RECOMMENDED INTERIM GUIDELINES

FOR THE

MANAGEMENT OF SALMON

NET-PEN CULTURE IN PUGET SOUND

Prepared for:

Washington Department of Ecology in conjunction
with the Departments of Fisheries,
Agriculture and Natural Resources

Prepared by:

Science Applications International Corporation

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FINAL REPORT

RECOMMENDED INTERIM GUIDELINES FOR THE MANAGEMENT OF SALMON NET-PEN CULTURE IN PUGET SOUND

December 30, 1986

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Director

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February, 1987

To Local Government, State Agencies, Citizens, Culturists and Others Concerned with Salmon Pen Siting:

The Department of Ecology is pleased to release the final report "Recommended Interim Guidelines for the Management of Salmon Net Pen Culture". The guidelines and procedures were developed by Dr. Donald Weston of Science Applications International Corporation in close consultation with staff and management of the Department of Fisheries, the Department of Natural Resources, and the Department of Agriculture. The guidelines are based on a previous study by Dr. Weston entitled "The Environmental Effects of Floating Mariculture in Puget Sound". In order to best apply the information from that work, Ecology contracted for the current report to identify siting and operational guidelines for use in reviewing salmon net pen proposals in Puget Sound.

In addition to consultations among the four state agencies, input was solicited and received from numerous scientific authorities, environmental groups, tribes, industry representatives, local government, and other interested groups and individuals. Ecology believes these siting and operational guidelines are based on the best information currently available. The guidelines provide criteria for selection of culture sites, husbandry practices, monitoring programs and state reporting requirements, which mitigate most anticipated adverse environmental effects. Projects that meet these guidelines are expected to result in minimal impacts to water quality, bottom sediments and critical habitats. The guidelines do not address issues such as aesthetic impacts or navigation conflicts that also must be considered during the permitting process.

The guidelines are not designed to be adopted state regulations. They are intended to be used by decision-making agencies as guidance for the interpretation and application of existing policy and regulations. As such, they will be valuable to culturists, local government, state agencies, citizens and all those with interest in the net pen culture industry. The department appreciates the concern and effort of all those who contributed to these recommendations.

Sincerely,

Andrea Beatty Riniker

Andrea Beatty Riniker
Director

ABR:bh

Enclosure

cc: Joseph J. Blum, Director
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GUIDELINE SUMMARY

PURPOSE AND SCOPE

The recommended interim guidelines are intended to provide a basis for a coordinated agency approach to the management of salmon net-pen culture in Puget Sound until completion of the programmatic Environmental Impact Statement (EIS). The goal of the guidelines is to avoid significant adverse environmental effects from net-pen operations permitted prior to completion of the programmatic EIS. This objective is pursued through a combination of recommendations for project siting, operational practices, and an annual monitoring program. It is the opinion of state agencies that those facilities sited and operated in accordance with these guidelines will result in little or no adverse environmental effects within those areas of potential impact addressed by the guidelines. It is anticipated that both state environmental managers and local authorities will rely heavily upon these guidelines in their review of culture applications and in their assessment of the potential environmental effects of these operations. The guidelines are not intended to replace existing regulations, master programs or local ordinances. The Department of Natural Resources Commissioner's Order of September 9, 1986 will be reviewed by DNR in light of these guidelines, and modification of the order will be given consideration.

These guidelines address net-pen operations which have not yet been permitted. They do not apply to projects already in operation or permitted unless these facilites undergo significant expansion or modification of their original permit specifications. In this case the expansion or modification may be evaluated for consistency with these guidelines.

The guidelines address all net-pen operations in which salmon are grown with the intent to harvest and market the fish upon attainment of sufficient size. The guidelines do not apply to net-pen operations in which salmon are held exclusively for delayed release to enhance wild stocks.

The geographic areas in which these guidelines apply include Puget Sound, the Strait of Juan de Fuca, the Strait of Georgia.

These guidelines are intended to provide siting and operational criteria until a programmatic EIS for salmon net-pen culture can be completed. These recommendations will then be reviewed for adequacy, revised as necessary, and adopted as part of a state management plan for the salmon net-pen industry.

The interim guidelines are generic in nature. It has not been possible to consider all potential site-specific variables, thus, the guidelines are intended to be flexible and do not eliminate the need for careful case-by-case review of permit applications. It is anticipated that site-specific conditions may require the guidelines to be made more restrictive or relaxed on a case-by-case basis. If a given project is made subject to restrictions or requirements not specified in these guidelines, state and/or local officials, if requested, should provide the applicant with an explanation of the environmental reasons for doing so. If relaxation of these guidelines is requested, it should be the responsibility of the applicant to demonstrate that deviation from these guidelines can be made with minimal environmental effect.

The guidelines have been developed entirely with the goal of environmental protection, and do not address social, economic, aesthetic or water/land use conflicts which must also be given consideration on a case-by-case basis.

GUIDELINES

1. Accumulation of feed and feces under the net-pens is minimized by guidelines which consider the size of the operation, the depth of water beneath the net-pens and the mean current velocity as measured mid-way between the bottom of the net-pens and the sea floor. Net-pen operations have been divided into size classes I through III. Depending on the size class of the operation, the minimum depth recommended beneath the net-pens ranges from 20 to 60 feet (Figure 1).

2. The habitats listed in Table 1 are considered to be of special significance and are therefore afforded an additional margin of protection from the potential accumulation of feed and feces. If these habitats are present in depths of 75 feet or less, net-pens should not be located over these habitats, within 300 feet in the direction(s) of prevailing tidal currents, or within 150 feet in any other direction. The Washington Department of Fisheries will have responsibility for the designation of and assessment of impacts on plant, invertebrate and fish habitats of special significance.

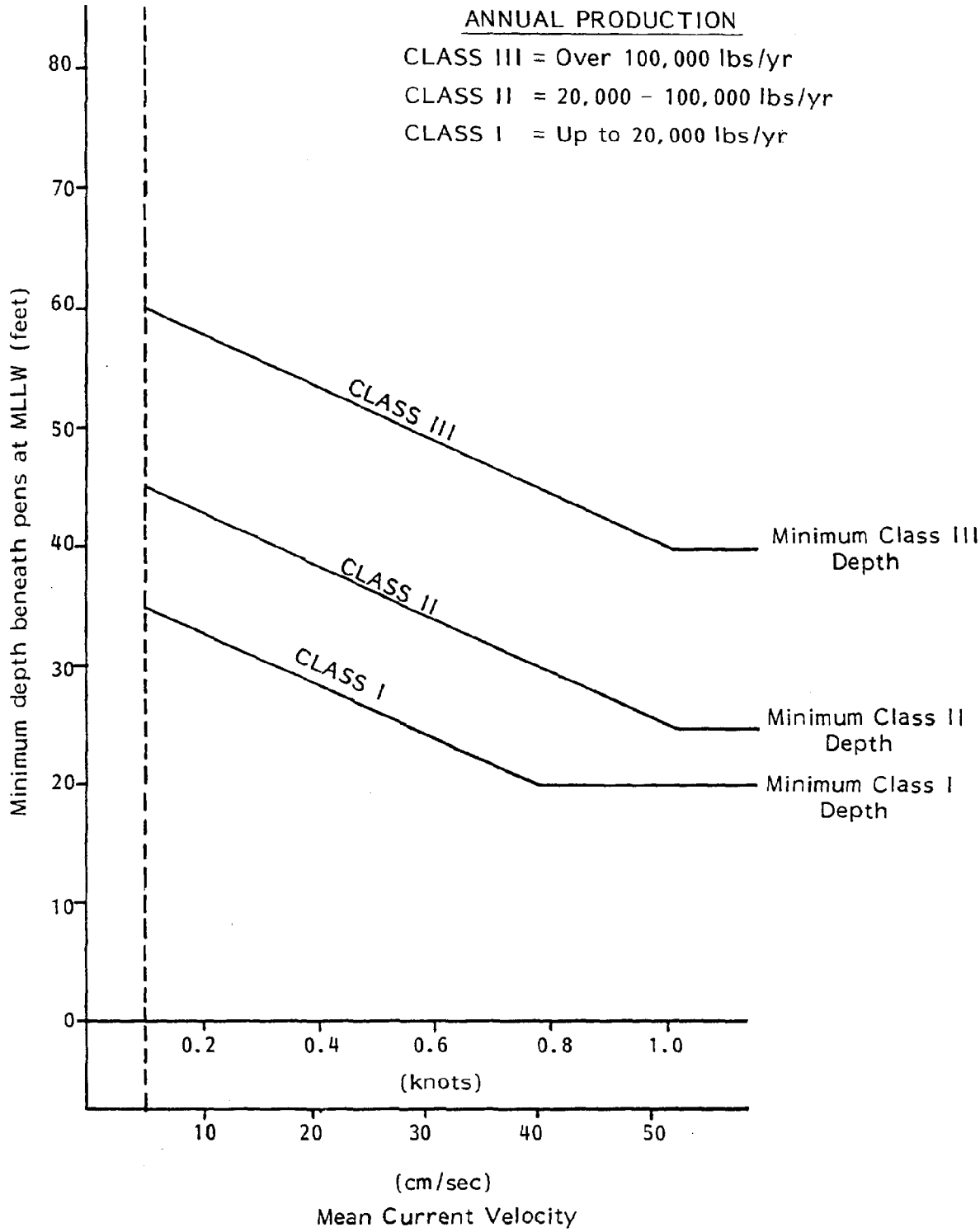

Figure 1

MINIMUM DEPTH AND CURRENT GUIDELINES
FOR NET-PEN SITING

Table 1

HABITATS OF SPECIAL SIGNIFICANCE

- Eelgrass (Zostera marina) beds having densities exceeding 13 turions (i.e., "shoots") per 0.25 m^2 in summer or 10 turions per 0.25 m^2 in winter. These densities should be based on 20 random 0.25 m^2 quadrat samples taken in the eelgrass bed. In addition to the density criteria above, culture should not be permissible if more than 10% of the samples exceed 20 turions per 0.25 m^2. These guidelines are those used by the Washington Department of Fisheries (WDF) in defining areas unacceptable for hardshell clam harvesting (DNR/WDF, 1981).

- Kelp beds (i.e., dense beds of attached macroalgae, especially bull kelp, Nereocystis luetkeana).

- Rocky reef habitats (high profile rock outcrops colonized by organisms such as hydroids, macroalgae, abalone, sea urchins, sea anemones, starfish, and other attached organisms).

- Geoduck (Panope abrupta) populations with densities exceeding 0.4 animals per m^2. This density is the criterion used by state agencies to define major geoduck beds (DNR/WDF, 1985).

- Hardshell clam populations with densities exceeding 1.2 kg (2.5 lbs) per m^2. This density is that required for hardshell clam harvest (DNR/WDF, 1981).

- Habitats having significant populations of, or which are important to the feeding, reproduction or other life stages of Dungeness crabs (Cancer magister), herring (Clupea), lingcod/greenling (Hexagrammidae), true cod (Gaddidae), soles and flounders (Pleuronectiformes), rock fishes (Scorpaenidae), cabezone and other large sculpins (Cottidae), or sea perch (Embiotocidae). The occurrence of these species in a potential culture area does not necessarily exclude it from development. The determination of whether the site is of special significance to these species will be determined by WDF on a case-by-case basis.

- Wildlife refuges and habitats of endangered or threatened species. (A 300 foot separation from net-pens is recommended regardless of current direction).

- Other habitats of special significance, regardless of depth, as determined on a case-by-case basis.

3. Net-pens should not be located within 1500 feet of bird and mammalian habitats of special significance including seal and sea lion haulout area, seabird nesting sites or colonies, and areas specifically identified as critical for feeding or migration of birds and mammals. The Washington Department of Game will be responsible for the designation of habitats of special significance for birds and mammals.

