blower or Compressor: The BAFF uses an air blower or compressor to supply pressurised air to create a continuous bubble curtain.
- Air Blower/Compressor Pipe: A temperature / pressure resistant pipe delivers air from the air blower or compressor to the BAFF control equipment.
- BAFF Control Equipment and Control Lines: The BAFF control equipment is used to operate the BAFF system. A main air supply and two control lines feed driver units fitted on each of the BAFF units. Solenoids located in the returning control line regulate the airflow to the driver units. Pressure feedback lines run from the BAFF units back to the control panel to allow pressure within the BAFF to be monitored. An alarm system indicates a sudden drop in pressure resulting from a failure in air supply.

2.2.1 Example Installations

It must be noted that the examples found did not include any facilities that fall into the category of offshore oil and gas extraction facilities. However, the following installations share similarities with fixed offshore structures. The use of this equipment on sea chests or mobile equipment may be possible but is not proven by example.

Beeston Hydro-electric Station

- Beeston Weir Hydro Scheme, a 1.3MW station was commissioned in May 2000. The £3 million ($ 5.5 million USD) Beeston Hydro Scheme was installed at an existing weir on the River Trent near Nottingham in the UK. A prime objective of the new hydro was to make the scheme fit the environment, and not the other way around.

- The river supports a mixed population of resident coarse fish and migratory eels. Owing to a history of poor water quality, the river currently has a very small population of salmonoid fish. However, the Environment Agency has a program underway of continuous improvement of water quality, with the goal of restoring the salmonoid population.

- To divert downstream migrating fish away from the headrace channel, a 80m long BAFF system was installed. It is located diagonally upstream of the weir to guide juvenile salmon and other fish moving downstream to the fish ladder. A new vertical single slot fish pass was added to facilitate upstream and downstream passage of both salmonoid and coarse fish, prior to construction of the hydro facility.

- The BAFF system produces a "wall of underwater sound" by using compressed air to generate a continuous bubble curtain into which low frequency sound (varying between 50 and 500 Hertz) is injected and entrapped. Although well-defined lines of high level sound (at least 160 decibels) are generated within the bubble curtain, the noise levels are negligible a few meters away from it. By restricting the sound curtain to a small area, the system allows fish to act normally throughout the remainder of the reservoir or river.

- A Smith-Root graduated electric barrier is located just below the power plant to divert adult salmon migrating upstream away from the tailrace and into the fish ladder.

Other Installations

- Backbarrow Hydro, UK: Eleven units BAFF system supplied to guide fish in headrace channel to a purpose built by wash. (August 2000)

- Blantyre, Hydro Station, Scotland, UK: Combined Sound Projector Array and BAFF system installed on low-head hydro-electric power station for evaluation trials. Results published in ETSU report H/01/00046/REP www.dti.gov.uk/NewReview/nr32/html/fish.html (Spring 1996)

- Northampton, Inland Waterway Pumping Station, UK: Two bubble curtain system installed on canal pumping station intake to reduce transfer of zander. (January 1999)

2.2.2 Air Curtain Conclusions

Air curtains have proven to be ineffective barriers to impingement and entrainment of fish stocks when they are use on their own. When used in combination with other acoustic deterrent systems, their effectiveness is greatly increased. This equipment type of equipment is commercially available and has been proven effective at a number of locations.

The typical application of this technology has been on hydro-electric power station intake structures rather than offshore oil and gas extraction facilities. The transfer of this technology to offshore oil and gas extraction facility intake structures may be possible with further development. As such, this technology has the potential to become suitable after further development.

2.3 Electro Fish Barriers

Electrical fields are frequently used to frighten, attract, stun or kill fish. On approaching the field, many fish exhibit a fright reaction and may be repelled (NEST, 1996).

The following information was obtained from the Smith-Root web page (www.smith-root.com). Smith-Root is a leading supplier of Electro Fish barriers:

Electric current passing between the electrodes, via the water medium, produces an electric field. When fish are within the field, they become part of the electrical circuit with some of the current flowing through their body. The electric current passing through fish can evoke reactions ranging from a slight twitch to full paralysis, depending on the current level and shock duration they receive. (Smith-Root.com)

One of the most important advantages of the parallel field orientation is that when a fish is crosswise to the electric field it receives almost no electric shock. Fish learn very quickly that by turning side ways to the flow they can minimize the effects of the electric field.

2.3.1 Example Installations

Great Lakes Division - 80" Mill, Pump House #2 (1994)

Ecorse, Michigan
Barrier Type: Smith-Root Concrete weir with bottom mounted electrodes.

Keeps gizzard shad and other river fish from entering the pumping systems used for steel mill cooling. Previously, dense fish runs caused several shutdowns each year. Since installation in 1994, they have not had single shutdown attributed to fish runs.

Shields Lake

Forest Lake, Minnesota 1996
Barrier Type: Smith-Root Plastic culvert with stainless steel electrodes. Keeps carp from entering Shields Lake.

Heron Lake

Worthington, Minnesota 1993
Barrier Type: Smith-Root Concrete weir with bottom mounted electrodes.
Keeps carp from entering Heron Lake. Barrier is very effective and currently in operation. This once sterile lake is now restored to a bird and game fish habitat.

2.3.2 Electro Fish Barrier Conclusions

Electro Fish Barriers have proven to be effective as fish impingement and entrainment barriers. The main limitation is that the high conductivity of seawater limits the size of a practical electro barrier. Discussions with a supplier of this type of equipment (Smith-Root) stated that a practical installation would be possible at a caisson or sea chest opening. Electro Fish Barriers are commercially available and have been shown to be effective at a number of locations. The most common location for this technology to be used is on river or lake intake locations for power stations where local fish stocks are to be protected.

The typical application of this technology has been onshore-based intake structures rather than offshore oil and gas extraction facilities. The transfer of this technology to offshore oil and gas extraction facility intake structures may be possible with further development. As such, this technology has the potential to become suitable after further development. It is particularly interesting for fitting to sea chest intake structures.

2.4 Intake Location

Beyond technology design alternatives, an operator may able to locate cooling water intake structures offshore or otherwise in areas that minimize entrainment and impingement (compared to conventional onshore locations). It is well known that there are certain areas within every waterbody with increased biological productivity, and therefore where the potential for entrainment and impingement of organisms is higher (Phase I Technical Development Document (EPA-821-R-01-036), DCN 3-0002)).

In oceans, nearshore coastal waters are generally the most biologically productive areas. The euphotic zone (zone of photosynthetic available light) typically does not extend beyond the first 100 meters (328 feet) of depth. Therefore, nearshore waters are generally more productive due to photosynthetic activity, and due to the input from estuaries and run-off of nutrients from land (Phase I Technical Development Document (EPA-821-R-01-036), DCN 3-0002)).

Woodside Energy Limited in Western Australia indicated that the depth of the intake structure may be used as a method of controlling fish entrainment in offshore oil and gas extraction facility seawater intake structures. Unfortunately, no further details on the systems that are employed by Woodside are currently known.

2.4.1 Intake Location Conclusions

Intake location appears to offer potential in reducing entrainment and impingement of marine organisms. This type of technology may be implemented on fixed platforms that are located in deep water. A detailed marine study into the density of organisms would be required for this approach to be successful. This type of technology is not suitable for MODUs since they would operate in various locations, depths and environments. Furthermore, a variable depth sea chest would be impractical.

2.5 Keel Cooling

Keel cooling is a process which bypasses the need to draw cooling water on board a vessel. This is achieved by installing a heat exchanger in the waterbody and pumping cooling water through a closed loop system. This technology was developed during the Second World War and is commonly used on many vessels today. The Shine Fisheries Factory Trawlers operating out of Fremantle in Western Australia use keel cooling for all cooling water on all of their vessels.

