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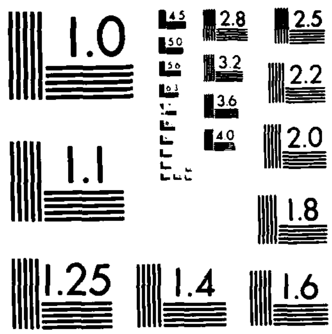

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Final Supplemental to U.S. Navy Environmental Impact Statement Carrier Battle Group Puget Sound Region Ship Homeporting Project

Technical Appendices

US Army Corps
Of Engineers
Seattle District

November 1986

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This EIS provides information on the proposed Everett homeport project, along with information on dredge disposal sites and methods. These aspects of the project are evaluated for their impacts on the community and the natural environment.

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TECHNICAL APPENDICES

FINAL

ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT

CARRIER BATTLE GROUP (CVBG) HOMEPORTING IN THE PUGET SOUND AREA, WASHINGTON STATE

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT

Corps of Engineers Permit Action Per Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act

NOVEMBER 1986

LIST OF APPENDICES

APPENDIX A

EVERETT NAVY TRAFFIC IMPACT SUPPLEMENTAL REPORT BY
PUGET SOUND COUNCIL OF GOVERNMENTS

Everett Navy Traffic Impact Supplemental Report

AUGUST 1986

PREPARED FOR:

Washington State Department of Transportation

PSCOG

Puget Sound Council of Governments
Grand Central on the Park
216 First Avenue South • Seattle, WA 98104
Phone (206) 464-7090

ABSTRACT

REPORT TITLE: Everett Navy Traffic Impact Supplemental Report

SUBJECT: An assessment of the impact of Homeport generated traffic on level of service and lane requirements in Everett.

DATE: August, 1986

SOURCE OF COPIES: State Aid Engineer
District 1 - Washington State
Department of Transportation
6431 Corson Avenue South
Seattle, WA 98104

ABSTRACT: This report contains a supplemental analysis of the traffic impact of the U.S. Navy Carrier Battle Group Homeport in Everett. Included in the analysis are updated estimates of Homeport generated traffic, the impact on peak hour traffic volumes at major intersections, an assessment of volume capacity ratios and level of service with existing geometry and recommendations regarding additional lane requirements. The report documents revised trip generation estimates based on the Navy's most recent plan for ship berthing and personnel strength at Everett, and refined traffic assignment techniques used to estimate traffic flows on the arterial system in Everett.

FUNDING: The technical study and the preparation of this report were requested and funded by the Washington State Department of Transportation in cooperation with the Federal Highway Administration.

FOREWORD

The Puget Sound Council of Governments (PSCOG) is a voluntary organization of local governments in King, Kitsap, Pierce, and Snohomish counties, created to provide a forum and maintain a comprehensive data base for regional decision making. The primary goals of the PSCOG are to guide the growth and development of the region, and to seek solutions to problems which cross jurisdictional boundaries.

This report is the third in a series prepared by PSCOG to assess the traffic impacts of the proposed U.S. Navy Carrier Battle Group in Everett. The first report assessed impacts on an areawide basis and the second was concerned with the evaluation of highway access alternatives. This report was prepared to provide supplemental data for the analysis of capacity and of improvements necessary to maintain an acceptable level of service.

Since the time the earlier studies were conducted, the Navy has announced an approved ship berthing/personnel loadings plan for Everett which calls for 13 ships and 7610 personnel assigned to the Carrier Battle Group.

Preparation of the report was requested and funded by the Washington State Department of Transportation in cooperation with the Federal Highway Administration.

Gerald Dinndorf was responsible for overall supervision of the study. The technical analysis and findings of the study were the responsibility of Mike Smith and Rob Bernstein with consulting assistance provided by Robert Shindler, who coordinated the technical analysis and prepared the report. Rebecca Stewart assisted in preparing the graphics. Report production was accomplished by Kim Tassin with the assistance of Holly Herrmann and Ellen Blackwood.

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I. INTRODUCTION

This report presents estimates of the traffic volumes that will be generated by the proposed U.S. Navy Carrier Battle Group Homeport in Everett and an assessment of the impact of this traffic on arterial street capacities and lane requirements. The study provides projections of future year (1990) traffic conditions with and without the Navy Homeport assuming highway access improvements as proposed in the "North-South Alternative," which the City of Everett selected as their preferred access alternative. The traffic impact assessment consists of a "volume-capacity" (V/C) analysis for each major intersection in the access corridor and a determination of the additional lanes required to accommodate the projected peak-hour traffic volumes.