4. Siting guidelines have been developed to minimize the likelihood that net-pen culture will adversely affect water quality or contribute significantly to phytoplankton productivity in any given area. Culture is not recommended in areas with chronic water quality problems. On the basis of this approach guidelines have been developed as shown in Figure 2 and Table 2 and as summarized below:

   - Recommended limits are placed on the maximum fish production within specified geographic areas for most of southern Puget Sound, the Port Orchard area, Whidbey Basin, northern Hood Canal, Sequim Bay and Discovery Bay. These production limits range from 50,000 lbs/yr in Sequim Bay to 5,900,000 lbs/yr in Skagit Bay. There are no restrictions on whether the production allotment for a given area is utilized by a single operation or divided among several smaller operations, provided that culture density does not exceed more than 1,000,000 lbs annual production per square nautical mile (defined as a square area having dimensions of 6076 feet on all sides).

   - Budd Inlet, Holmes Harbor and Hood Canal south of Hazel Point are areas of special concern because of chronic low dissolved oxygen at depth and persistent nitrogen depletion in surface waters. Net-pen culture, therefore, is not recommended unless the applicant can demonstrate that: 1) respiration and biochemical oxygen demand (BOD) will not significantly depress dissolved oxygen concentrations; and 2) nutrient input attributable to net-pen culture will not affect the frequency, extent, intensity or duration of phytoplankton blooms.

   - There are no water quality-based limits on the number of net pen operations in the Strait of Juan de Fuca, the Strait of Georgia, San Juan Islands, Main Basin of Puget Sound, and the southern Sound in the area of Anderson Island, Nisqually Reach and Tacoma Narrows. Culture density, however, should not exceed 1,000,000 lbs annual production per square nautical mile. More stringent production limits may be imposed in some instances to protect water quality in specific embayments.

5. Unpelletized wet feed (i.e., minced fish or shellfish) should not be used in net-pen culture.

6. If predator control is necessary, non-lethal predator control measures should be used against both bird and mammalian predators. Predator control methods must comply with appropriate federal and state rules, and the pen operator shall possess all necessary permits.

7. Tributyltin should not be used as an antifouling agent on the nets. The use of other antifouling agents should be reviewed on a case-by-case basis by state environmental management agencies. Any antifoulant use should be reported to the Washington Department of Ecology.

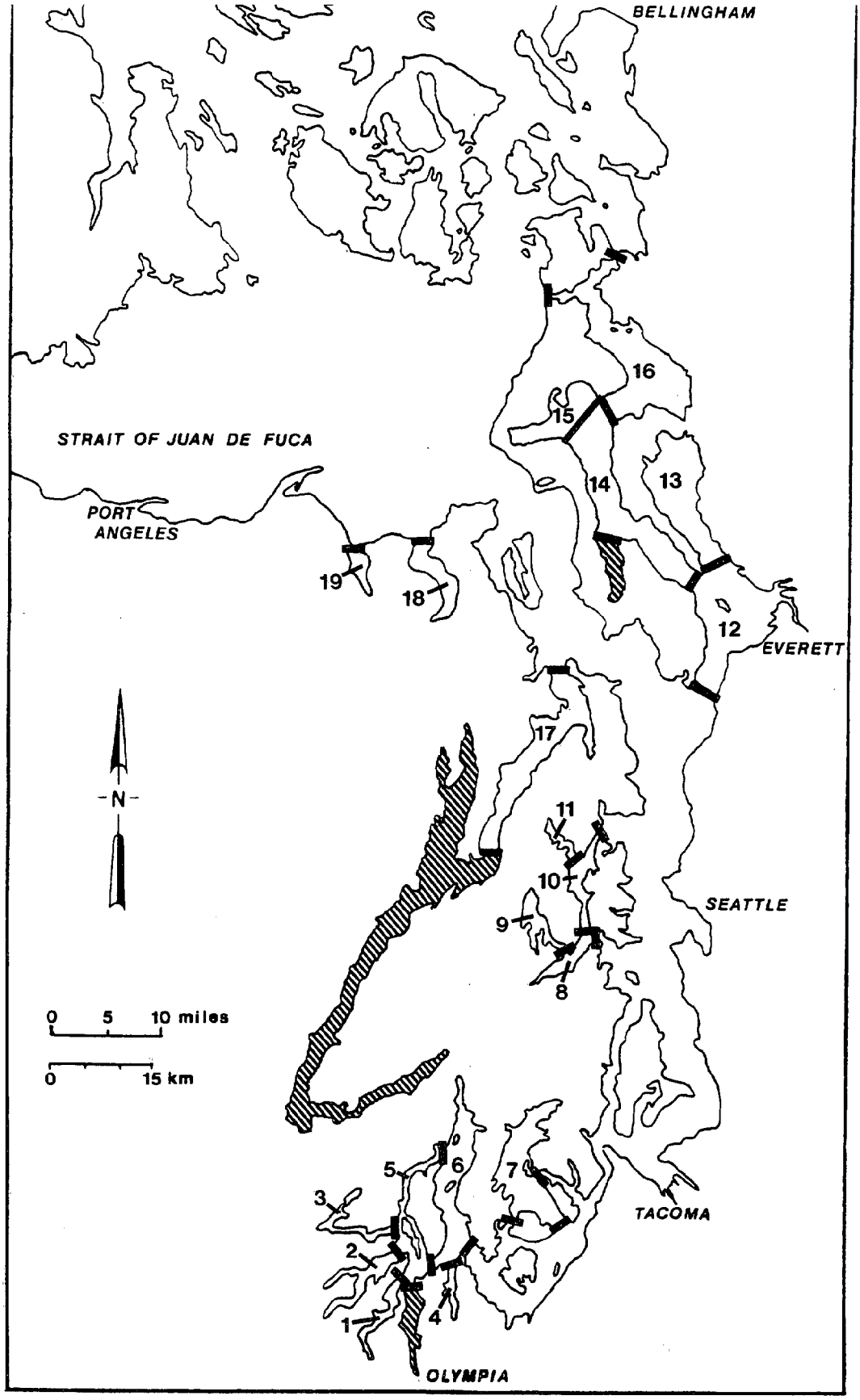

Figure 2. SUB-DIVISIONS OF PUGET SOUND USED IN ESTABLISHING THE WATER QUALITY GUIDELINES. CROSS-HATCHING DENOTES AREAS OF SPECIAL CONCERN.

Table 2

WATER QUALITY GUIDELINES

Area[1]	Description	Maximum Annual Salmon production (thousand lbs/yr)
1	Eld Inlet	190
2	Totten and Skookum Inlets	190
3	Hammersley Inlet and Oakland Bay	240
4	Henderson Inlet	80
5	Squaxin, Peale and Pickering Passage	680
6	Dana Passage and Case Inlet	980
7	Carr Inlet	1100
8	Sinclair Inlet	190
9	Dyes Inlet	460
10	Port Orchard	260
11	Liberty Bay	120
12	Possession Sound	3200
13	Port Susan	1100
14	Saratoga Passage	2000
15	Penn Cove and Crescent Harbor	730
16	Skagit Bay	5900
17	Northern Hood Canal	1900
18	Discovery Bay	540
19	Sequim Bay	50

The following are areas of special concern in which culture is not recommended unless the applicant can demonstrate that culture will not result in adverse environmental effects:

- Budd Inlet
- Holmes Harbor
- Hood Canal south of Hazel Point

The interim guidelines place no limits on the number of net-pen operations or total allowable production in the following areas:

- Strait of Juan de Fuca
- Strait of Georgia
- San Juan Islands
- Main Basin of Puget Sound
- Southern Puget Sound in the vicinity of Tacoma Narrows, Nisqually Reach and Anderson Island

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[1]See Figure 2 for the location of the areas and McLellan (1954) for the precise geographic boundaries.

8. Only antibiotics licensed by the Food and Drug Administration shall be used, and these should be used only on a short-term basis for disease treatment or disease prevention. Antibiotics should not be used prophylactically on a long-term basis. The Washington Department of Fisheries should be notified of all antibiotic usage at the time of treatment, and should be informed of the disease or condition being treated and the antibiotic used.

9. Transfer of live fish or their reproductive products within the state or their importation into state shall be done in accordance with all applicable state and federal standards.

10. To facilitate environmental review, applications for culture should be accompanied by an operations plan which is to be submitted to the Department of Natural Resources (DNR) for distribution to other agencies. This plan should include projections for: (1) improvements at site (e.g., pens, log booms) and their relationship to natural features (e.g. bathymetry, shorelines); (2) pen number, size and configuration; (3) schedule of development and maintenance; (4) species cultured; (5) fish size at harvest; (6) annual production; (7) pounds of fish on hand throughout the year; (8) average and maximum stocking density; (9) source of eggs and smolts; (10) type of feed used; (11) feeding method; (12) chemical use (e.g., antibiotics); (13) predator control measures; and (14) antifoulant use.

11. A site characterization survey should be performed prior to permit application. This survey includes: (1) a bathymetric survey; (2) a hydrographic survey; and (3) a diver survey of biological resources to be done in the period April through September. The applicant is strongly encouraged to consult with state and local officials prior to permit application and in designing the site characterization survey. The initial state contact should be made with the Washington State Department of Agriculture, and this agency will facilitate additional contacts with the Departments of Fisheries, Ecology, Natural Resources, Game and Parks and Recreation.

12. A benthic baseline survey consisting of sediment chemistry and benthic infauna sampling should be performed by all operations with an anticipated annual production in excess of 100,000 lbs. The baseline survey should be conducted after net-pen installation, but before stocking with fish.

13. An annual summer diver survey should be performed by all operations with an anticipated annual production in excess of 20,000 lbs. For those operations growing in excess of 100,000 lbs per year, annual summer monitoring should also include: (1) sediment chemistry and infauna sampling; (2) water quality sampling; and (3) a hydrographic survey.

BACKGROUND INFORMATION AND DISCUSSION FOR THE INTERIM GUIDELINES

1.0 INTRODUCTION

The net-pen culture of salmon is expanding throughout the world including Puget Sound. This growth is creating additional management responsibilities for state and local agencies. At both the state and local level there is a need for a coordinated approach to environmental review and regulation of this relatively new industry. These interim guidelines are intended to provide a basis for such a coordinated approach until completion of the programmatic Environmental Impact Statement (EIS) for the salmon net-pen industry.

The goal of the guidelines is to avoid significant adverse environmental effects from net-pen operations permitted prior to completion of the programmatic EIS. The recently completed review, "The Environmental Effects of Floating Mariculture in Puget Sound" (Weston, 1986), and many other studies have demonstrated that the environmental effects of net-pen culture are highly dependent upon siting and operational practices. Therefore, the goal of the guidelines is pursued through a combination of recommendations for project siting and operational practices, as well as a recommended protocol for annual monitoring. Although environmental protection is the primary goal, these interim guidelines have been developed to meet two secondary goals. First, it is anticipated that the guidelines will lessen the burden of environmental review at the county level. These guidelines should assist local government review of permit applications under the Shoreline Management Act and the State Environmental Policy Act. Secondly, it is also anticipated that these guidelines will assist the industry in application for new sites, and facilitate permitting of operations in sites which meet these guidelines. The permitting of sites which do not meet the guidelines is likely to be a more difficult process and will place the burden of proof on the applicant to demonstrate that culture can be conducted with minimal environmental affect.

As the term "interim guidelines" implies, this document is intended to provide guidance to state and local authorities responsible for the regulation of salmon net-pen culture. These recommendations for siting, operation and monitoring are intended to be flexible, and do not eliminate the need for careful case-by-case review of permit applications. The interim guidelines are, by necessity, generic in nature. It is therefore anticipated that site-specific

conditions may require that these guidelines be made more restrictive or relaxed occasionally on a case-by-case basis. Departures from these guidelines, however, are expected to be relatively rare. If a given project is made subject to restrictions or requirements not specified in these guidelines, state and/or local officials should provide the applicant, if requested, with an explanation of the environmental reasons for doing so. If relaxation of these guidelines is requested, it is the responsibility of the applicant to demonstrate that deviation from these guidelines can be made with minimal environmental effect.