Fernstrum Company has confirmed that this system is suitable for retrofitting to an existing on-board cooling water system. Furthermore, it is not limited to mobile vessels. The coolers may be designed using natural convection (fixed structure) rather than forced convection (moving structure) to meet a heat transfer requirement. Therefore, this equipment could be used on the cooling water systems of stationary or mobile offshore oil and gas extraction facilities. It is believed that Brown and Root installed one of the Fernstrum systems on a new offshore oil and gas extraction facility approximately 20 years ago. Unfortunately details of this system are currently unavailable. Bio-fouling of keel coolers is limited with the use of Cu-Ni alloys for fabrication. See Anti Bio-fouling Technologies below.

2.5.1 Keel Cooling Conclusions

Keel cooling is a suitable technology for MODUs. Stationary offshore oil and gas extraction facilities may also be able to benefit from this technology.

2.6 Strobe Lights and Illumination

The reaction of fish to light is not consistent. It changes with the type of light, intensity, angular distribution, polarization and duration (Hocutt 1980). Some fish may exhibit a positive response to a light source while the same light may repel others. Also, the reaction of a fish to a light source may vary depending on the life stage of the particular species (Fore 1969). Studies have been undertaken into the use of strobe lights. The effectiveness of a strobe has been found to vary with species, time of day and fish size (Taft *et al* 1987).

Compared with other behavioral barriers, strobe lights and other illumination generally appear to be the least effective. A combination of strobe lights and air curtains are more effective for repelling fish than either on their own but were less effective than the air curtain

/ acoustic deterrents (NEST 1996). Based on this research, strobe lights and illumination may be rejected as a suitable technology on their own. However, their use in combination with other technologies may prove to be successful.

3.0 ANTI BIO FOULING TECHNOLOGIES

Several anti bio-fouling technologies are available including air sparges, copper-nickel (Cu-Ni) alloys, chemical injection, and hot kill. Each technology and its potential application to offshore oil and gas extraction facilities is discussed below.

3.1 Air Sparges

The use of compressed air (air sparges) to physically remove bio matter from a screen face is commonly used in the industry. It is particularly useful when drifting seaweed or trash (such as plastic bags) impinges on the screen face.

This is a suitable technology in most marine areas. In the case that there are prolific marine organisms that may grow on the screen surface such as molluscs (zebra mussel), corral or seaweed growth, further methods may need to be taken to protect the screen, such as use of specific materials or "hot kill" which are described later in this section.

3.2 Cu-Ni Alloys

Alloys of copper and nickel have been found to limit marine growth on a submerged surface. These alloys are used in the manufacture of screen surfaces to prevent problems with invasive marine growth.

Johnson Screens offer screens manufactured from "Z Alloy" (90/10 CuNi). This material is commonly used for other sea water equipment (such as in plate types heat exchangers). This technology has proven to be suitable for seawater fabricated screen applications.

3.3 Chemical Injection

There are many chemicals that may be used to prevent bio-fouling of sea water systems. These include solutions of chlorine, copper and many other possible biocides. These systems are generally designed to mix in with the intake flow and protect the down stream process rather than the screen face. It would be very difficult and expensive to design a chemical system to protect an entire intake screen from bio-fouling. Furthermore, there would be a significant impact to the environment around the intake structure. Therefore, chemical injection for the protection of an intake barrier is considered impractical and not a suitable technology for this purpose.

3.4 Hot Kill

The Hot Kill process involves recirculating hot water back through the intake structure to kill any marine growth than may have attached to the intake pipe or screen.

Kwinana Power Station is a medium sized multi fuel (gas, oil and coal) power station that has operated in Cockburn Sound Western Australia for more than 40 years. The Sound is the natural habitat of the Blue Mussel, which grows prolifically throughout the area. The power station was designed with two separate intake systems (one unit on line, the other off line). The intake systems include a sub sea screened intake (mesh size unknown), inlet pipe of approximately 500m and an onshore concrete stilling sump with travelling (rotatory) screens. Auto chlorination (electrolysis) is used to treat the water after the rotating screens before the cooling water pumps. The mussels in the intake system have been controlled by recirculating the hot water return back through the off line intake unit. This is done for 2 hours at a temperature of 46-48°C (115-118°F). After the 2 hour kill has been achieved, the discharge flow is sent back to the main discharge channel. This system has worked well for a number of years in an environment of prolific mussel growth.

Unfortunately retrofitting offshore oil and gas extraction facilities with additional intakes (if required), cross over piping, and hot water return is very expensive. This type of solution is best incorporated during the design phase of a facility.

III. CONCLUSION

As suggested by the technology studies evaluated in this chapter, the technologies presented can substantially reduce impingement mortality and entrainment. With proper design, installation, and operation and maintenance, a facility can realize marked reductions. However, EPA recognizes that there is a high degree of variability in the performance of each technology, which is in part due to the

site-specific environmental conditions at a given facility. EPA also recognizes that much of the data cited in this document was collected under a variety of performance standards and study protocols that have arisen over the years since EPA promulgated its last guidance in 1977.

EPA believes that these technologies can meet the performance standards established in today's final rule. While EPA acknowledges that site-specific factors may affect the efficacy of impingement and entrainment reduction technologies, EPA believes that there are a reasonable number of options available from which most facilities may choose to meet the performance standards. EPA also believes that, in cases where one technology can not meet the performance standards alone, a combination of additional intake technologies, operational measures and/or restoration measures can be employed to meet the performance standards.

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Attachment A to Chapter 8

COOLING WATER INTAKE STRUCTURE TECHNOLOGY FACT SHEETS

Intake Screening Systems	Fact Sheet No. 1: Single-Entry, Single-Exit Vertical Traveling Screens (Conventional Traveling Screens)

Description:

The single-entry, single-exit vertical traveling screens (conventional traveling screens) consist of screen panels mounted on an endless belt; the belt rotates through the water vertically. The screen mechanism consists of the screen, the drive mechanism, and the spray cleaning system. Most of the conventional traveling screens are fitted with 3/8-inch mesh and are designed to screen out and prevent debris from clogging the pump and the condenser tubes. The screen mesh is usually supplied in individual removable panels referred to as " baskets" or "trays".

The screen washing system consists of a line of spray nozzles operating at a relatively high pressure of 80 to 120 pounds per square inch (psi). The screens are usually designed to rotate at a single speed. The screens are rotated either at predetermined intervals or when a predetermined differential pressure is reached across the screens based on the amount of debris in the intake waters.

Because of this intermittent operation of the conventional traveling screens, fish can become impinged against the screens during the extended period of time while the screens are stationary and eventually die. When the screens are rotated the fish are removed from the water and then subjected to a high pressure spray; the fish may fall back into the water and become re-impinged or they may be damaged (EPA, 1976, Pagano *et al*, 1977).

Intake Screening Systems	Fact Sheet No. 1: Single-Entry, Single-Exit Vertical Traveling Screens (Conventional Traveling Screens)

Testing Facilities and/or Facilities Using the Technology:

- The conventional traveling screens are the most common screening device presently used at steam electric power plants. Sixty percent of all the facilities use this technology at their intake structure (EEI, 1993).

Research/Operation Findings:

- The conventional single-entry single screen is the most common device resulting in impacts from entrainment and impingement (Fritz, 1980).

Design Considerations:

- The screens are usually designed structurally to withstand a differential pressure across their face of 4 to 8 feet of water.
- The recommended normal maximum water velocity through the screen is about 2.5 feet per second (ft/sec). This recommended velocity is where fish protection is not a factor to consider.
- The screens normally travel at one speed (10 to 12 feet per minute) or two speeds (2.5 to 3 feet per minute and 10 to 12 feet per minute). These speeds can be increased to handle heavy debris load.

Advantages:

- Conventional traveling screens are a proven "off-the-shelf" technology that is readily available.