This report supplements two previous reports prepared by the Puget Sound Council of Governments (PSCOG) on the impact of the proposed Homeport in Everett. The first of these, dated January 1985, examined the economic, local development, travel demand and traffic impacts of the Homeport on an areawide basis. The second, dated June 1985, provided a more detailed traffic impact assessment for each of five highway access alternatives. The current study focuses on traffic conditions forecast for the preferred alternative at a level necessary to determine specific capacity deficiencies and to develop information necessary for the design of improvements.

Sources of information for the current study include: the data and analysis results of the two previous PSCOG studies, the information presented in the Navy's Final Environmental Impact Statement (FEIS) for the proposed Homeporting action, extensive traffic count data provided by the City of Everett, and the current Navy staffing plan for Everett.

The traffic estimates used in this study are based on the Navy's approved ship berthing/personnel loadings plan for Everett announced in January 1986. This plan provides for a total of 13 ships and 7610 military personnel in the Carrier Battle Group to be homeported in Everett. In previous impact assessment studies--both the Navy FEIS and the PSCOG traffic analysis--the assumption had been for 15 ships and about 8200 military personnel.

The difference between the personnel strength assignments used in the previous studies and the revised number is discussed in the report as are its implications with respect to the daily and peak hour traffic volumes used for the impact assessment.

II. BACKGROUND CONDITIONS

The evaluation of highway access improvements needed to serve the proposed Navy Homeport requires forecasts of future transportation conditions including both background traffic and traffic generated by the project. The forecast year in this case is 1990, the earliest year that the project could be constructed and become operational. Estimates of background traffic, that is, traffic volumes in the affected area as they would be expected to exist without the project, are necessary to establish a baseline for the analysis. The impact of the Navy Homeport is determined by comparing conditions with the Navy traffic to those without.

EXISTING TRAFFIC

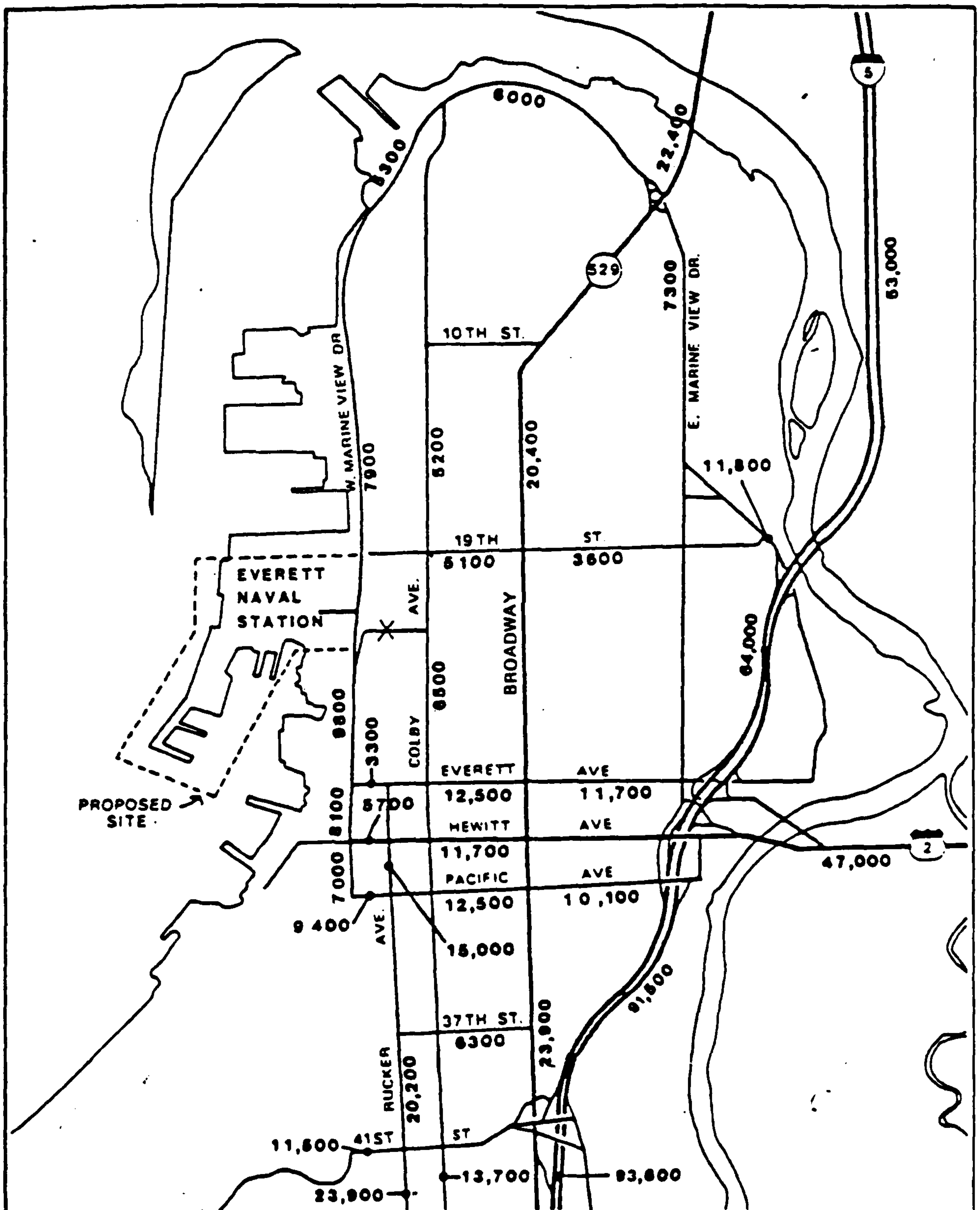
Existing traffic conditions in the Everett area were determined from actual traffic count data for arterial segments and for intersections collected in recent years (1983-1986). Much of the information on existing traffic was acquired for use in the previous PSCOG study which evaluated highway access alternatives for the Homeport development. Primary sources of information available at the time were the published reports, "1983 Traffic Flow Map" by the City of Everett and the "1983 Annual Traffic Report" of the Washington State Department of Transportation. Additional information in the form of unpublished traffic counts was provided by the City of Everett Traffic Engineer.