These guidelines are formulated to minimize possible effects of net-pen operation on habitats of special significance as well as sediment and water quality. They do not address considerations of aesthetics, navigation or water/land use conflicts. These and similar issues are best considered at the county level on a case-by-case basis.

The guidelines apply to all net-pen operations in which salmon are grown with the intent to harvest and market the fish upon attainment of sufficient size. The guidelines do not apply to net-pen operations in which salmon are held primarily for research purposes because these facilities are typically of very small size and thus have a reduced potential for environmental effects. The guidelines do not apply to delayed release facilities used for enhancement of wild stocks. There are three reasons for this exclusion. First, fish are held in the delayed release facilities only for a period of four to six months, thus reducing the potential for effects such as feed and feces accumulation under the pens. Secondly, fish are not in the pens during the summer months when water quality concerns are the greatest. Finally, only commercial operations growing fish to a marketable size show significant growth potential in the near future in Puget Sound. Rapid growth of delayed release operations is not anticipated, thus the issue will be deferred to consideration in the programmatic EIS.

The interim guidelines are to be used in the permitting and management of net-pen operations in Puget Sound, the Strait of Juan de Fuca and the Strait of Georgia. They apply to net-pen operations which have not yet been permit-

ted, and do not apply to projects already in operation or permitted unless these facilities undergo significant expansion of modification of their original permit specifications. In this case, the expansion or modification may be evaluated for consistency with these guidelines.

2.0 DEPTH AND CURRENT GUIDELINES

The net-pen culture of salmon generates substantial amounts of excess feed and feces which ultimately settle to the sea floor. The amount of feed and fecal material generated will depend on the level of production of the operation, and the fate of the material will depend principally upon the depth and water currents at the site. These guidelines consider current velocity and facility production in conjunction with water depth.

The objectives of the guidelines are: (1) to minimize the rate of accumulation of feed and feces on the bottom; and (2) to minimize biological changes in benthic communities caused by culture activities. The guidelines consider both depth and current in an attempt to insure that feed and feces are dispersed over a broad enough area to minimize chemical and biological changes in the sediment. If net-pens are sited in accordance with the guidelines, the depth and lateral extent of visible accumulation of feed and feces should be considerably reduced from that currently reported under existing net-pens. There may be subtle and localized changes in sediment chemistry, or enhancement of species tolerant of organic enrichment. The potential for complete absence of macrofauna or the accumulation of thick mats of feed and feces that have been previously reported will be significantly reduced.

It should be emphasized that these guidelines represent the one of the few attempts anywhere in the world to minimize feed and feces accumulation by establishing depth criteria for siting, and the only effort to incorporate current velocity and facility production. Data that would allow exact determination of the combinations of depth and current required for adequate dispersal are, for the most part, lacking. In addition, few data exist on the assimilative capacity of the benthos. The interim criteria draw upon all available data, but rely heavily on scientific judgment. It is clear that more data are needed. The anticipated programmatic EIS will evaluate the effectiveness of these depth and current guidelines, and permit later refinement if necessary. The annual monitoring program recommended by these guidelines (Section 7.0) will, in part, serve to provide the data needed for this evaluation.

The variables of water depth current and operation size all interact to determine the extent of feed and feces accumulation on the bottom. The interim depth and current guidelines recognize this interaction in the siting of net-pen operations. The guidelines are displayed graphically in Figure 3. It is evident from this figure that recommendations for water depth and current velocity are dependent upon the size of the operation: the greater the annual production of the facility, the greater must be the water depth and/or current velocity. Net-pen operations are divided into three size classes as follows:

Class I:

- Operations with a production capacity of up to 20,000 pounds/year.

Class II:

- Operations with a production capacity in excess of 20,000 pounds/year, but no greater than 100,000 pounds/year.

Class III:

- Operations with a production capacity in excess of 100,000 pounds/year.

Figure 3 illustrates depth and current guidelines for each operational class. At any given current velocity, the minimum recommended depth beneath the pens is specified. Since these guidelines attempt to maximize the dispersal of feed and feces as they settle from the net-pens, current velocity should be measured mid-way between the bottom of the net-pens and the sea floor as described in Section 6.1. Surface current velocity is not an appropriate substitute. The guidelines are based on mean rather than maximum current velocity. A minimum mean current velocity of 0.1 knots (5 cm/sec) is recommended. At sites with a mean current velocity below this value, currents will not be adequate to insure dispersal of solid wastes, and no culture should be permitted.

The depth of concern has been defined as the distance from the bottom of the net-pens to the sea floor rather than total water depth. In application of the guidelines to a net-pen complex on a sloping bottom, the depth of concern is the smallest depth under any of the net-pens, and this value is to be used

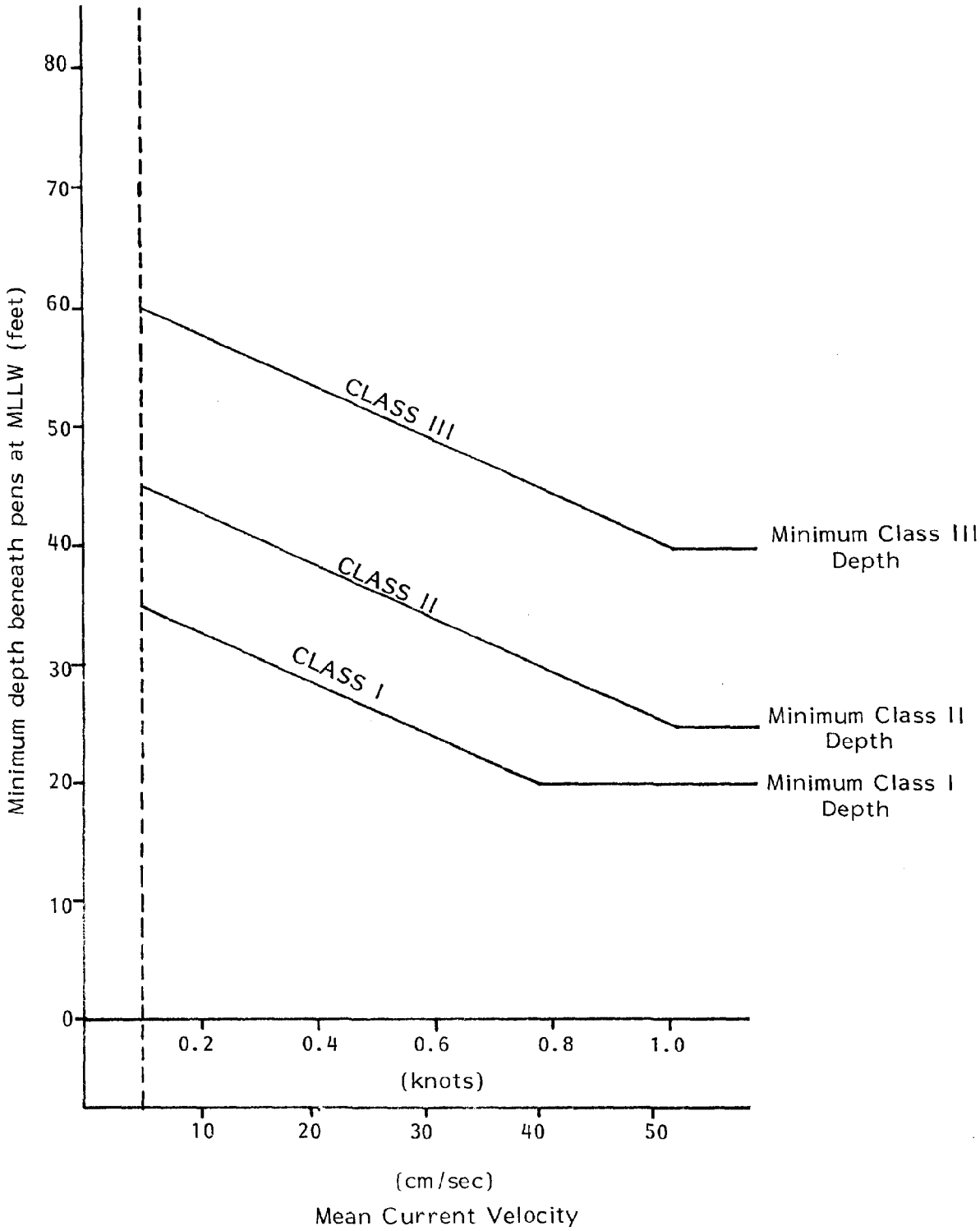

Figure 3

MINIMUM DEPTH AND CURRENT GUIDELINES
FOR NET-PEN SITING
(See text for explanation of Class I, II, and III operations and for definition of mean current velocity)

in determining compliance with the guidelines. Depths are based on mean lower low water (MLLW). MLLW is the chart datum employed on nautical charts, thus simplifiying application of the guidelines.

Pen configuration is also a significant factor in determining the depth and lateral extent of solids accumulation beneath a net-pen facility. Pens oriented in a row parallel to the prevailing current will tend to cause the greatest depth of solids accumulation per unit area, but may affect the least amount of bottom area. Pens oriented perpendicular to the prevailing current may affect a greater area of bottom, but may have the least accumulation per unit area. The guidelines do not specifically address pen configuration because it will be extremely operation-specific, and because of the limitations in sedimentation models which currently do not allow prediction of an optimal design. For those operations which meet the depth and current guidelines, however, pen configuration may ultimately prove to be an important consideration in further mitigating effects. This issue will require further consideration in the programmatic EIS.

3.0 HABITATS OF SPECIAL SIGNIFICANCE

Net-pens should not be located where their siting or the accumulation of excess feed and feces are likely to adversely affect habitats important to commercial or sport fisheries, that are of critical ecological importance, or that are especially sensitive to degradation by culture activities. These habitats should be afforded protection over and above the depth and current guidelines discussed in Section 2.0. The habitats of special significance are listed in Table 3. The Washington Department of Fisheries (WDF) will have responsibility for the designation of and assessment of impacts on plant, invertebrate and fish habitats of special significance. The WDF has considerable existing data concerning habitats of special significance for foodfish and shellfish, and is able to provide available information or comments in this regard.

It is recommended that net-pens not be sited within 300 feet from habitats of special significance located in the direction(s) of prevailing tidal currents. A 150-foot separation is recommended in all other directions. These distances are to be measured laterally from the net-pen perimeter. A review of the literature (Weston, 1986) found that visible accumulation of feed and feces or changes in sediment chemistry was generally reported to extend to distance from the net-pens of 100 feet or less. The greatest reported distance of visible accumulation was 150 feet from the net-pens. A separation of 300 feet in the direction(s) of prevailing currents should provide an additional margin of protection.

Habitats of special significance are, by definition, herein limited to water depths of 75 feet or less at mean lower low water (MLLW). Except in special cases (Item 8 of Table 3), no habitat restrictions are placed on net-pens if water depths within a 300-foot distance are in excess of 75 feet. For example, the occurrence of dense geoduck beds within 300 feet from a proposed net-pen site in the direction of prevailing current is sufficient to exclude that site from consideration if the beds are in a depth of 75 feet or less. These geoduck beds will not ordinarily be of concern in siting if they are at a depth greater than 75 feet. The 75-foot limitation to habitats of special significance has been established principally because of the reduced likelihood of feed and feces bottom accumulation at greater depths. For many of the

Table 3

HABITATS OF SPECIAL SIGNIFICANCE

1. Eelgrass (Zostera marina) beds having densities exceeding 13 turions (i.e., "shoots") per 0.25 m^2 in summer or 10 turions per 0.25 m^2 in winter. These densities should be based on 20 random 0.25 m^2 quadrat samples taken in the eelgrass bed. In addition to the density criteria above, culture should not be permissible if more than 10% of the samples exceed 20 turions per 0.25 m^2. These guidelines are those used by the Washington Department of Fisheries (WDF) in defining areas unacceptable for hardshell clam harvesting (DNR/WDF, 1981).

2. Kelp beds (i.e., dense beds of attached macroalgae, especially bull kelp, Nereocystis luetkeana).

3. Rocky reef habitats (high profile rock outcrops colonized by organisms such as hydroids, macroalgae, abalone, sea urchins, sea anemones, starfish, and other attached organisms).