Limitations:

- Impingement and entrainment are both major problems in this unmodified standard screen installation, which is designed for debris removal not fish protection.

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ASCE. Design of Water Intake Structures for Fish Protection. Task Committee on Fish-Handling Capability of Intake Structures of the Committee on Hydraulic Structures of the Hydraulic Division of the American Society of Civil Engineers, New York, NY. 1982.

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Intake Screening Systems	Fact Sheet No. 2: Modified Vertical Traveling Screens

Description:

Modified vertical traveling screens are conventional traveling screens fitted with a collection "bucket" beneath the screen panel. This intake screening system is also called a bucket screen, Ristroph screen, or a Surry Type screen. The screens are modified to achieve maximum recovery of impinged fish by maintaining them in water while they are lifted to a release point. The buckets run along the entire width of the screen panels and retain water while in upward motion. At the uppermost point of travel, water drains from the bucket but impinged organisms and debris are retained in the screen panel by a deflector plate. Two material removal systems are often provided instead of the usual single high pressure one. The first uses low-pressure spray that gently washes fish into a recovery trough. The second system uses the typical high-pressure spray that blasts debris into a second trough. Typically, an essential feature of this screening device is continuous operation which keeps impingement times relatively short (Richards, 1977; Mussalli, 1977; Pagano et al., 1977; EPA , 1976).

Testing Facilities and/or Facilities Using the Technology:

Facilities which have tested the screens include: the Surry Power Station in Virginia (White et al, 1976) (the screens have been in operation since 1974), the Madgett Generating Station in , Wisconsin, the Indian Point Nuclear Generating Station Unit 2 in New York, the Kintigh (formerly Somerset) Generating Station in New Jersey, the Bowline Point Generating Station (King et al, 1977), the Roseton Generating Station in New York, the Danskammer Generating Station in New York (King et al, 1977), the Hanford Generating Plant on the Columbia River in Washington (Page et al, 1975; Fritz, 1980), the Salem Genereating on the Delaware River in New Jersey, and the Monroe Power Plant on the Raisin River in Michigan.

Research/Operation Findings:

Modified traveling screens have been shown to have good potential for alleviating impingement mortality. Some information is available on initial and long-term survival of impinged fish (EPRI, 1999; ASCE, 1982; Fritz, 1980). Specific research and operation findings are listed below:

- In 1986, the operator of the Indian Point Station redesigned fish troughs on the Unit 2 intake to enhance survival. Impingement injuries and mortality were reduced from 53 to 9 percent for striped bass, 64 to14 percent for white perch, 80 to 17 percent for Atlantic tomcod, and 47 to 7 percent for pumpkinseed (EPRI, 1999).

- The Kintigh Generating Station has modified traveling screens with low pressure sprays and a fish return system. After enhancements to the system in 1989, survivals of generally greater than 80 percent have been observed for rainbow smelt, rock bass, spottail shiner, white bass, white perch, and yellow perch. Gizzard shad survivals

Intake Screening Systems	Fact Sheet No. 2: Modified Vertical Traveling Screens

have been 54 to 65 percent and alewife survivals have been 15 to 44 percent (EPRI, 1999).

- Long-term survival testing was conducted at the Hanford Generating Plant on the Columbia River (Page et al, 1975; Fritz, 1980). In this study, 79 to 95 percent of the impinged and collected Chinook salmon fry survived for over 96 hours.

- Impingement data collected during the 1970s from Dominion Power's Surry Station indicated a 93.8 percent survival rate of all fish impinged. Bay anchovies had the lowest survival rate of 83 percent. The facility has modified Ristroph screens with low pressure wash and fish return systems (EPRI 1999).

- At the Arthur Kill Station, 2 of 8 screens are modified Ristroph type; the remaining six screens are conventional type. The modified screens have fish collection troughs, low pressure spray washes, fish flap seals, and separate fish collection sluices. 24-hour survival for the unmodified screens averages 15 percent, while the two modified screens have 79 and 92 percent average survival rates (EPRI 1999).

Design Considerations:

- The same design considerations as for Fact Sheet No. 1: Conventional Vertical Traveling Screens apply (ASCE, 1982).

Advantages:

- Traveling screens are a proven "off-the-shelf" technology that is readily available. An essential feature of such screens is continuous operation during periods where fish are being impinged compared to conventional traveling screens which operate on an intermittent basis

Limitations:

- The continuous operation can result in undesirable maintenance problems (Mussalli, 1977).

- Velocity distribution across the face of the screen is generally very poor.

Latent mortality can be high, especially where fragile species are present.

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Intake Screening Systems	Sheet No. 3: Inclined Single-Entry, Single-Exit Traveling Screens (Angled Screens)

Description:

Inclined traveling screens utilize standard through-flow traveling screens where the screens are set at an angle to the incoming flow as shown in the figure below. Angling the screens improves the fish protection effectiveness of the flush mounted vertical screens since the fish tend to avoid the screen face and move toward the end of the screen line, assisted by a component of the inflow velocity. A fish bypass facility with independently induced flow must be provided. The fish have to be lifted by fish pump, elevator, or conveyor and discharged to a point of safety away from the main water intake (Richards, 1977).

Testing Facilities and/or Facilities Using the Technology:

Angled screens have been tested/used at the following facilities: the Brayton Point Station Unit 4 in Massachusetts; the San Onofre Station in California; and at power plants on Lake Ontario and the Hudson River (ASCE, 1982; EPRI, 1999).

Research/operation Findings:

- Angled traveling screens with a fish return system have been used on the intake for Brayton Point Unit 4. Studies from 1984 through 1986 that evaluated the angled screens showed a diversion efficiency of 76 percent with latent survival of 63 percent. Much higher results were observed excluding bay anchovy. Survival efficiency for the major taxa exhibited an extremely wide range, from 0.1 percent for bay anchovy to 97 percent for tautog. Generally, the taxa fell into two groups: a hardy group with efficiency greater than 65 percent and a sensitive group with efficiency less than 25 percent (EPRI, 1999).

- Southern California Edison at its San Onofre steam power plant had more success with angled louvers than with angled screens. The angled screen was rejected for full-scale use because of the large bypass flow required to yield good guidance efficiencies in the test facility.

Design Considerations:

Many variables influence the performance of angled screens. The following recommended preliminary design criteria were developed in the studies for the Lake Ontario and Hudson River intakes (ASCE, 1982):

- Angle of screen to the waterway: 25 degrees

- Average velocity of approach in the waterway upstream of the screens: 1 foot per

Intake Screening Systems	Sheet No. 3: Inclined Single-Entry, Single-Exit Traveling Screens (Angled Screens)

second

- Ratio of screen velocity to bypass velocity: 1:1
- Minimum width of bypass opening: 6 inches

Advantages:

- The fish are guided instead of being impinged.
- The fish remain in water and are not subject to high pressure rinsing.

Limitations:

- Higher cost than the conventional traveling screen
- Angled screens need a stable water elevation.
- Angled screens require fish handling devices with independently induced flow (Richards, 1977).

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ASCE. Design of Water Intake Structures for Fish Protection. Task Committee on Fish-Handling Capability of Intake Structures of the Committee on Hydraulic Structures of the Hydraulic Division of the American Society of Civil Engineers, New York, NY. 1982.

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Intake Screening Systems	Fact Sheet No.4: Fine Mesh Screens Mounted on Traveling Screens

Description:

Fine mesh screens are used for screening eggs, larvae, and juvenile fish from cooling water intake systems. The concept of using fine mesh screens for exclusion of larvae relies on gentle impingement on the screen surface or retention of larvae within the screening basket, washing of screen panels or baskets to transfer organisms into a sluiceway, and then sluicing the organisms back to the source waterbody (Sharma, 1978). Fine mesh with openings as small as 0.5 millimeters (mm) has been used depending on the size of the organisms to be protected. Fine mesh screens have been used on conventional traveling screens and single-entry, double-exit screens. The ultimate success of an installation using fine mesh screens is contingent on the application of satisfactory handling and recovery facilities to allow the safe return of impinged organisms to the aquatic environment (Pagano et al, 1977).