In the current study, because of the volume/capacity analysis involved in the assessment, it was necessary to supplement the data base with peak hour traffic counts at all major intersections on the access routes to the Homeport. In response to this need, counts were made by the City of Everett.

PROJECTED 1990 BASELINE TRAFFIC

Arterial Segment Volumes

Traffic volumes in the forecast year without the project constitute the background portion of total traffic and the baseline for impact assessments. The projected 1990 traffic used as a baseline in the current study is the same as was used for the previous PSCOG study which evaluated highway access alternatives. Figure 1 shows the 1990 volumes for the Everett area. These projections were derived by expanding the 1983 existing traffic estimates to account for normal (non-project) growth between 1983 and 1990. The factors used in the projection were obtained from PSCOG traffic model assignments adjusted for localized trends where historical traffic count data were available.



PSCCC	1990 BACKGROUND TRAFFIC EVERETT VICINTY	FIGURE 1

Generally, very little growth is forecast for the arterials serving local trips within the City of Everett. A traffic growth of between two and five percent is projected for these arterials for the seven year period 1983 to 1990 with the higher rate being in South Everett. These traffic growth projections reflect the PSCOG population and employment forecasts which indicate a 2.2 percent decline in jobs balanced by a 10 percent increase in households for the 1980-1990 decade.

In contrast, moderate to high rates of traffic growth are forecast on the regional highway routes in the area, I-5 and State Route 2, and the arterial connections to these routes. Projected increases for the seven year period 1983 to 1990 are as follows:

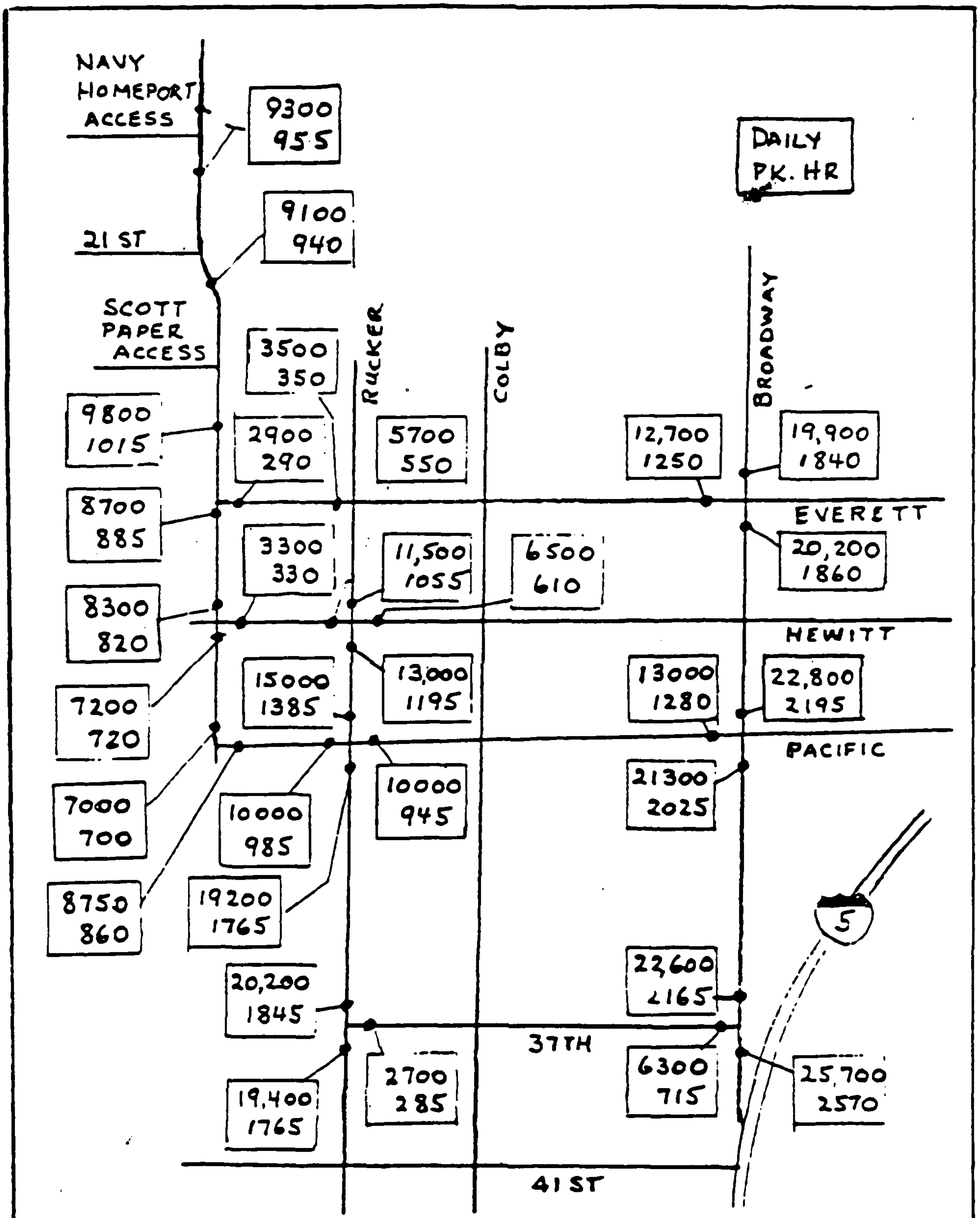
I-5, South of Pacific	16 percent
SR-2, East of I-5	25 Percent
Broadway, South of 37th St.	10 percent
Broadway, North of Pacific	7 percent
Pacific, East of Broadway	12 percent
Everett, East of Broadway	10 percent

These higher growth rates reflect the population and employment forecasts which indicate continuing growth in suburban Snohomish County.

Without the Navy Homeport, modest traffic growth is forecast on West Marine View Drive, the principal artery serving the Everett Waterfront. For the segment of this arterial north of 18th Street, an increase of four percent was estimated for the period 1983 - 1990, and for the segment to the south, an increase of nine percent. These increases reflect the expectation of continued growth in non-industrial development on the waterfront.

Intersection Volumes

The peak period intersection counts provided by the City of Everett were used as a basis for estimating 1990 peak hour intersection volumes, and also for refining the 1990 traffic volumes on the arterial network in the access corridor. The counts were expanded to represent a 1990 traffic forecast using the growth factors described above. In the process adjustments were made to convert the single day counts to Average Weekday Traffic (AWDT) and to assure consistency between intersections. Figure 2 shows the 1990 background traffic volumes--daily and p.m. peak hour--in the immediate study area. Included in this area are the arterial links and intersections which will bear the greatest impact from the addition of Navy generated traffic.