4. Geoduck (Panope abrupta) populations with densities exceeding 0.4 animals per m^2. This density is the criterion used by state agencies to define major geoduck beds (DNR/WDF, 1985).

5. Hardshell clam populations with densities exceeding 1.2 kg (2.5 lbs) per m^2. This density is that required for hardshell clam harvest (DNR/WDF, 1981).

6. Habitats having significant populations of, or which are important to the feeding, reproduction or other life stages of Dungeness crabs (Cancer magister), herring (Clupea), lingcod/greenling (Hexagrammidae), true cod (Gaddidae), soles and flounders (Pleuronectiformes), rock fishes (Scorpaenidae), cabezone and other large sculpins (Cottidae), or sea perch (Embiotocidae). The occurrence of these species in a potential culture area does not necessarily exclude it from development. The determination of whether the site is of special significance to these species will be determined by WDF on a case-by-case basis.

7. Wildlife refuges and habitats of endangered or threatened species. (A 300 foot separation from net-pens is recommended regardless of current direction).

8. Other habitats of special significance, regardless of depth, as determined on a case-by-case basis.

habitats of special significance, the 75-foot depth limitation is of little consequence for these habitats are found only in much shallower water (e.g., eelgrass, kelp, herring spawning areas).

Net-pens should not be sited within 1500 feet of habitats of special significance as identified by the Washington Department of Game (WDG). These include seal and sea lion haulout areas, seabird nesting sites or colonies, and areas specifically identified as critical for feeding or migration of birds and mammals. It is not clear what effects, if any, net-pen operations would have on these species or habitats, however, the intent of this guideline is to reduce the likelihood of interactions between net-pen operations and these species, and thus reduce the need for predator control measures. WDG will have the responsibility for the designation of mammal and bird habitats of special significance.

4.0 WATER QUALITY GUIDELINES

The primary objective of the water quality guidelines is to minimize any potential effect of net-pen activities on phytoplankton productivity (i.e., initiate or sustain blooms). Secondarily, the guidelines attempt to prevent the input of feed and feces with a high biochemical oxygen demand (BOD) in areas which have chronically low dissolved oxygen concentrations. The guidelines address only incidentally potential toxic effects that result from the accumulation of metabolites (principally ammonia) or the respiratory depletion of oxygen in the water passing directly through the culture structure. Salmon are very sensitive to both elevated ammonia concentrations and low dissolved oxygen, and thus, the size of the operation is likely to be self-limiting with respect to toxic effects. In addition, net-pen operations of the size typical of Puget Sound are unlikely to cause increases in ammonia concentrations to the point where toxicity would become a concern (Weston, 1986).

A general overview of the water quality interim guidelines is shown in Table 4 and Figure 4. Net-pen culture is not recommended in Budd Inlet, Holmes Harbor or Hood Canal south of Hazel Point unless the applicant can demonstrate culture can be conducted without significant environmental effects. In the Main Basin of Puget Sound, portions of the southern Sound (Anderson Island, Tacoma Narrows and Nisqually Reach), the Strait of Juan de Fuca, the San Juan Islands and the Strait of Georgia the guidelines establish no water quality-based limitations on the number of net-pen operations, although the density of culture should not exceed more than 1 million pounds annual production within one square nautical mile (hereafter defined as a square area having the dimensions of 6076 feet on all sides). Much of the remainder of Puget Sound has been sub-divided into areas numbered 1 through 19 based primarily on the sub-divisions of Puget Sound used by McLellan (1954). In each of these sub-divisions, a maximum annual salmon production has been recommended. The guidelines place no restrictions on how the maximum production is distributed among operations. A single operation may utilize the production allotment for a sub-division, or the production allotment may be divided among several smaller operations. However, the annual production density should not exceed 1 million pounds per square nautical mile.

Table 4

WATER QUALITY GUIDELINES

Area[1]	Description	Maximum Annual Salmon production (thousand lbs/yr)
1	Eld Inlet	190
2	Totten and Skookum Inlets	190
3	Hammersley Inlet and Oakland Bay	240
4	Henderson Inlet	80
5	Squaxin, Peale and Pickering Passage	680
6	Dana Passage and Case Inlet	980
7	Carr Inlet	1100
8	Sinclair Inlet	190
9	Dyes Inlet	460
10	Port Orchard	260
11	Liberty Bay	120
12	Possession Sound	3200
13	Port Susan	1100
14	Saratoga Passage	2000
15	Penn Cove and Crescent Harbor	730
16	Skagit Bay	5900
17	Northern Hood Canal	1900
18	Discovery Bay	540
19	Sequim Bay	50

The following are areas of special concern in which culture is not recommended unless the applicant can demonstrate that culture will not result in adverse environmental effects:

- Budd Inlet
- Holmes Harbor
- Hood Canal south of Hazel Point

The interim guidelines place no limits on the number of net-pen operations or total allowable production in the following areas:

- Strait of Juan de Fuca
- Strait of Georgia
- San Juan Islands
- Main Basin of Puget Sound
- Southern Puget Sound in the vicinity of Tacoma Narrows, Nisqually Reach and Anderson Island

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[1]See Figure 4 for the location of the areas and McLellan (1954) for the precise geographic boundaries.

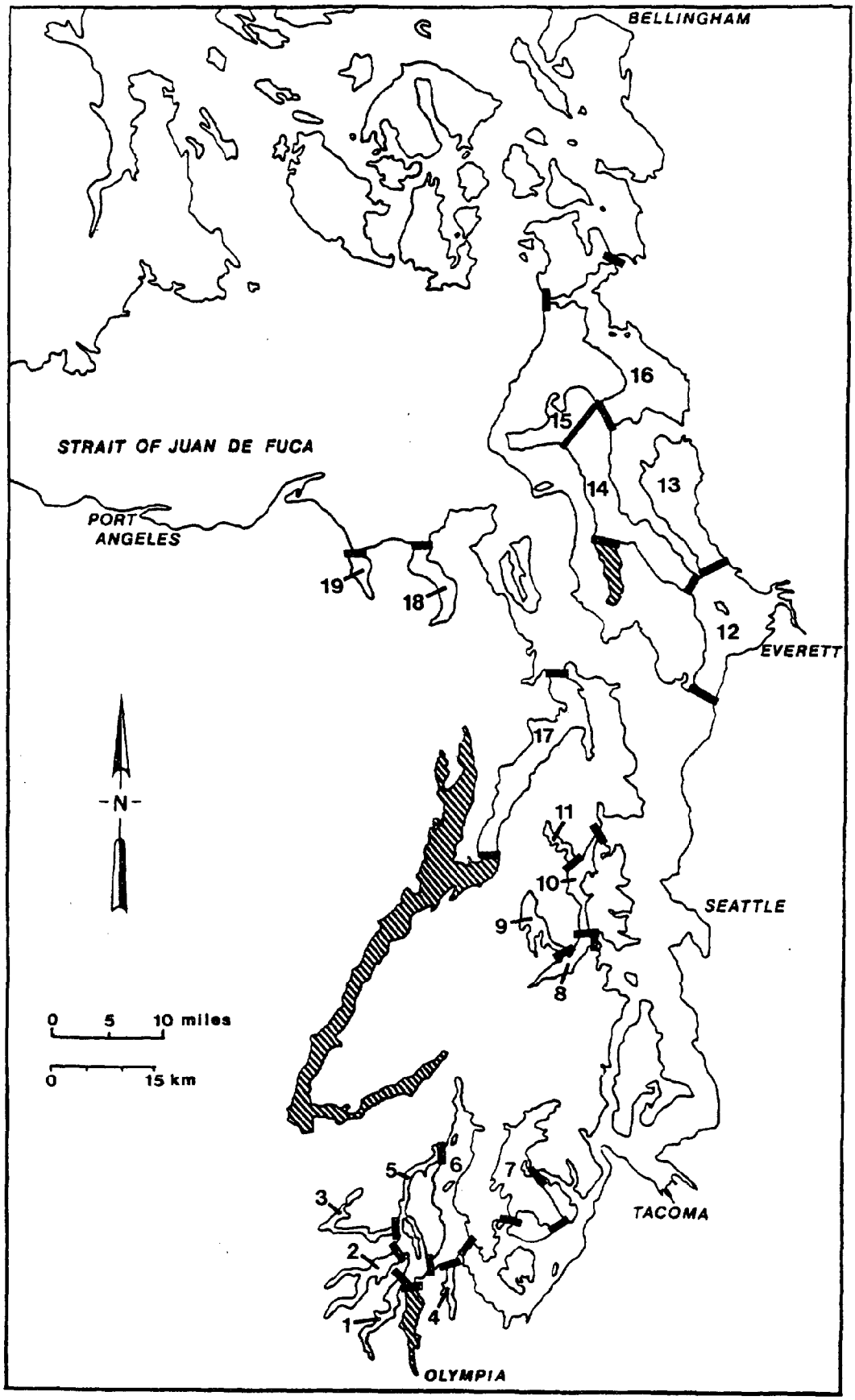

Figure 4. SUB-DIVISIONS OF PUGET SOUND USED IN ESTABLISHING THE WATER QUALITY GUIDELINES. CROSS-HATCHING DENOTES AREAS OF SPECIAL CONCERN.

To understand the basis for the water quality guidelines, existing water quality conditions throughout Puget Sound must be examined. Figures 5 through 7 illustrate dissolved oxygen and nitrogen concentrations throughout the Sound based on the Department of Ecology water quality monitoring data. Ecology monitoring stations are sampled monthly from April through November. Samples are collected at depths of 0, 33 and, if the water is of sufficient depth, at 98 ft. (corresponding to 0, 10 and 30 m). Data collected from April 1981 through November 1985 (approximately 40 sampling events) were used in development of these guidelines.

Figure 5 illustrates the percentage of observations with less than 5 mg/l dissolved oxygen in samples collected at a depth of 33 ft.. Two areas, Budd Inlet and the extreme southern end of Hood Canal, had chronically low dissolved oxygen concentrations at depths of 33 ft. Dissolved oxygen concentrations less than 5 mg/l were regularly reported at depths of 98 ft. in Hood Canal northwards to, and including, Dabob Bay (Figure 6). In Holmes Harbor dissolved oxygen concentrations less than 5 mg/l were observed in 15% of the samples.

Figure 7 illustrates the frequency with which nitrogen concentrations (sum of ammonia, nitrite and nitrate) drop below 0.1 mg/l. In Puget Sound nitrogen concentrations below this value suggest that nitrogen may limit phytoplankton growth, and that the addition of nitrogen by net-pen culture could increase primary productivity. The highest frequency of nitrogen limitation was observed in Hood Canal northwards to and including Dabob Bay. Nitrogen depletion below 0.1 mg/l was also observed at a frequency greater than 60% in Holmes Harbor, Budd Inlet, Totten Inlet, Port Orchard and Liberty Bay. In the Strait of Juan de Fuca, the San Juan Islands and the Main Basin of Puget Sound nitrogen was rarely limiting to phytoplankton growth.