Testing Facilities and/or Facilities Using the Technology:

The Big Bend Power Plant along Tampa Bay area has an intake canal with 0.5-mm mesh Ristroph screens that are used seasonally on the intakes for Units 3 and 4. At the Brunswick Power Plant in North Carolina, fine mesh used seasonally on two of four screens has shown 84 percent reduction in entrainment compared to the conventional screen systems.

Research/Operation Findings:

- During the mid-1980s when the screens were initially installed at Big Bend, their efficiency in reducing impingement and entrainment mortality was highly variable. The operator evaluated different approach velocities and screen rotational speeds. In addition, the operator recognized that frequent maintenance (manual cleaning) was necessary to avoid biofouling. By 1988, system performance had improved greatly. The system's efficiency in screening fish eggs (primarily drums and bay anchovy) exceeded 95 percent with 80 percent latent survival for drum and 93 percent for bay anchovy. For larvae (primarily drums, bay anchovies, blennies, and gobies), screening efficiency was 86 percent with 65 percent latent survival for drum and 66 percent for bay anchovy. Note that latent survival in control samples was also approximately 60 percent (EPRI, 1999).

- At the Brunswick Power Plant in North Carolina, fine mesh screen has led to 84 percent reduction in entrainment compared to the conventional screen systems. Similar results were obtained during pilot testing of 1-mm screens at the Chalk Point Generating Station in Maryland. At the Kintigh Generating Station in New Jersey, pilot testing indicated 1-mm screens provided 2 to 35 times reductions in entrainment over conventional 9.5-mm screens (EPRI, 1999).

- Tennessee Valley Authority (TVA) pilot-scale studies performed in the 1970s

Intake Screening Systems	Fact Sheet No.4: Fine Mesh Screens Mounted on Traveling Screens

showed reductions in striped bass larvae entrainment up to 99 percent using a 0.5-mm screen and 75 and 70 percent for 0.97-mm and 1.3-mm screens. A full-scale test by TVA at the John Sevier Plant showed less than half as many larvae entrained with a 0.5-mm screen than 1.0 and 2.0-mm screens combined (TVA, 1976).

- Preliminary results from a study initiated in 1987 by the Central Hudson and Gas Electric Corporation indicated that the fine mesh screens collect smaller fish compared to conventional screens; mortality for the smaller fish was relatively high, with similar survival between screens for fish in the same length category (EPRI, 1989).

Design Considerations:

Biological effectiveness for the whole cycle, from impingement to survival in the source water body, should be investigated thoroughly prior to implementation of this option. This includes:

- The intake velocity should be low so that if there is any impingement of larvae on the screens, it is gentle enough not to result in damage or mortality.
- The wash spray for the screen panels or the baskets should be low-pressure so as not to result in mortality.
- The sluiceway should provide smooth flow so that there are no areas of high turbulence; enough flow should be maintained so that the sluiceway is not dry at any time.
- The species life stage, size and body shape and the ability of the organisms to withstand impingement should be considered with time and flow velocities.
- The type of screen mesh material used is important. For instance, synthetic meshes may be smooth and have a low coefficient of friction, features that might help to minimize abrasion of small organisms. However, they also may be more susceptible to puncture than metallic meshes (Mussalli, 1977).

Advantages:

- There are indications that fine mesh screens reduce entrainment.

Intake Screening Systems	Fact Sheet No.4: Fine Mesh Screens Mounted on Traveling Screens

Limitations:

- Fine mesh screens may increase the impingement of fish, i.e., they need to be used in conjunction with properly designed and operated fish collection and return systems.
- Due to the small screen openings, these screens will clog much faster than those with conventional 3/8-inch mesh. Frequent maintenance is required, especially in marine environments.

References:

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Passive Intake Systems	Fact Sheet No. 5:Wedgewire Screens

Description:

Wedgewire screens are designed to reduce entrainment by physical exclusion and by exploiting hydrodynamics.Physical exclusion occurs when the mesh size of the screen is smaller than the organisms susceptible to entrainment. Hydrodynamic exclusion results from maintenance of a low through-slot velocity, which, because of the screen's cylindrical configuration, is quickly dissipated, thereby allowing organisms to escape the flow field (Weisberd et al, 1984). The screens can be fine or wide mesh. The name of these screens arise from the triangular or "wedge" cross section of the wire that makes up the screen. The screen is composed of wedgewire loops welded at the apex of their triangular cross section to supporting axial rods presenting the base of the cross section to the incoming flow (Pagano et al, 1977). A cylindrical wedgewire screen is shown in the figure below. Wedgewire screens are also called profile screens or Johnson screens.

Testing Facilities and/or Facilities Using the Technology:

Wide mesh wedgewire screens are used at two large power plants, Eddystone and Campbell.Smaller facilities with wedgewire screens include Logan and Cope with fine mesh and Jeffrey with wide mesh (EPRI 1999).

Research/Operation Findings:

- In-situ observations have shown that impingement is virtually eliminated when wedgewire screens are used (Hanson, 1977; Weisberg et al, 1984).
- At Campbell Unit 3, impingement of gizzard shad, smelt, yellow perch, alewife, and shiner species is significantly lower than Units 1 and 2 that do not have wedgewire screens (EPRI, 1999).
- The cooling water intakes for Eddystone Units 1 and 2 were retrofitted with wedgewire screens because over 3 million fish were reportedly impinged over a 20-month period.The wedgewire screens have generally eliminated impingement at Eddystone (EPRI, 1999).
- Laboratory studies (Heuer and Tomljanovitch, 1978) and prototype field studies (Lifton, 1979; Delmarva Power and Light, 1982; Weisberg et al, 1983) have shown that fine mesh wedgewire screens reduce entrainment.
- One study (Hanson, 1977) found that entrainment of fish eggs (striped bass), ranging in diameter from 1.8 mm to 3.2 mm, could be eliminated with a cylindrical wedgewire screen incorporating 0.5 mm slot openings. However, striped bass larvae, measuring

Passive Intake Systems	Fact Sheet No. 5:Wedgewire Screens

5.2 mm to 9.2 mm were generally entrained through a 1 mm slot at a level exceeding 75 percent within one minute of release in the test flume.

- At the Logan Generating Station in New Jersey, monitoring shows shows 90 percent less entrainment of larvae and eggs through the 1 mm wedgewire screen then conventional screens.In situ testing ofl and 2-mm wedgewire screens was performed in the St. John River for the Seminole Generating Station Units 1 and 2 in Florida in the late 1970s.This testing showed virtually no impingement and 99 and 62 percent reductions in larvae entrainment for the 1-mm and 2-mm screens, respectively, over conventional screen (9.5 mm) systems (EPRI, 1999).

Design Considerations:

- To minimize clogging, the screen should be located in an ambient current of at least 1 feet per second (ft/sec).
- A uniform velocity distribution along the screen face is required to minimize the entrapment of motile organisms and to minimize the need of debris backflushing.
- In northern latitudes, provisions for the prevention of frazil ice formation on the screens must be considered.
- Allowance should be provided below the screens for silt accumulation to avoid blockage of the water flow (Mussalli et al, 1980).

Advantages:

- Wedgewire screens have been demonstrated to reduce impingement and entrainment in laboratory and prototype field studies.