PSCOG	1990 BACKGROUND TRAFFIC PRIMARY IMPACT AREA	FIGURE 2

Analysis of the intersection counts in the study area indicated that in recent years the peak hour has declined as a percent of daily traffic and the directional split has become more evenly balanced. Typically the p.m. peak hour is in the range of 9 to 10 percent of the AWDT with a directional split on the order of 55/45 percent. This trend is very likely due to changes in the ratio of manufacturing to non-manufacturing employment in the Everett area.

Intersection diagrams showing the projected 1990 peak hour background traffic are included in the Appendix. P.M. peak hour data are shown for 15 intersections and A.M. peak hour data for five intersections.

III. HOMEPORT GENERATED TRAFFIC

This chapter presents the forecasts of traffic to be generated by the Navy Homeport when it is fully operational and describes the process used to make the forecasts. Included are:

- Assumptions regarding personnel strength at the Homeport as described in current Navy plans for the installation.
- Estimates of the number and characteristics of trips to be generated by the installation when maximum personnel strength conditions occur.
- Forecast of the distribution of these trips as determined by the location of the off-base origin or destination of the trip.
- Estimates of peak hour traffic for use in the design analysis.

The first step in the process involves determining the measure of activity to be used for estimating the number of trips generated by the proposed facility. The generally accepted technique is to estimate trip generation by using actual rates from an existing facility comparable to the one proposed. These rates indicate the number of daily and/or peak hour trips made in relation to the selected measure of activity. In the case of the military installations such as the Navy Homeport either of two measures are generally used: total military personnel assigned to the station, or the combined total of military personnel and civilian workers. Both measures have been used in previous studies of the proposed Homeport in Everett.

PERSONNEL STRENGTH

In the development of the environmental impact statement for the proposed Homeporting project, an estimate of 15 ships was used in the assessment of worst case impacts. This estimate was used in the Final Environmental Impact Statement (FEIS) June 1985, and by PSCOG in the assessment of traffic impacts for the "Carrier Battle Group Homeport Access Report," August 1985. However, since the publication of these reports the Department of the Navy has developed more specific estimates of the ships and personnel that will be assigned to the Everett site.

In January 1986, the Navy announced an approved ship berthing/personnel loadings plan(1) for Everett which provides for 11 ships with 6430 active duty and 170 reserve military personnel assigned. The plan also includes the potential future homeporting of two additional ships with 85 active duty and 55 reserve military personnel assigned. In addition to these 13 ships and their 6740 assigned personnel, shoreside personnel permanently assigned to the Homeport would include about 870 military and 475 civilian employees. Personnel Strength estimates for the current Navy plan are shown in Table I along with comparative estimates as used in the previous impact assessment work.

The number of personnel actually at the Everett site at any one time would vary. In general, personnel fluctuations would be directly related to the deployment of the Aircraft Carrier with its support ships and their return to the Homeport. The maximum number of CBG personnel operating at the Homeport would occur for a period of about four to six weeks duration prior to deployment of the carrier. Total CBG military personnel at this time (shipboard and shore-based) would number about 7610.

In addition to the personnel strength of the 13 ship carrier battle group, personnel of other Navy units will be at the station at various times during the operating cycle of the Homeport. Prior to deployment of the Aircraft Carrier squadron personnel of the Carrier Air Wing numbering about 1500 persons will take up quarters aboard the Carrier. Also a Destroyer Tender (AD), presumably Homeported elsewhere, will spend one month per quarter at Everett. The assigned personnel for this ship is about 1800 persons. Expected personnel levels at the Everett site through the 19 month operations cycle are shown in Figure II-3 of the FEIS.

An estimate of the number of personnel living in the community (off the base) is necessary for the traffic analysis. According to the FEIS (Table IV-33), slightly over 50 percent of the military personnel assigned to the Carrier Battle Group are expected to reside aboard their ships. In addition 465 of the 870 shore-based military personnel are expected to reside in the BEQ (Bachelor Enlisted Quarters) on-site. All of the Carrier Air Wing and Destroyer Tender personnel since they are based or homeported elsewhere, will reside on their ships. The remainder of the military and civilian personnel are expected to reside off the base. With the current Ship/Personnel Loadings Plan for the Everett site, it is estimated that 4073 persons will be living in the community (see Table I).

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(1) Department of the Navy, Memorandum for the Deputy Director, Interagency Construction Division Naval Facilities Engineering Command, by L. A. Fermo, Capt. USN, 27 January 1986.