The data displayed in Figures 5 through 7 were used to determine the maximum intensity of culture recommended in any given area under these interim guidelines. The conclusions drawn from the Ecology water quality monitoring data set were also compared and verified with readily available published data (Collias, et al., 1974; Friebertshauser, et al., 1971). It should, however, be recognized that the data search conducted for the interim guidelines was by

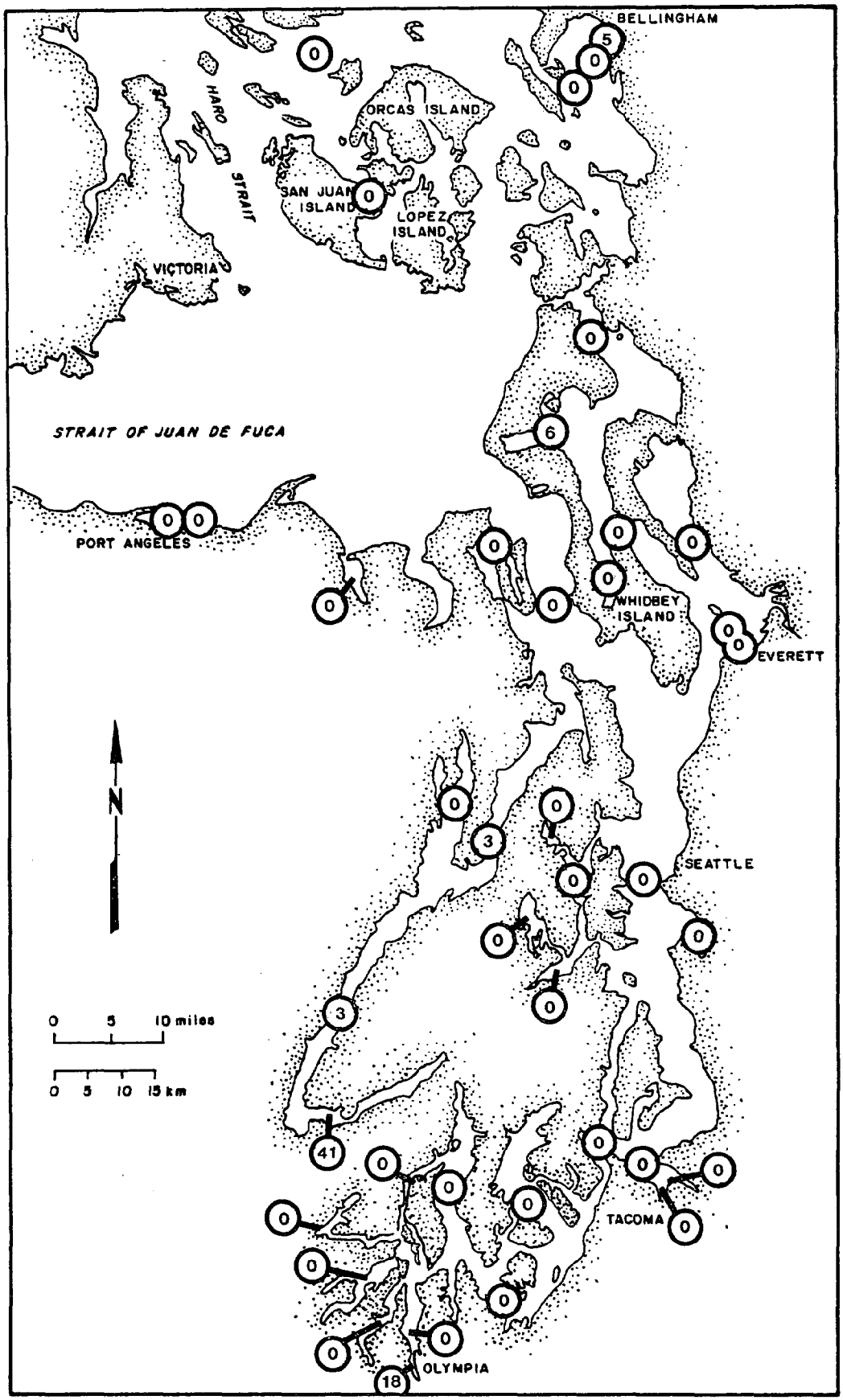

Figure 5. PERCENTAGE OF OBSERVATIONS WITH < 5 mg/ℓ OXYGEN AT A DEPTH OF 33 ft (n=35-40)

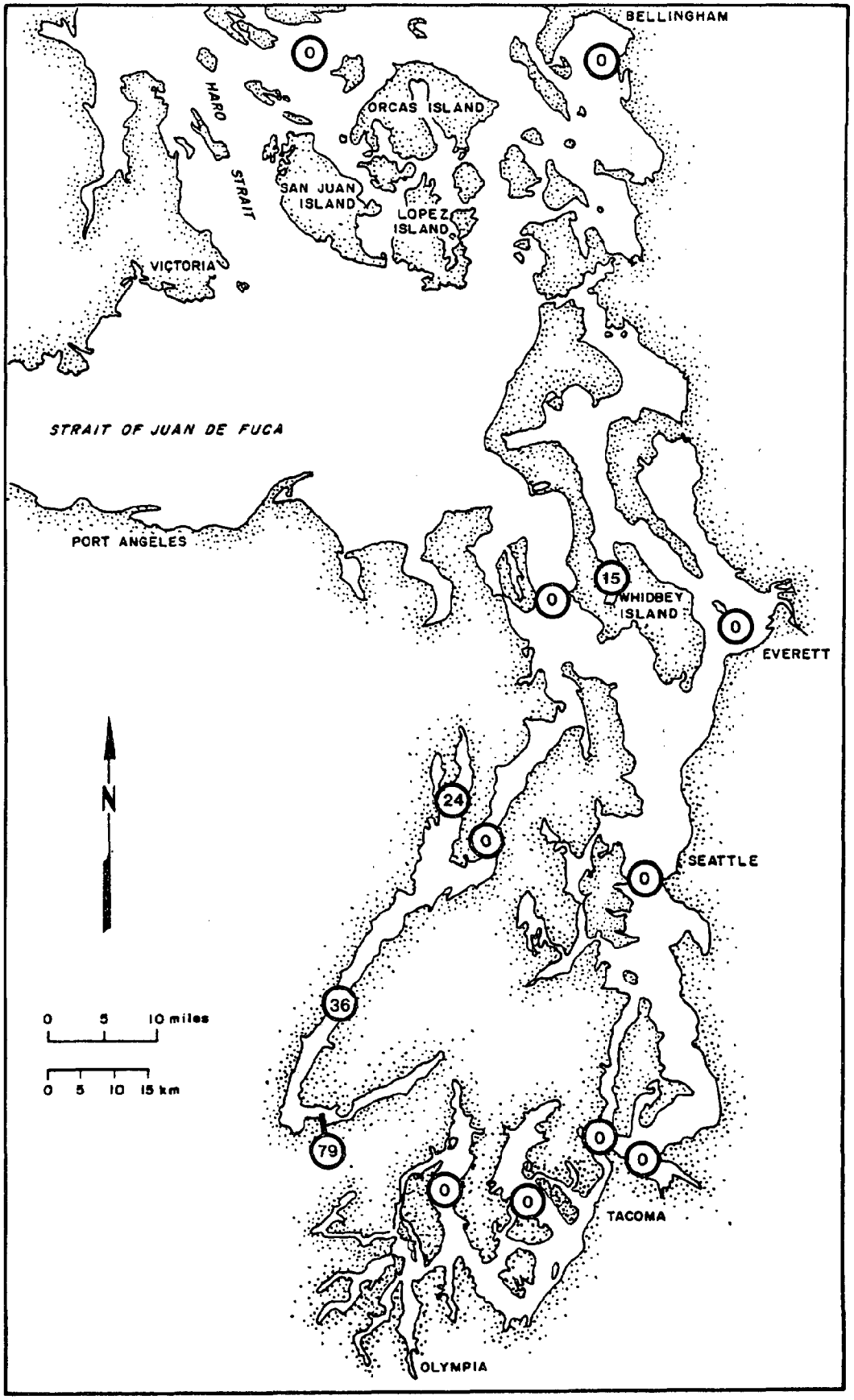

Figure 6. PERCENTAGE OF OBSERVATIONS WITH < 5 mg/ℓ OXYGEN AT A DEPTH OF 98 ft (n=35-40)

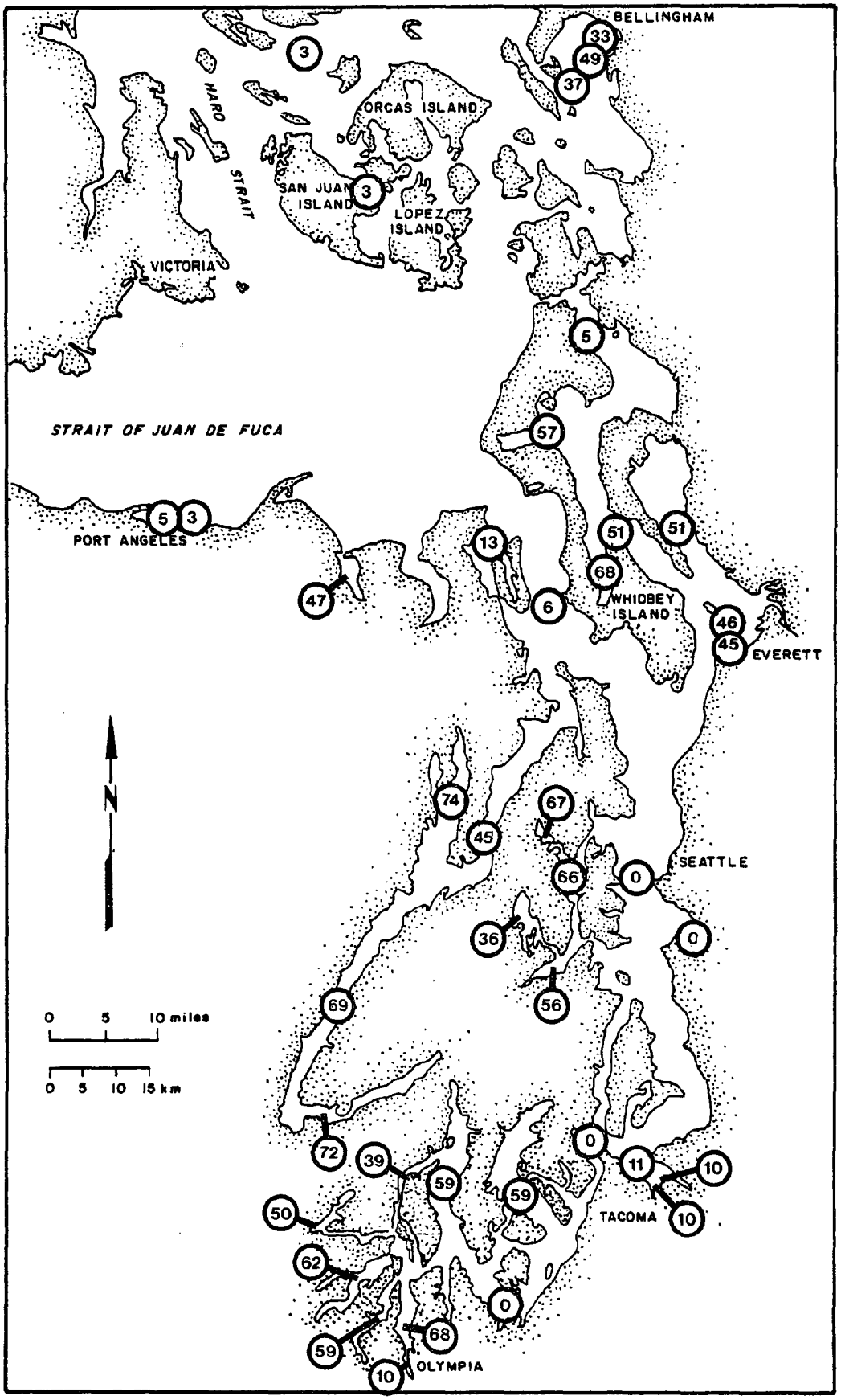

Figure 7. PERCENTAGE OF OBSERVATIONS WITH LESS THAN 0.1 mg/ℓ NITROGEN IN SURFACE WATERS (n=35-40)

no means exhaustive. Much additional data from site-specific studies could not be utilized because of the limited time available for development of the interim guidelines. As this site-specific information becomes available, there may be justification to either relax these guidelines or make them more restrictive on a case-by-case basis. Assessment of additional data through the programmatic EIS process may also result in changes in the intensity of culture permissible in any given area. Given that the interim guidelines are based on a limited data set, a deliberately conservative approach has been used in their formulation.