Limitations:

- The physical size of the screening device is limiting in most passive systems, thus, requiring the clustering of a number of screening units. Siltation, biofouling and frazil ice also limit areas where passive screens such as wedgewire can be utilized.
- Because of these limitations, wedgewire screens may be more suitable for closed-cycle make-up intakes than once-through systems. Closed-cycle systems require less flow and fewer screens than once-through intakes; back-up conventional screens can therefore be used during maintenance work on the wedge-wire screens (Mussalli et al, 1980).

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Passive Intake Systems | **Fact Sheet No. 5:Wedgewire Screens**

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Passive Intake Systems	Fact Sheet No. 6:Perforated Pipes

Description:

Perforated pipes draw water through perforations or slots in a cylindrical section placed in the waterway. The term "perforated" is applied to round perforations and elongated slots as shown in the figure below.The early technology was not efficient:velocity distribution was poor, it served specifically to screen out detritus, and was not used for fish protection (ASCE, 1982). Inner sleeves have been added to perforated pipes to equalize the velocities entering the outer perforations. Water entering a single perforated pipe intake without an internal sleeve will have a wide range of entrance velocities and the highest will be concentrated at the supply pipe end. These systems have been used at locations requiring small amounts of water such as make-up water. However, experience at steam electric plants is very limited (Sharma, 1978).

Testing Facilities And/or Facilities Using the Technology:

Nine steam electric units in the U.S. use perforated pipes.Each of these units uses closed-cycle cooling systems with relatively low make-up intake flow ranging from 7 to 36 MGD (EEI, 1993).

Research/Operation Findings:

- Maintenance of perforated pipe systems requires control of biofouling and removal of debris from clogged screens.
- For withdrawal of relatively small quantities of water, up to 50,000 gpm, the perforated pipe inlet with an internal perforated sleeve offers substantial protection for fish. This particular design serves the Washington Public Power Supply System on the Columbia River (Richards, 1977).
- No information is available on the fate of the organisms impinged at the face of such screens.

Design Considerations:

The design of these systems is fairly well established for various water intakes (ASCE, 1982).

Advantages:

The primary advantage is the absence of a confined channel in which fish might become trapped.

Limitations:

Clogging, frazil ice formation, biofouling and removal of debris limit this technology to small flow withdrawals.

Passive Intake Systems	Fact Sheet No. 6:Perforated Pipes

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Passive intake Systems	Fact Sheet No. 7:Porous Dikes/Leaky Dams

Description:

Porous dikes, also known as leaky dams or leaky dikes, are filters resembling a breakwater surrounding a cooling water intake.The core of the dike consists of cobble or gravel, which permits free passage of water.The dike acts both as a physical and a behavioral barrier to aquatic organisms and is depicted in the figure below.The filtering mechanism includes a breakwater or some other type of barrier and the filtering core (Fritz, 1980).Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish.However, its effectiveness in screening fish eggs and larvae is not established (ASCE, 1982).

Testing Facilities and/or Facilities Using the Technology:

- Two facilities which are both testing facilities and have used the technology are: thePoint Beach Nuclear Plant in Wisconsin and the Baily Generating Station in Indiana (EPRI, 1985). The Brayton Point Generating Station in Massachusetts has also tested the technology.

Research/Operation Findings:

- Schrader and Ketschke (1978) studied a porous dike system atthe Lakeside Plant on Lake Michigan and found that numerous fish penetrated large void spaces, but for most fish accessibility was limited.
- The biological effectiveness of screening of fish larvae and the engineering practicability have not been established (ASCE, 1982).
- The size of the pores in the dike dictates the degree of maintenance due to biofouling and clogging by debris.
- Ice build-up and frazil ice may create problems as evidenced at the Point Beach Nuclear Plant (EPRI, 1985).

Design Considerations:

- The presence of currents past the dike is an important factor which may probably increase biological effectiveness.
- The size of pores in the dike determines the extent of biofouling and clogging by debris (Sharma, 1978).
- Filtering material must be of a size that permits free passage of water but still prevents entrainment and impingement.

Passive intake Systems	Fact Sheet No. 7:Porous Dikes/Leaky Dams

Advantages:

- Dikes can be used at marine, fresh water, and estuarine locations.

Limitations:

- The major problem with porous dikes comes from clogging by debris and silt, and from fouling by colonization of fish and plant life.
- Backflushing, which is often used by other systems for debris removal, is not feasible at a dike installation.
- Predation of organisms screened at these dikes may offset any biological effectiveness (Sharma, 1978).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 8:Louver Systems

Description:

Louver systems are comprised of a series of vertical panels placed at an angle to the direction of the flow (typically 15 to 20 degrees).Each panel is placed at an angle of 90 degrees to the direction of the flow (Hadderingh, 1979).The louver panels provide an abrupt change in both the flow direction and velocity (see figure below).This creates a barrier, which fish can immediately sense and will avoid.Once the change in flow/velocity is sensed by fish, they typically align with the direction of the current and move away laterally from the turbulence.This behavior further guides fish into a current created by the system, which is parallel to the face of the louvers.This current pulls the fish along the line of the louvers until they enter a fish bypass or other fish handling device at the end of the louver line.The louvers may be either fixed or rotated similar to a traveling screen.Flow straighteners are frequently placed behind the louver systems.

These types of barriers have been very successful and have been installed at numerous irrigation intakes, water diversion projects, and steam electric and hydroelectric facilities.It appears that this technology has, in general, become accepted as a viable option to divert juvenile and adult fish.

Testing Facilities and/or Facilities Using the Technology:

Louver barrier devices have been tested and/or are in use at the followingfacilities:the California Department of Water Resource's Tracy Pumping Plant; the California Department of Fish and Game's Delta Fish Protective Facility in Bryon; the Conte Anadromous Fish Research Center in Massachusetts, and the San Onofre Nuclear Generating Station in California (EPA, 1976; EPRI, 1985; EPRI, 1999).In addition, three other plants also have louvers at their facilities: the Ruth Falls Power Plant in Nova Scotia, the Nine Mile Point Nuclear Power Station on Lake Erie, and T.W. Sullivan Hydroelectric Plant in Oregon.Louvers have also been tested at the Ontario Hydro Laboratories in Ontario, Canada (Ray et al, 1976).

Research/Operation Findings:

Research has shown the following generalizations to be true regarding louver barriers:

1) the fish separation performance of the louver barrier decreases with an increase in the velocity of the flow through the barrier;2) efficiency increases with fish size (EPA, 1976; Hadderingh, 1979);3) individual louver misalignment has a beneficial effect on the efficiency of the barrier;4) the use of center walls provides the fish with a guide wall to swim along thereby improving efficiency (EPA, 1976); and 5) the most effective slat spacing and array angle to flow depends upon the size, species and ability of the fish to be diverted (Ray et al, 1976).

In addition, the following conclusions were drawn during specific studies:

• Testing of louvered intake structures offshore was performed at a New York facility. The louvers were spaced 10 inches apart to minimize clogging.The array was angled at 11.5 percent to the flow.Center walls were provided for fish guidance to the bypass.Test species included alewife and rainbow smelt.The

Fish Diversion or Avoidance Systems	Fact Sheet No. 8:Louver Systems

mean efficiency predicted was between 22 and 48 percent (Mussalli 1980).

• During testing at the Delta Facility's intake in Byron California, the design flow was 6,000 cubic feet per second (cfs), the approach velocity was 1.5 to 3.5 feet per second (ft/sec), and the bypass velocities were 1.2 to 1.6 times the approach velocity.Efficiencies were found to drop with an increase in velocity through the louvers.For example, at 1.5 to 2 ft/sec the efficiency was 61 percent for 15 millimeter long fish and 95 percent for 40 millimeter fish.At 3.5 ft/sec, the efficiencies were 35 and 70 percent (Ray et al. 1976).

• The efficiency of a louver device is highly dependent upon the length and swimming performance of a fish.Efficiencies of lower than 80 percent have been seen at facilities where fish were less than 1 to 1.6 inches in length (Mussalli, 1980).

• In the 1990s, an experimental louver bypass system was tested at the USGS' Conte Anadromous Fish Research Center in Massachusetts.This testing showed guidance efficiencies for Connecticut River species of 97 percent for a "wide array" of louvers and 100 percent for a "narrow array"(EPRI, 1999).

• At the Tracy Fish Collection Facility located along the San Joaquin River in California, testing was performed from 1993 and 1995 to determine the guidance efficiency of a system with primary and secondary louvers.The results for green and white sturgeon, American shad, splittail, white catfish, delta smelt, Chinook salmon, and striped bass showed mean diversion efficiencies ranging from 63 (splittail) to 89 percent (white catfish)(EPRI, 1999).

• In 1984 at the San Onofre Station, a total of 196,978 fish entered the louver system with 188,583 returned to the waterbody and 8,395 impinged.In 1985, 407,755 entered the louver system with 306,200 returned and 101,555 impinged.Therefore, the guidance efficiencies in 1984 and 1985 were 96 and 75 percent, respectively.However, 96-hour survival rates for some species, i.e., anchovies and croakers, were 50 percent or less.Louvers were originally considered for use at San Onofre because of 1970s pilot testing at the Redondo Beach Station in California where maximum guidance efficiencies of 96-100 percent were observed.(EPRI, 1999)

• At the Maxwell Irrigation Canal in Oregon, louver spacing was 5.0 cm with a 98 percent efficiency of deflecting immature steelhead and above 90 percent efficiency for the same species with a louver spacing of 10.8 cm.

• At the Ruth Falls Power Plant in Nova Scotia, the results of a five-year evaluation for guiding salmon smelts showed that the optimum spacing was to have wide bar spacing at the widest part of the louver with a gradual reduction in the spacing approaching the bypass.The site used a bypass:approach velocity ratio of 1.0 : 1.5 (Ray et al, 1976).

• Coastal species in California were deflected optimally (Schuler and Larson, 1974 in Ray et al, 1976) with 2.5 cm spacing of the louvers, 20 degree louver array to the direction of flow and approach velocities of 0.6 cm per second.

• At the T.W. Sullivan Hydroelectric Plant along the Williamette River in Oregon, the louver

Fish Diversion or Avoidance Systems	Fact Sheet No. 8:Louver Systems

system is estimated to be 92 percent effective in diverting spring Chinook, 82 percent for all Chinook, and 85 percent for steelhead.The system has been optimized to reduce fish injuries such that the average injury occurrence is only 0.44 percent (EPRI, 1999).

Design Considerations:

The most important parameters of the design of louver barriers include the following:

- The angle of the louver vanes in relation to the channel velocity ,
- The spacing between the louvers which is related to the size of the fish,
- Ratio of bypass velocity to channel velocity,
- Shape of guide walls,
- Louver array angles, and
- Approach velocities.

Site-specific modeling may be needed to take into account species-specific considerations and optimize the design efficiency (EPA, 1976; O'Keefe, 1978).

Advantages:

- Louver designs have been shown to be very effective in diverting fish (EPA, 1976).

Limitations:

- The costs of installing intakes with louvers may be substantially higher than other technologies due to design costs and the precision required during construction.
- Extensive species-specific field testing may be required.
- The shallow angles required for the efficient design of a louver system require a long line of louvers increasing the cost as compared to other systems (Ray et al, 1976).
- Water level changes must be kept to a minimum to maintain the most efficient flow velocity.

Fish Diversion or Avoidance Systems	Fact Sheet No. 8:Louver Systems

- Fish handling devices are needed to take fish away from the louver barrier.

- Louver barriers may, or may not, require additional screening devices for removing solids from the intake waters.If such devices are required, they may add a substantial cost to the system (EPA, 1976).

- Louvers may not be appropriate for offshore intakes (Mussalli, 1980).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 9: Velocity Cap

Description:

A velocity cap is a device that is placed over vertical inlets at offshore intakes (see figure below). This cover converts vertical flow into horizontal flow at the entrance into the intake. The device works on the premise that fish will avoid rapid changes in horizontal flow. Fish do not exhibit this same avoidance behavior to the vertical flow that occurs without the use of such a device. Velocity caps have been implemented at many offshore intakes and have been successful in decreasing the impingement of fish.

Testing Facilities And/or Facilities Using the Technology:

The available literature (EPA, 1976; Hanson, 1979; and Pagano et al, 1977) states that velocity caps have been installed at offshore intakes in Southern California, the Great Lakes Region, the Pacific Coast, the Caribbean and overseas; however, exact locations are not specified.

Velocity caps are known to have been installed at the El Segundo, Redondo Beach, and Huntington Beach Steam Electric Stations and the San Onofre Nuclear Generation Station in Southern California (Mussalli, 1980; Pagano et al, 1977; EPRI, 1985).

Model tests have been conducted by a New York State Utility (ASCE, 1982) and several facilities have installed velocity caps in the New York State /Great Lakes Area including the Nine Mile Point Nuclear Station, the Oswego Steam Electric Station, and the Kintigh Generating Station (EPRI, 1985).

Additional known facilities with velocity caps include the Edgewater Generation Station in Wisconsin, the Seabrook Power Plant in New Hampshire, and the Nanticoke Thermal Generating Station in Ontario, Canada (EPRI, 1985).

Research/Operation Findings:

- Horizontal velocities within a range of 0.5 to 1.5 feet per second (ft/sec) did not significantly affect the efficiency of a velocity cap tested at a New York facility; however, this design velocity may be specific to the species present at that site (ASCE, 1982).
- Preliminary decreases in fish entrapment averaging 80 to 90 percent were seen at the El Segundo and Huntington Beach Steam Electric Plants (Mussalli, 1980).
- Performance of the velocity cap may be associated with cap design and the total volumes of water flowing into the cap rather than to the critical velocity threshold of the cap (Mussalli, 1980).

Fish Diversion or Avoidance Systems	Fact Sheet No. 9: Velocity Cap

Design Considerations:

- Designs with rims around the cap edge prevent water from sweeping around the edge causing turbulence and high velocities, thereby providing more uniform horizontal flows (EPA, 1976; Mussalli, 1980).
- Site-specific testing should be conducted to determine appropriate velocities to minimize entrainment of particular species in the intake (ASCE, 1982).
- Most structures are sized to achieve a low intake velocity between 0.5 and 1.5 ft/sec to lessen the chances of entrainment (ASCE, 1982).
- Design criteria developed for a model test conducted by Southern California Edison Company used a velocity through the cap of 0.5 to 1.5 ft/sec; the ratio of the dimension of the rim to the height of the intake areas was 1.5 to 1 (ASCE, 1982; Schuler, 1975).

Advantages:

- Efficiencies of velocity caps on West Coast offshore intakes have exceeded 90 percent (ASCE, 1982).

Limitations:

- Velocity caps are difficult to inspect due to their location under water (EPA, 1976).
- In some studies, the velocity cap only minimized the entrainment of fish and did not eliminate it.Therefore, additional fish recovery devices are be needed in when using such systems (ASCE, 1982; Mussalli, 1980).
- Velocity caps are ineffective in preventing passage of non-motile organisms and early life stage fish (Mussalli, 1980).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 9: Velocity Cap

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Fish Diversion or Avoidance Systems	Fact Sheet No. 10:Fish Barrier Nets

Description:

Fish barrier nets are wide mesh nets, which are placed in front of the entrance to an intake structure (see figure below).The size of the mesh needed is a function of the species that are present at a particular site. Fish barrier nets have been used at numerous facilities and lend themselves to intakes where the seasonal migration of fish and other organisms require fish diversion facilities for only specific times of the year.