The maximum recommended intensity of culture in any given area has been based on the frequency of oxygen depletion and nitrogen limitation in that area. Budd Inlet, Holmes Harbor and Hood Canal south of Hazel Point appear to have chronic oxygen depletion at depth and persistent nitrogen limitation in surface waters. In view of the existing poor water quality in these areas, any application for culture should be given careful scrutiny as to the potential environmental consequences. Culture is not recommended in these areas unless the applicant can demonstrate: 1) respiration and BOD will not significantly reduce dissolved oxygen concentrations; and 2) input of additional nutrients will not affect the frequency, extent, intensity or duration of phytoplankton blooms. The exclusion of much of Hood Canal is generally consistent with Washington Department of Ecology policy pertaining to municipal wastewater discharges to this water body. Since 1972 Ecology has required secondary treatment of all wastewater discharges to Hood Canal, and currently requires tertiary treatment (Bollen, unpub.; M. Palko, WDOE, pers. comm.). Although Ecology policy applies to all of Hood Canal, persistent oxygen and nitrogen depletion in the area north of Hazel Point were not evident in the data set reviewed for the interim guidelines. This area, therefore, has not been excluded from net-pen culture under these guidelines.

Areas where oxygen depletion or nitrogen limitation were observed infrequently include the the southern Sound in the area of Anderson Island, Tacoma Narrows and Nisqually Reach, the Main Basin of Puget Sound, the Strait of Juan de Fuca, San Juan Islands and the Strait of Georgia. In these areas, phytoplankton productivity is generally governed by factors other than nitrogen availability; thus the input of additional nitrogen from net-pen culture should not

stimulate additional phytoplankton growth. In addition, dissolved oxygen concentrations are rarely, if ever, reduced to biologically limiting levels. Inputs of nutrients and BOD associated with net-pen operation probably would not have measurable biological consequences, although site-specific conditions should be assessed on a case-by-case basis. These areas are also likely to be well-flushed with little opportunity for a nutrient enriched or oxygen depleted water mass to maintain its integrity for an appreciable length of time. Therefore, the interim guidelines place no water quality-based restrictions on the number of net-pen culture operations in these areas. However, in order to avoid excessive culture in a very localized area, it is recommended that the density of culture not exceed 1 million pounds annual production per square nautical mile. More stringent productin limits may be imposed in some instances to protect water quality in specific embayments.

In the remainder of Puget Sound (most of the southern Sound, Port Orchard area, Whidbey Basin, northern Hood Canal, Sequim and Discovery Bays) recommended limits are placed on the maximum production of fish in any given region. The 1 million pounds annual production per square nautical mile applies in these areas as well. The approach taken in development of these guidelines allows net-pens to increase by a very small percentage the natural flux of nitrogen into the embayment that occurs with each tidal cycle. The natural tidal flux of nitrogen into the embayment is determined and net-pens are allowed to increase this flux by 1%. The weight of cultured fish that would produce this 1% increase is the maximum recommended production for the embayment. Each area of Puget Sound will have some capacity to assimilate additionial nitrogen input. This assimilative capacity will, however, vary in each area, and in no case is there a means to predict, a priori, what this assimilative capacity may be. Lacking these data, the 1% increase has been specified throughout Puget Sound as an increase of small enough magnitude that it should be adequately protective.

The sub-divisions in the water quality guidelines are shown in Figure 4 and in general are based on those of McLellan (1954). In most cases the boundaries used by McLellan have been adapted without modifications since there is clear geomorphologic and hydrographic justification (e.g., Eld Inlet, Dyes Inlet and Sequim Bay). A number of McLellan's subdivisions have been grouped if there

was no apparent hydrographic reason for maintaining their distinction (e.g., three of McLellan's subdivisions grouped to form the Port Orchard sub-division of the interim guidelines).

Determination of the natural tidal nitrogen flux in a given area begins with calculation of the "half-life" of water in the area:

$$0.50 = e^{(-\frac{\Delta V}{V} \cdot T \cdot R)}$$

where 0.50 represents removal of half the initial water volume, v is the intertidal volume, v is the total volume of the embayment, T is the number of tidal cycles and R is the refluxing coefficient (a value of 0.5 was used). The equation is solved for T and then this solution is substituted in:

$$E = \frac{0.5v}{T}$$

where E represents the effective intertidal volume. Multiplying E by the nitrogen concentration of the water (measured at the surface in these calculations) yields the natural tidal nitrogen flux. A 1% increase in this flux from net-pen culture is then calculated. A more detailed discussion of the approach can not be presented here, but further explanation of some elements can be found in URS (1986). The calculations for each embayment are presented in Table 5, and further details on the approach are presented in the notes which follow Table 5.

Table 5

CALCULATIONS FOR WATER QUALITY GUIDELINES[1]

Area	Description	Total Volume (10^{12} ℓ)	Δv/v	T	Effective Intertidal Volume (10^{11} ℓ)	Nitrogen Concentration (mg/ℓ)	Tidal Nitrogen Flux (10^6 g)	Fish Production (10^3 lbs/yr)
1	Eld Inlet	0.130	0.455	3.05	0.213	0.049	1.04	190
2	Totten and Skookum Inlets	0.168	0.536	2.59	0.324	0.032	1.04	190
3	Hammersley Inlet and Oakland Bay	0.0519	0.840	1.65	0.157	0.083	1.30	240
4	Henderson Inlet	0.0426	0.558	2.48	0.0859	0.049	0.421	80
5	Squaxin, Peale and Pickering Passage	0.481	0.309	4.49	0.536	0.070	3.75	680
6	Dana Passage and Case Inlet	2.22	0.143	9.69	1.15	0.047	5.41	980
7	Carr Inlet	4.44	0.085	16.4	1.35	0.046	6.21	1100
8	Sinclair Inlet	0.375	0.124	11.2	0.167	0.063	1.05	190
9	Dyes Inlet	0.204	0.313	4.43	0.230	0.11	2.53	460
10	Port Orchard	0.431	0.194	7.14	0.302	0.048	1.45	260
11	Liberty Bay	0.0387	0.577	2.40	0.0806	0.079	0.637	120
12	Possession Sound	12.6	0.039	35.6	1.77	0.10	17.7	3200
13	Port Susan	4.36	0.068	20.4	1.07	0.059	6.31	1100
14	Saratoga Passage	8.75	0.049	28.1	1.56	0.072	11.2	2000
15	Penn Cove and Crescent Harbor	0.829	0.207	6.70	0.619	0.065	4.02	730
16	Skagit Bay	0.881	0.407	3.40	1.30	0.25	32.5	5900
17	Northern Hood Canal	5.04	0.064	21.6	1.17	0.089	10.4	1900
18	Discovery Bay	0.465	0.067	20.7	0.112	0.267[2]	2.99	540
19	Sequim Bay	0.0845	0.128	9.98	0.0423	0.066	0.279	50

[1] See explanatory notes for Table 5 on following page.

[2] Ecology does not maintain a water quality monitoring station in Discovery Bay as they do in all other areas listed. Therefore the nitrogen concentration is based on the June 1986 survey of the bay by Rensel (unpub. data).

Explanatory notes for Table 5

- Tidal flushing is treated as an exponential decay process. "New" water is introduced into the embayment on the flood tide. The ebb tide removes some portion of the "new" water as well as some portion of the "old" water. Over successive tidal cycles the intertidal volume consists of a greater and greater proportion of "new" water and a lesser and lesser proportion of "old" water. The effective tidal volume has been calculated by determining the number of tidal cycles required to remove 50 percent of the "old" water, and then determining the average volume of "old" water removed per tide.

- The calculations allow for refluxing; some portion of the water entering on the flood tide is the same water which left on the previous ebb tide. The refluxing coefficient will vary with each embayment, but a generalized estimate has been established at 0.5 for all interim guideline calculations.

- Intertidal and total volumes have been determined from the data of McLellan (1954). This source also provides the precise geographic boundaries that define the sub-divisions.

- Nitrogen concentrations are based on mean surface concentrations at each Ecology water quality monitoring station during the summer months (June through September) over the past five years (1981 through 1985).

- The quantity of nitrogen released into the environment by net-pen culture has been based on data from Ackefors and Södergren (1985), Penczak _et al_. (1982) and Warrer-Hansen (1982). These authors reported values ranging from 83 to 100 g N/kg fish produced/yr. This rate of nitrogen production has been expressed as 0.055 g N/lb. fish produced/tidal cycle in the interim guideline calculations.

5.0 MISCELLANEOUS GUIDELINES

1. Feed should be provided to the fish in a pelletized form. Unpelletized wet feed (i.e., minced fish or shellfish) should not be used in net-pen culture. The amount of uningested feed is several times greater for unpelletized wet feed than for either pelletized dry or moist feed (Ackefors and Södergren, 1985).

2. If predator control measures are necessary, non-lethal methods should be used against both bird and mammalian predators. The use of predator control measures is contingent upon receipt of appropriate National Marine Fisheries Service and U.S. Fish and Wildlife Service permits and must be conducted in accordance with permit restrictions and pertinent state requirements.

3. The use of tributyltin (TBT) as an antifouling agent should not be used on either the net-pens or the surrounding predator control nets. Studies have shown TBT to be exceptionally toxic to shellfish larvae (Hall and Pinkney, 1985). The National Marine Fisheries Service has also shown that fish held in TBT-treated nets tend to accumulate residues of the chemical in their tissues (Short and Thrower, 1986). Although no public health risk has been demonstrated for TBT residues in food fish, the cessation of its usage would appear prudent. It should be noted that there is currently no known use of TBT in Puget Sound net-pen culture. The use of other antifouling agents is not precluded under the guidelines, but proposed antifoulants should be evaluated by state agencies on a case-by-case basis. Antifoulant use should be reported to the Washington Department of Ecology.

4. Only antibiotics licensed by the Food and Drug Administration (FDA) for use in food fish shall be used. At the present time, FDA-approved antibiotics are limited to oxytetracycline (Terramycin), sulfamerizine and Romet 30. These substances should be used as sparingly as possible as required for disease treatment, or only on a short-term basis for disease prevention. Antibiotics should not be used prophylactically on a long-term basis. The WDF chief pathologist should be notified of antibiotic usage at time of treatment and should be provided information on the disease or condition being treated and the antibiotic used.

5. Transfer of live fish or their reproductive products within the state or their introduction into state waters shall be in accordance with applicable federal standards (Title 50) and state laws, rules, and policies (e.g., RCW 75.08.080, 75.08.285, 75.08.295; WAC 220-20-039, 220-20-040, 220-69-300, 220-76-015; WDF Policy 82-1). Depending on the point of origin and the species being transferred or introduced, the culturist may be required to obtain a transfer or importation permit, provide a Fish Health Inspection Report, provide a health history of the stock and hatchery, surface disinfect eggs, or hold fish in a quarantine facility. The state importation and transfer requirements may be modified in the near future by rules currently being adopted under the Aquaculture Disease Control Law (RCW 75.58).

6. Applications for culture must be accompanied by an operations plan which is to be submitted to and approved by DNR. This plan should include projections for:

- Improvements at site (e.g., pens, log booms) and their relationship to natural features (e.g. bathymetry, shorelines);
- Pen number, size and configuration;
- Schedule of development and maintenance;
- Fish species cultured;
- Size at harvest;
- Annual production;
- Pounds of fish on hand throughout the year;
- Average and maximum stocking density;
- Source of eggs and smolts;
- Feed type used;
- Method of feeding;
- Use of chemicals (e.g., antibiotics);
- Predator control measures;
- Antifoulant use.

6.0 ENVIRONMENTAL SURVEYS

Before a site can be developed for net-pen culture, an applicant must acquire numerous local, state, and federal permits. The permits, licenses, or approvals generally required include a Substantial Development Permit (local), SEPA (local), Aquaculture License and Permit (WDF), Seed Stock Importation Permit (WDF), Hydraulics Project Approval (WDF), Marine Lands Lease (DNR), Coastal Zone Certification (WDOE), Shoreline Conditional Use or Variance (WDOE), and Section 10/404 Permit (COE).