Testing Facilities And/or Facilities Using the Technology:

The Bowline Point Generating Station, the J.P. Pulliam Power Plant in Wisconsin, the Ludington Storage Plant in Michigan, and the Nanticoke Thermal Generating Station in Ontario use barrier nets (EPRI, 1999).

Barrier Nets have been tested at the Detroit Edison Monroe Plant on Lake Erie and the Chalk Point Station on the Patuxent River in Maryland (ASCE, 1982; EPRI, 1985).The Chalk Point Station now uses barrier nets seasonally to reduce fish and Blue Crab entry into the intake canal (EPRI, 1985).The Pickering Generation Station in Ontario evaluated rope nets in 1981 illuminated by strobe lights (EPRI, 1985).

Research/Operation Findings:

- At the Bowline Point Generating Station in New York, good results (91 percent impingement reductions) have been realized with a net placed in a V arrangement around the intake structure (ASCE, 1982; EPRI, 1999).

- In 1980, a barrier net was installed at the J.R. Whiting Plant (Michigan) to protect Maumee Bay.Prior to net installation, 17,378,518 fish were impinged on conventional traveling screens.With the net, sampling in 1983 and 84 showed 421,978 fish impinged (97 percent effective), sampling in 1987 showed 82,872 fish impinged (99 percent effective), and sampling in 1991 showed 316,575 fish impinged (98 percent effective) (EPRI, 1999).

- Nets tested with high intake velocities (greater than 1.3 feet per second) at the Monroe Plant have clogged and subsequentially collapsed.This has not occurred at facilities where the velocities are 0.4 to 0.5 feet per second (ASCE, 1982).

- Barrier nets at the Nanticoke Thermal Generating Station in Ontario reduced intake of fish by 50 percent (EPRI, 1985).

- The J.P Pulliam Generating Station in Wisconsin uses dual barrier nets (0.64 centimeters stretch mesh) to permit net rotation for cleaning.Nets are used from April to December or when water temperatures go above 4 degrees Celsius.Impingement has been reduced by as much as 90 percent.Operating costs run about $5,000 per year, and nets are replaced every two years at $2,500 per net (EPRI, 1985).

Fish Diversion or Avoidance Systems	Fact Sheet No. 10:Fish Barrier Nets

- The Chalk Point Station in Maryland realized operational costs of $5,000-10,000 per year with the nets being replaced every two years (EPRI, 1985).However, crab impingement has been reduced by 84 percent and overall impingrment liability has been reduced from $2 million to $140,000 (EPRI, 1999).

- The Ludington Storage Plant (Michigan) provides water from Lake Michigan to a number of power plant facilities.The plant has a 2.5-mile long barrier net that has successfully reduced impingement and entrainment.The overall net effectiveness for target species (five salmonids, yellow perch, rainbow smelt, alewife, and chub) has been over 80 percent since 1991 and 96 percent since 1995.The net is deployed from mid-April to mid-October, with storms and icing preventing use during the remainder of the year (EPRI, 1999).

Design Considerations:

- The most important factors to consider in the design of a net barrier are the site-specific velocities and the potential for clogging with debris (ASCE, 1982).

- The size of the mesh must permit effective operations, without excessive clogging.Designs at the Bowline Point Station in New York have 0.15 and 0.2 inch openings in the mesh nets, while the J.P. Pulliam Plant in Wisconsin has 0.25 inch openings (ASCE, 1982).

Advantages:

- Net barriers, if operating properly, should require very little maintenance.

- Net barriers have relatively little cost associated with them.

Limitations:

- Net barriers are not effective for the protection of the early life stages of fish or zooplankton (ASCE, 1982).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 10:Fish Barrier Nets

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Fish Diversion or Avoidance Systems	Fact Sheet No. 11:Aquatic Filter Barrier Systems

Description:

Aquatic filter barrier systems are barriers that employ a filter fabric designed to allow for passage of water into a cooling water intake structure, but exclude aquatic organisms. These systems are designed to be placed some distance from the cooling water intake structure within the source waterbody and act as a filter for the water that enters into the cooling water system. These systems may be floating, flexible, or fixed. Since these systems generally have such a large surface area, the velocities that are maintained at the face of the permeable curtain are very low. One company, Gunderboom, Inc., has a patented full-water-depth filter curtain comprised of polyethylene or polypropylene fabric that is suspended by flotation billets at the surface of the water and anchored to the substrate below. The curtain fabric is manufactured as a matting of minute unwoven fibers with an apparent opening size of 20 microns. The Gunderboom Marine/Aquatic Life Exclusion System (MLES)™ also employs an automated "air burst"™ technology to periodically shake the material and pass air bubbles through the curtain system to clean it of sediment buildup and release any other material back in to the water column.

Testing Facilities and/or Facilities Using the Technology:

- Gunderboom MLES ™have been tested and are currently installed on a seasonal basis at Unit 3 of the Lovett Station in New York. Prototype testing of the Gunderboom system began in 1994 as a means of lowering ichthyoplankton entrainment at Unit 3.This was the first use of the technology at a cooling water intake structure.The Gunderboom tested was a single layer fabric.Material clogging resulted in loss of filtration capacity and boom submergence within 12 hours of deployment. Ichthyoplankton monitoring while the boom was intact indicated an 80 percent reduction in entrainable organisms (Lawler, Matusky, and Skelly Engineers, 1996).

- A Gunderboom MLES ™ was effectively deployed at the Lovett Station for 43 days in June and July of 1998 using an Air-Burst cleaning system and newly designed deadweight anchoring system.The cleaning system coupled with a perforated material proved effective at limiting sediment on the boom, however it required an intensive operational schedule (Lawler, Matusky, and Skelly Engineers, 1998).

- A 1999 study was performed on the Gunderboom MLES ™ at the Lovett Station in New York to qualitatively determine the characteristics of the fabric with respect to the impingement of ichthyoplankton at various flow regimes.Conclusions were that the viability of striped bass eggs and larvae were not affected (Lawler, Matusky, and Skelly Engineers, 1999).

- Ichthyoplankton sampling at Unit 3 (with Gunderboom MLES ™ deployed) and Unit 4 (without Gunderboom) in May through August 2000 showed an overall

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effectiveness of approximately 80 percent.For juvenile fish, the density at Unit 3 was 58 percent lower.For post yolk-sac larvae, densities were 76 percent lower.For yolk-sac larvae, densities were 87 percentlower (Lawler, Matusky & Skelly Engineers 2000).

Research/operation Findings:

Extensive testing of the Gunderboom MLES ™ has been performed at the Lovett Station in New York.Anchoring, material, cleaning, and monitoring systems have all been redesigned to meet the site-specific conditions in the waterbody and to optimize the operations of the Gunderboom.Although this technology has been implemented at only one cooling water intake structure, it appears to be a promising technology to reduce impingement and entrainment impacts.It is also being evaluated for use at the Contre Costa Power Plant in California.

Design Considerations:

The most important parameters in the design of a Gunderboom ®Marine/Aquatic Life Exclusion System include the following (Gunderboom, Inc.1999):

- Size of booms designed for 3-5 gpm per square foot of submerged fabric.Flows greater than 10-12 gallons per minute.
- Flow-through velocity is approximately 0.02 ft/s.
- Performance monitoring and regular maintenance.

Advantages:

- Can be used in all waterbody types.
- All larger and nearly all other organisms can swim away from the barrier because of low velocities.
- Little damage is caused to fish eggs and larvae if they are drawn up against the fabric.
- Modulized panels may easily be replaced.
- Easily deployed for seasonal use.
- Biofouling appears to be controllable through use of the sparging system.
- Impinged organisms released back into the waterbody.

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- Benefits relative to cost appear to be very promising, but remain unproven to date.
- Installation can occur with no or minimal plant shutdown.

Limitations:

- Currently only a proven technology for this application at one facility.
- Extensive waterbody-specific field testing may be required.
- May not be appropriate for conditions with large fluctuations in ambient flow and heavy currents and wave action.
- High level of maintenance and monitoring required.
- Recent studies have asserted that biofouling can be significant.
- Higher flow facilities may require very large surface areas; could interfere with other waterbody uses.

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Description:

Sound barriers are non-contact barriers that rely on mechanical or electronic equipment that generates various sound patterns to elicit avoidance responses in fish. Acoustic barriers are used to deter fish from entering industrial water intakes and power plant turbines. Historically, the most widely-used acoustical barrier is a pneumatic air gun or "popper." The pneumatic air gun is a modified seismic device which produces high-amplitude, low-frequency sounds to exclude fish. Closely related devices include "fishdrones" and "fishpulsers" (also called "hammers"). The fishdrone produces a wider range of sound frequencies and amplitudes than the popper. The fishpulser produces a repetitive sharp hammering sound of low-frequency and high-amplitude.Both instruments have ahd limited effectiveness in the field (EPRI, 1995; EPRI, 1989; Hanson, et al., 1977; EPA, 1976; Taft, et al., 1988; ASCE, 1992).

Researchers have generally been unable to demonstrate or apply acoustic barriers as fish deterrents, even though fish studies showed that fish respond to sound, because the response varies as a function of fish species, age, and size as well as environmental factors at specific locations. Fish may also acclimate to the sound patterns used (EPA, 1976; Taft et al., 1988; EPRI, 1995; Ray at al., 1976; Hadderingh, 1979; Hanson et al., 1977; ASCE, 1982).

Since about 1989, the application of highly refined sound generation equipment originally developed for military use (e.g., sonar in submarines) has greatly advanced acoustic barrier technology. Ibis technology has the ability to generate a wide array of frequencies, patterns, and volumes, which are monitored and controlled by computer. Video and computer monitoring provide immediate feedback on the effectiveness of an experimental sound pattern at a given location. In a particular environment, background sounds can be accounted for, target fish species or fish populations can quickly be characterized, and the most effective sound pattern can be selected (Menezes, at al., 1991; Sonalysts, Inc.).

Testing Facilities and/or Facilities with Technology in Use:

No fishpulsers and pneumatic air guns are currently in use at power plant water intakes.

Research facilities that have completed studies or have on-going testing involving fishpulsers or pneumatic air guns include the Ludington Storage Plant on Lake Michigan; Nova Scotia Power; the Hells Gate Hydroelectric Station on the Black River; the Annapolis Generating Station on the Bay of Fundy; Ontario Hydro's Pickering Nuclear Generating station; the Roseton Generating Station in New York; the Seton Hydroelectric Station in British Columbia; the Surry Power Plant in Virginia; the Indian Point Nuclear Generating Station Unit 3 in New York; and the U.S. Army Corps of Engineers on the Savannah River (EPRI, 1985; EPRI, 1989; EPRI, 1988; and Taft, et al., 1998).

Updated acoustic technology developed by Sonalysts, Inc. has been applied at the James A. Fitzpatrick Nuclear Power Plant in New York on Lake Ontario; the Vernon Hydroelectric

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plant on the Connecticut River (New England Power Company, 1993; Menezes, et al., 1991; personal communication with Sonalysts, Inc., by SAIC, 1993); and in a quarry in Verplank, New York (Dunning, et al., 1993).

Research/operation Findings:

- Most pre-1976 research was related to fish response to sound rather than on field applications of sound barriers (EPA, 1976; Ray et al., 1976; Uziel, 1980; Hanson, et al., 1977).

- Before 1986, no acoustic barriers were deemed reliable for field use. Since 1986, several facilities have tried to use pneumatic poppers with limited successes. Even in combination with light barriers and air bubble barriers, poppers and fishpulsers, were ineffective for most intakes (Taft and Downing, 1988; EPRI, 1985; Patrick, et al., 1988; EPRI, 1989; EPRI, 1988; Taft, et al., 1988; McKinley and Patrick, 1998; Chow, 1981).

- A 1991 full-scale 4-month demonstration at the James A. FitzPatrick (JAF) Nuclear Power Plant in New York on Lake Ontario showed that the Sonalysts, Inc. FishStartle System reduced alewife impingement by 97 percent as compared to a control power plant located 1 mile away. (Ross, et al., 1993; Menezes, et al., 1991). JAF experienced a 96 percent reduction compared to fish impingement when the acoustic system was not in use. A 1993 3-month test of the system at JAF was reported to be successful, i.e., 85 percent reduction in alewife impingement. (Menezes, et al., 1991; EPRI, 1999).

- In tests at the Pickering Station in Ontario, poppers were found to be effective in reducing alewife impingement and entrainment by 73 percent in 1985 and 76 percent in 1986.No benefits were observed for rainbow smelt and gizzard shad. Sound provided little or no deterrence for any species at the Roseton Generating Station in New York.

- During marine construction of Boston's third Harbor Tunnel in 1992, the Sonalysts, Inc. FishStartle System was used to prevent shad, blueback herring, and alewives from entering underwater blasting areas during the fishes' annual spring migration. The portable system was used prior to each blast to temporarily deter fish and allow periods of blastmg as necessary for the construction of the tunnel (personal communication to SAIC from M. Curtin, Sonalysts, Inc., September 17, 1993).

- In fall 1992, the Sonalysts, Inc. FishStartle System was tested in a series of experiments conducted at the Vernon Hydroelectric plant on the Connecticut River. Caged juvenile shad were exposed to various acoustical signals to see which signals elicited the strongest reactions. Successful in situ tests involved applying the signals with a transducer system to divert juvenile shad from the forebay to a bypass pipe. Shad exhibited consistent avoidance reactions to the signals and did not show

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evidence of acclimation to the source (New England Power Company, 1993).

Design Considerations:

- Sonalysts Inc.'s FishStartle system uses frequencies between 15 hertz to130 kilohertz at sound pressure levels ranging from 130 to 206+ decibels referenced to one micropascal (dB//uPa). To develop a site-specific FishStartle program, a test program using frequencies in the low frequency portion of the spectrum between 25 and 3300 herz were used. Fish species tested by Sonalysts, Inc. include white perch, striped bass, atlantic tomcod, spottail shiner, and golden shiner (Menezes et al., 1991).

- Sonalysts' FishStartle system used fixed programming contained on Erasable Programmable Read Only Memory (EPROM) micro circuitry. For field applications, a system was developed using IBM PC compatible software. Sonalysts' FishStartle system includes a power source, power amplifiers, computer controls and analyzer in a control room, all of which are connected to a noise hydrophone in the water. The system also uses a television monitor and camera controller that is linked to an underwater light and camera to count fish and evaluate their behavior.

- One Sonalysts, Inc. system has transducers placed 5 m from the bar rack of the intake.

- At the Seton Hydroelectric Station in British Columbia, the distance from the water intake to the fishpulser was 350 m (1150 ft); at Hells Gate, a fishpulser was installed at a distance of 500 feet from the intake.

- The pneumatic gun evaluated at the Roseton intake had a 16.4 cubic cm (1.0 cubic inch) chamber connected by a high pressure hose and pipe assembly to an Air Power Supply Model APS-F2-25 air compressor. The pressure used was a line pressure of 20.7 MPa (3000 psi) (EPRI, 1988).

Advantages:

- The pneumatic air gun, hammer, and fishpulser are easily implemented at low costs.

- Behavioral barriers do not require physical handling of the fish.

Limitations:

- The pneumatic air gun, hammer, and fishpulser are not considered reliable.

- Sophisticated acoustic sound generating system require relatively expensive

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systems, including cameras, sound generating systems, and control systems. No cost information is available since a permanent system has yet to be installed.

- Sound barrier systems require site-specific designs consisting of relatively high technology equipment that must be maintained at the site.

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