Many of these permits address water or land use conflicts which range far beyond the biological effects considered by these guidelines. However, the effect of development on the marine environment is a major consideration, therefore certain site-specific information is required for permit review. In order to assess the suitability of a site for net-pen culture and to evaluate the extent of environmental effects after initiation of culture, several environmental surveys should be performed at net-pen operations. These surveys include a site characterization survey, a baseline survey, and annual monitoring. The components of each of these surveys are summarized in Table 6 and discussed in detail in Sections 6.1 through 6.3.

6.1 SITE CHARACTERIZATION SURVEY

A site characterization survey should be performed prior to permit application. This survey would serve two principal functions. The primary purpose would be to provide state and local governments with the information necessary to evaluate the potential extent of environmental effects. Although not its primary intent, the site characterization survey will also provide the applicant with information critical to determining the suitability of the site for culture. A site characterization survey is composed of four principal elements: (1) initial consultation with state and local government; (2) a bathymetric survey; (3) a hydrographic survey; and (4) a diver survey.

CONSULATION WITH STATE AND LOCAL GOVERNMENT

After selecting a potential culture site, but prior to performing the site characterization field survey, the prospective applicant should contact state

Table 6

RECOMMENDED ENVIRONMENTAL SURVEYS FOR
PUGET SOUND NET-PEN CULTURE

	Site Characterization Survey	Baseline Survey	Annual Monitoring
Class I Facilities	• Recommended consultation with state and local authorities • Bathymetric survey • Hydrographic survey - Current velocity and direction • Diver survey	• None	• None
Class II Facilities	• Recommended consultation with state and local authorities • Bathymetric survey • Hydrographic survey - Current velocity and direction • Diver survey	• None	• Benthic survey - Diver survey
Class III Facilities	• Recommended consultation with state and local authorities • Bathymetric survey • Hydrographic survey - Current velocity and direction - Drogue tracking - Vertical hydrographic profiling • Diver survey	• Sediment chemistry sampling • Benthic infauna sampling	• Benthic survey[1] - Diver survey - Sediment chemistry - Benthic infauna • Water quality sampling • Current velocity and direction

[1] Replaced by baseline survey during first year of facility operation

resource management agencies (Departments of Ecology, Fisheries, Natural Resources, Game and Parks and Recreation), federal and local officials (the shoreline administrator). Initial contact should be made with the Department of Agriculture, and this agency will then facilitate consultations with all other appropriate state agencies. These consultations cannot be required of the applicant, but are highly recommended to provide state and local officials with an opportunity to comment on the potential site at an early stage in the planning process. Resource management agencies may be able to identify nearby habitats of special significance (Section 3.0) or existing conditions (e.g., water quality problems) that would make the site unacceptable for development. County officials may be able to identify major use conflicts that would significantly reduce the probability of permit approval. Other government agencies or tribes may also need to be contacted if the potential site is likely to affect land or resources under their jurisdiction.

One of the principal purposes of these consultations is to determine the proximity of the potential site to habitats of special significance. WDF staff may be aware of nearby critical spawning areas or major shellfish beds. WDG staff should be able to identify haulout areas for seals and sea lions, seabird nesting sites and colonies, and critical feeding areas and migration routes for both seabirds and marine mammals. WDG maintains a Wildlife Data System which can be accessed to obtain informaiton on endangered, threatened, sensitive, or monitor species.

State and local government officials should be given an opportunity to comment on the proposed field surveys (i.e., bathymetric, hydrographic and diver surveys). The survey content should be determined in consultation with those agencies having permit authority. The survey protocol described below is intended to provide the information necessary for permit review by a standardized and cost-effective method. This protocol should be adequate in most instances, but there may be certain site-specific concerns that would require minor modification of the generic protocol. For example, the diver survey may be modified to devote particular attention to areas of special concern. Departure from this protocol should be allowed only with strong justification, and modifications should generally result in the collection of more, rather than less, data.

BATHYMETRIC SURVEY

A bathymetric survey should be performed in order to apply the guidelines pertaining to depth and current (Section 2.0) and to identify the presence of any bathymetric features which might affect bottom accumulation of excess feed and fecal material (e.g., depressions). The area of concern is the seabed directly under the net-pens and within 300 feet of the net-pen perimeter. Multiple fathometer transects should be established with a density and spacing so as to adequately characterize the bathymetry under and around the pens. The position of the transects will depend upon the intended pen configuration. Figure 8 provides a recommended survey design given a rectangular net-pen configuration. The bathymetric survey report should note the period during the tidal cycle when the survey was made, and it should relate the measured depths to MLLW (mean lower low water).

HYDROGRAPHIC SURVEY

Information on current velocities and directions is necessary to apply the depth and current guidelines (Section 2.0) and to predict the dilution and dispersion of excess feed and wastes. The hydrographic survey should include: (1) current velocity and direction; (2) drogue tracking; and (3) vertical profiles of temperature, salinity and dissolved oxygen. Class I and II facilities, as defined in Section 2.0, should not be required to perform the drogue tracking and vertical hydrographic profiling studies because of their small size and reduced potential for water quality degradation.

Current velocity and direction - Current velocity and direction should be monitored at the center of the potential net-pen site. Both near-surface and mid-depth measurements should be made. The near surface measurements should be taken at a depth of 6 feet (corresponding to one-half the depth of typical net-pens). The mid-depth measurements should be taken mid-way between the maximum depth of the proposed net-pens and the sea floor. At both depths current velocity and direction should be monitored throughout one complete tidal cycle (one flood tide, one ebb tide). A minimum of ten measurements evenly spaced throughout the tidal cycle should be made at each depth. For purposes of applying the depth and current guidelines, "mean current" is determined by an arithmetic average of these ten or more measurements. The measurements

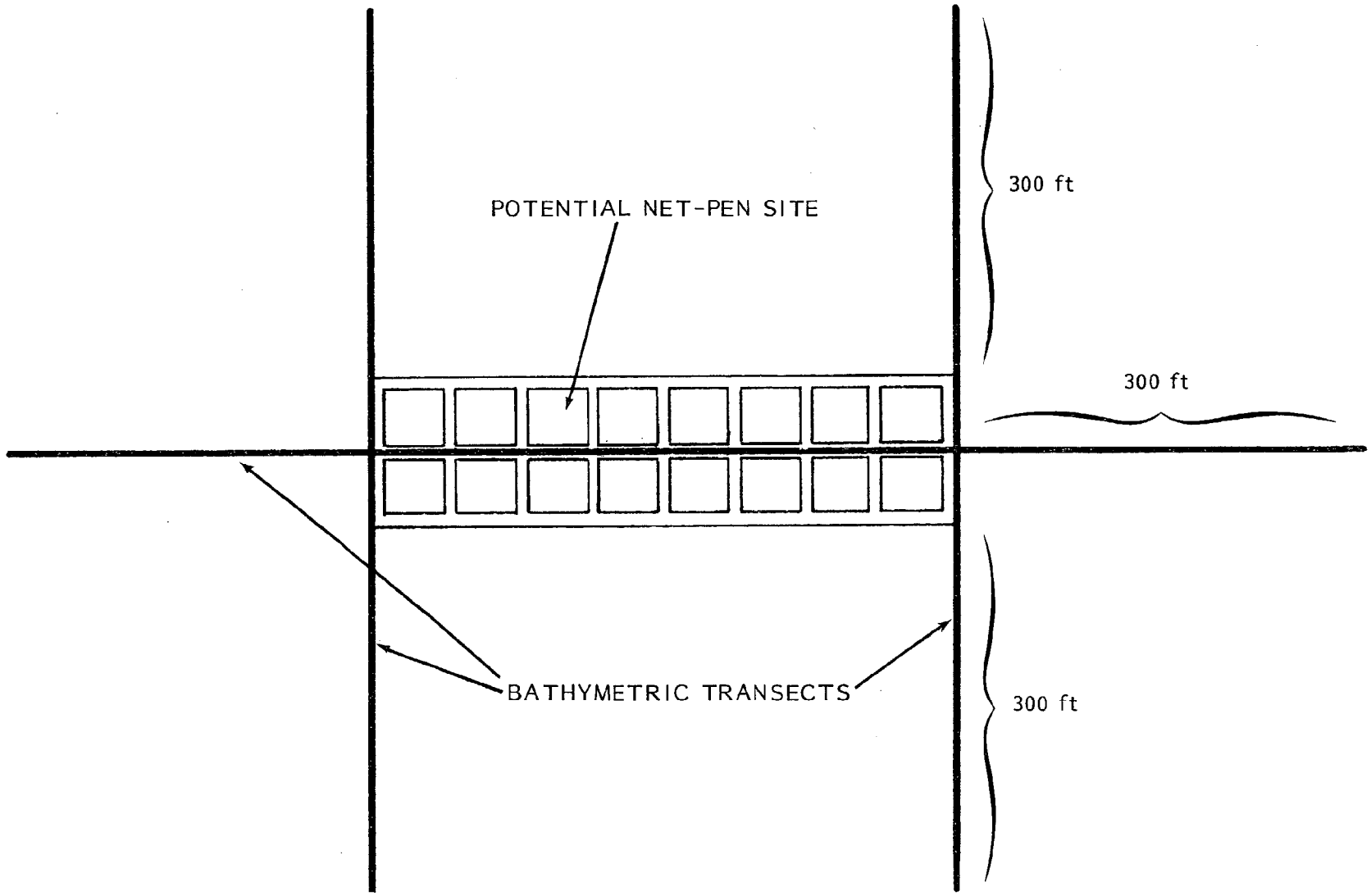

Figure 8. RECOMMENDED BATHYMETRIC SURVEY TRANSECTS FOR SITE CHARACTERIZATION

should be made during a period of "average" tides, and should not be representative of either extreme neap or extreme spring tides. The report of results should note any conditions (e.g., weather, extreme tidal range) that might make the data unrepresentative of "typical" conditions. If the prospective applicant believes the data do not reflect "typical" tidal currents and direction, resampling may be done, but all data collected should be used in determining a mean velocity.

Drogue tracking - Drogue tracking should be performed to estimate the potential fate of particulate material, and the potential for eddy circulation (i.e., the same parcel of water is repeatedly cycled through the area of the net-pen). Two drogues should be released from the center of the potential net-pen site. One should be set at a depth of 6 feet. The second drogue should be set at a depth mid-way between the bottom of the potential net-pens and the sea floor. The trajectory of these drogues should be followed for as long as daylight permits, and not less than 8 hours. The drogues may be reset at the original release site during this 8-hour period if they are transported beyond a practical tracking range.

Salinity, temperature, and dissolved oxygen profiles - Vertical profiles of salinity, temperature, and dissolved oxygen may be used to evaluate the intensity of water column stratification, a factor important both from the standpoints of environmental protection and the health of the cultured fish. Prospective applicants should provide any existing information on the site from such sources as the Ecology water quality monitoring network, Collias, et al. (1974), Friebertshauser, et al. (1971) and other site-specific studies. The prospective applicant should also take measurements of temperature, salinity and dissolved oxygen throughout the water column at the center of the potential site during the hydrographic survey. Measurements should be made at depths of 1, 10, 20, 30 feet, and at 30 foot intervals thereafter. The deepest measurement should be made 3 feet above the sea floor.

DIVER SURVEY

The diver survey is primarily intended to determine if habitats of special significance (Section 3.0) are present in the vicinity. Since many of the habitats of special significance would be readily visible only in the spring

and summer months (e.g. geoduck beds), the diver survey should be performed during April through September. The requirements for a diver survey during site characterization depend on the water depths in the vicinity of the site. No diver survey should be required if the area within 300 feet of the potential site is greater than 75 feet deep. A diver survey is required if water depth (MLLW) at the site or within a 300 foot radius of the potential location is less than or equal to 75 feet. If any portion of the area within 300 feet of the potential net-pens is in depths of 75 feet or less, it is potentially subject to accumulation of feed and fecal material, and therefore should be surveyed by a diver, even if the net-pens will be located over a site that is deeper than 75 feet. The design of the diver survey should be formulated in consultation with state and local government officials. WDF will take the lead role for the state in design of this survey. The number and spacing of the transects will depend on the particular site and should be established during these consultations. As a general guide, if all or most of the area is 75 feet or shallower, then 3 to 5 transects, each 200 feet long, should be surveyed per acre of pen. A larger pen complex would require additional transects; fewer transects would be required if most of the area is in depths greater than 75 feet. A diver should traverse the area making observations on substrate type, presence/absence of Beggiatoa mats and the density of geoducks and hardshell clams, eelgrass, kelp, demersal fish, crabs, and other large invertebrates. If eelgrass is present, counts of turion density in 0.25 m^2 quadrats are required to determine compliance with guidelines pertaining to habitats of special significance. Geoduck and hardshell clam density should be estimated by counts along transects. The abundance of other invertebrates and fishes should be noted by descriptors such as "rare," "common," etc.

REPORT PREPARATION

The results of the bathymetric, hydrographic and diver surveys should be assembled in a site characterization report to be submitted to Departments of Ecology, Fisheries, Game, Natural Resources and the county shoreline administrator. The site characterization report should include a figure of the proposed net-pen site in plan view at a scale of 200 feet or less to the inch. The figure should show nearby landmarks, the size and configuration of the proposed net-pens, bathymetric contours and the position of the diver transects. The report should also include identification of habitats of special

significance in the vicinity as determined in consultation with state agencies and the applicant's own surveys. The report should be a summary, analysis and interpretation of the data. The report should include, for example, a sectional view of the bathymetric profiles. A figure of the drogue trajectories should be also be included. The benthic survey should be described in narrative form with quantitative data provided when required or available.

6.2 BASELINE SURVEY

The baseline survey is intended to characterize bottom conditions at the net-pen site, before they could potentially be altered by culture activities. Sediment chemistry and benthic infaunal sampling were not included in the site characterization survey because of an anticipated uncertainty in the precise net-pen location and the difficulty of relocating samples without the aid of a moored net-pen as a position reference. Therefore, a baseline benthic survey should be required after emplacement of the net-pens, but before stocking the pens with fish. This survey should include sediment chemistry and benthic infauna sampling and may also include a diver survey if required by state resource management agencies or the county shoreline administrator. The baseline survey should be required for Class III operations, as defined in Section 2.0, but should not be required of Class I and II operations.

Stations should be established along a transect on the "downcurrent" side of the pens as determined by the prevailing currents (as measured at the mid-depth station in the site characterization survey). Stations should be established along this transect beginning directly under the perimeter of the net-pens and extending away from the net-pens at distances of 20, 50, 100, and 200 feet in the direction of prevailing currents. Each site should be sampled by three replicate diver cores or three replicate grab or box corer samples from which sub-cores are removed. Cores should be collected for analysis of total organic carbon, total Kjeldahl nitrogen and grain size distribution (median phi, percent gravel, sand, silt/clay). Cores should be inserted to a depth of two inches in the sediment. Care should be taken to insure that the core is representative of the undisturbed sediment column. Transparent cores should be used so that the redox potential discontinuity (RPD) depth can be noted and recorded. The position of the RPD is reflected by change in sedi-

ment color form brown to black. Each core should be homogenized for analysis, but the replicates should be treated as distinct samples and not pooled prior to analysis.

Benthic infauna samples may be collected either by a diver using a core sampler having an area of at least 0.01 m^2 or by a grab or box corer having an area of at least 0.1 m^2. The same stations sampled for sediment chemistry (0, 20, 50, 100 and 200 feet from the net-pens) should be sampled for benthic infauna. Three replicate samples should be collected at each site. The same grab/box corer samples used for sediment chemistry should be used for benthic infaunal analysis provided no more than one-quarter of the surface of each sample has been removed for sediment chemistry sampling. Each benthic infauna sample should be sieved on a 0.5 mm screen or nested 1.0 and 0.5 mm screens. All macrofaunal organisms retained on the screen(s) should be identified to the lowest practical taxonomic level, generally species.

The results of the baseline benthic survey should be assembled in a report consistent with the report guidelines provided for the site characterization survey (Section 6.1) and the annual monitoring (Section 6.3). The baseline report should be submitted to DNR, and this agency will take responsibility for distribution to other appropriate state and local authorities.

6.3 ANNUAL MONITORING

The annual monitoring program is designed to serve two purposes. First, it is intended to monitor potential changes in water and sediment quality resulting from culture acitivities. Secondly, it is intended as a data gathering effort in support of the programmatic EIS. As additional data are obtained on the environmental effects of salmon net-pen culture, the annual monitoring protocol may be substantially revised. It is also possible that monitoring at some culture sites may be curtailed or eliminated entirely if little or no measurable effect on environmental quality is found after several years of operation. The determination to curtail or eliminate monitoring at any site will be made after agency review of survey results. However, no schedule for "phasing out" of the monitoring program at any site has been provided at this time since the interim guidelines are intended only for short-term application.

The annual monitoring progam consists of three principal elements: (1) a benthic survey; (2) water quality sampling; and (3) a hydrographic survey. Class I facilities should be exempted from annual monitoring. Class II facilities should be required to conduct only a diver survey.

BENTHIC SURVEY

The benthic survey is intended to assess the extent of solids accumulation on the bottom in the vicinity of the culture operation and the biological effect of this accumulation. The survey consists of diver observations and sampling of sediment chemistry and benthic infauna. During the first year of facility operation, the benthic sampling conducted during the baseline survey should suffice in place of the annual monitoring benthic survey. Thereafter, the benthic survey as described below should be conducted annually.

Diver observations should be made if the net-pen or any portion of the bottom within 300 feet of the site is at a water depth of 75 feet or less. Four transects, each at least 200 feet in length, should be established as illustrated in Figure 9. The transects should be extended if feed or feces accumulation is visible 200 feet from the pens. Additional transects may be required to survey habitats or resources of special concern. Some transects may be shortened or eliminated entirely if they would require the diver to operate in depths greater than 75 feet. If any portion of the area within 300 feet of the net-pens is in depths of 75 feet or less, it should be surveyed even if the net-pens are located in depths greater than 75 feet.

One of the principal objectives of the diver survey is to document the depth and lateral extent of solids accumulation. The diver should estimate the depth of feed and feces accumulation at 20-foot intervals along each transect, and should note the greatest distance from the net-pens that visible accumulation is present. The diver should also note the presence/absence of Beggiatoa mats and estimate densities of demersal fish, crabs and other invertebrates. The annual monitoring benthic survey for Class III operations should also include collection of sediment chemistry and benthic infauna samples. The station location and sampling protocol should be exactly as described in the baseline benthic survey (Section 6.2).

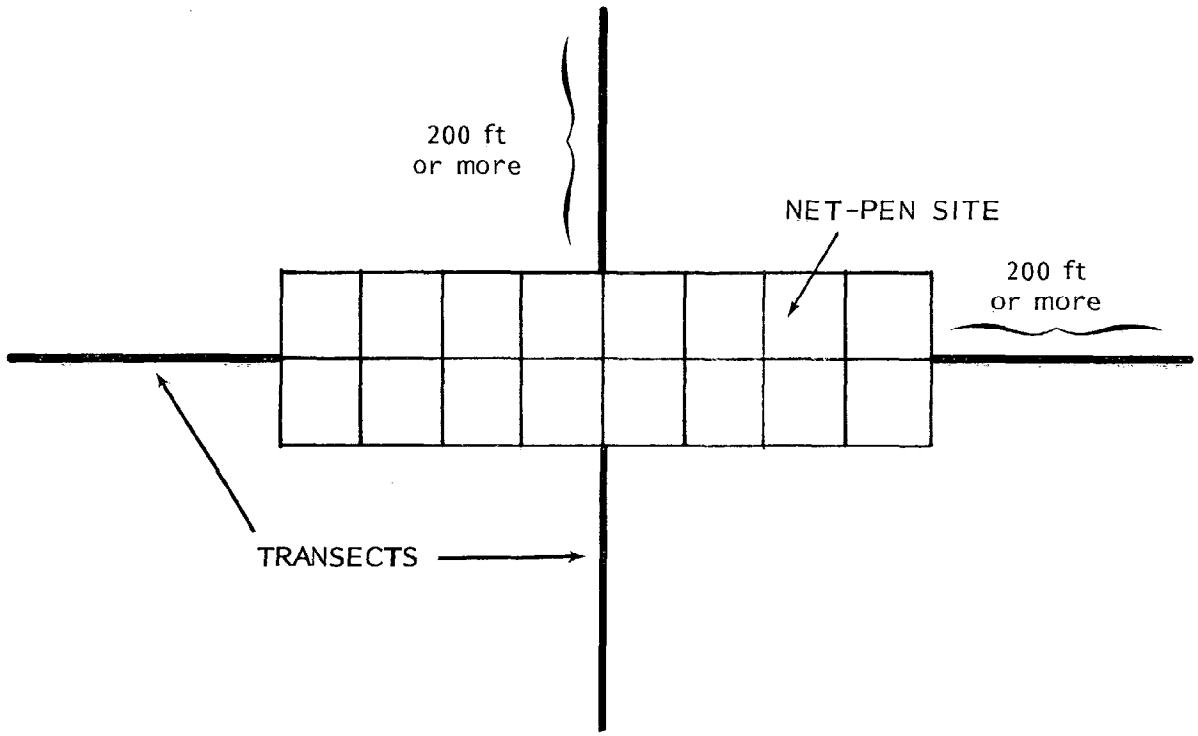

Figure 9. RECOMMENDED DIVER TRANSECTS DURING THE ANNUAL MONITORING SURVEY

WATER QUALITY SURVEY

Water quality sampling is intended to document the effect of culture activity on dissolved oxygen and nutrients in the water passing through the culture structure. The survey should be conducted in July, August or September of each year that the facility is in operation. Sampling in July through September is recommended since it is during this period that dissolved oxygen reductions or nutrient enrichment are of greatest concern. Three stations should be sampled: 100 feet upcurrent of the net-pens; 20 feet downcurrent; and 100 feet downcurrent. The precise location of the stations will depend on net-pen configuration, but they should be located so as to monitor the water passing through the greatest possible number of net-pens. Sampling should be conducted within one hour of slack tide. Three replicates should be taken at each station at a depth mid-way between the water surface and the bottom of the net-pens. Samples should be analyzed for the following parameters: dissolved oxygen; temperature; salinity; pH; ammonia; and nitrite/nitrate (either separate or combined). The concentration of unionized ammonia should also be calculated.

HYDROGRAPHIC SURVEY

Current velocity and direction should be measured at the depth at which the water quality samples are taken. A single measurement should be made 20 feet downcurrent of the net-pens concurrently with collection of the water quality sample from this station. Loading estimates (g/kg fish/day) should be calculated for ammonia and nitrite/nitrate based on: (1) the net increase in concentration between the upcurrent station and the 20 foot downcurrent station; (2) the current velocity 20 feet downcurrent; (3) the cross-sectional area of the net-pen complex; and (4) the weight of fish on hand at the time of the water quality survey.

REPORT PREPARATION

The comments made regarding the site characterization report apply here as well. Specifically, analysis and interpretation of the data should be provided, not merely presentation of the raw data. However, the raw data should be provided in appendices so as to permit independent assessment of conclusions.

In addition to a description of methods and data analysis and interpretation, the annual monitoring report should also include information on operational practices over the past year. This information should include:

- General description of facility (species cultured, size at which fish will be marketed, etc.).
- Size, number and configuration of net-pens at time of sampling.
- Significant changes in size, number and configuration of net-pens over the previous year.
- Annual production (pounds).
- Estimated weight of fish on hand during survey (pounds).
- Stocking density (average and range) (pounds/ft^3).
- Type of feed used and feeding method employed.
- Types of antibiotics used and frequency of usage over the past year.
- Interactions with birds and marine mammals and a summary of types and frequency of predator control measures used.
- Types of antifoulants employed and frequency of net treatment.

The annual monitoring report should be submitted to DNR and this agency will take responsibility for distribution to other appropriate state and local authorities.

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