TABLE I

PERSONNEL STRENGTH

On-Site Personnel As Estimated for the Access Report(1)

Homeport Assigned	Military	Civilian	Total	Living in Community
CBG Afloat	7322	--	7322	3472
CBG Ashore	869	475	1344	879
CBG Future & Res.	--	--	--	--
TOTAL CBG	8191	475	8666	4351
Other Personnel				
Destroyer Tender	1800	--	1800	--
Carrier Air Wing	1500	--	1500	--
TOTAL	11,491	475	11,966	4351

Current Personnel Plan as Revised(2)

Homeport Assigned	Military	Civilian	Total	Living in Community
CBG Afloat	6430	--	6430	3049
CBG Ashore	870	475	1345	880
CBG Future & Res.	310	--	--	144
TOTAL CBG	7610	475	8085	4073
Other Personnel				
Destroyer Tender	1800	--	1800	--
TOTAL	9410	475	9885	4073

SOURCE:
(1) Reported in the FEIS, Table II-1.
(2) Department of the Navy approved Ship Berthing/Personnel Loadings Plan for Everett, January 1986.

TRIP GENERATION

As was noted previously, there have been two methods used to derive and apply trip generation rates for the proposed Homeport project. One approach, that of calculating the rate in relation to total employment at the site, including both military and civilian employees was used in the Navy's FEIS for the project. A second approach, that of calculating the rate in relation to military personnel strength disregarding civilian employment in the equation was used in the previous PSCOG impact analysis. The second approach will also be used in the current reassessment in order to maintain consistency with the previous analysis and the traffic estimates reported in the "Access Report."

The rate used is 2.46 vehicle trips per day per person for military personnel assigned to the Carrier Battle Group and its shore-based support units at the Homeport and the lower rate of 1.72 vehicle trips per day for military personnel assigned to the Destroyer Tender.

The rate of 2.46 vehicle trips per day for military personnel is obtained from the traffic count and survey data collected in the course of a traffic engineering and planning study conducted in 1983 at the Mayport Naval Station in Florida. (2). The use of data from the Mayport Naval Station is supported by the similarity of mission and activities between the Florida base and the one proposed at Everett, and also the general similarity of travel conditions in the communities where the bases are situated. The lower rate of 1.72 trips per day for personnel of the Destroyer Tender takes into account that these personnel will be quartered on board their ship while at the Everett station and hence will not generate home-to-work trips from off-base housing.

For the purpose of assessing impacts it is necessary to use a forecast of the traffic that will occur when the Everett facility is operating at its maximum sustained level of activity. This will occur when the Aircraft Carrier and its surface support ships are preparing for deployment, and the CBG personnel are at full strength. During these occasions there will be times when the destroyer tender with its crew of 1800 persons will also be in port. The coincidence of these two scheduled events - maximum activity level of the CBG with the destroyer tender in port - represent the "worst case" condition for traffic impact assessment. Under these conditions the Everett facility is forecasted to generate about 21,800 vehicle

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(2) "Traffic Engineering - Planning Study, Naval Station, Mayport, Florida," 1984. Military Traffic Management Command, (MTMC), Report TE 83-41-26.

trips per day. The trip generation estimates are shown in Table II.

MODE SPLIT

The mode-split, geographic distribution and peaking characteristics of trips generated by a facility such as the proposed Everett Homeport vary according to trip purpose. Two separate trip purposes are identified for this purpose:

1. Home-work trips by military personnel and civilian employees assigned to the Homeport but living off-base.

2. All other trips including:

   - Social, recreational, shopping and miscellaneous trips by personnel assigned to the base (typically off-duty trips).

   - Work-related trips by employees on the base and by visitors on official business.

   - Trips by trucks and service vehicles.

The number of daily home-work trips generated by the Everett facility for the "worst case" condition is determined by two factors: (1) the number of military and civilian employees who will be living off the base and (2) the percent who will be commuting to work on an average day during the period of maximum activity. As shown in Table I, it is estimated that about 4070 of the military and civilian employees assigned to the Homeport will live in the community. Allowing for persons on leave or temporary assignment away from the base, it is expected that 90 percent will report for work on an average day. Thus, for the "worst cast" condition there would be 3666 person trips to work on an average day and the same number from work for a total of 7332.

Given a forecast of person trips, the number of vehicle trips are derived by subtracting those expected to use transit and those traveling as passengers. Based on traffic data for the Mayport Station and census journey-to-work statistics for the Everett area it was estimated that about 280 (approximately four percent) of the daily home-work trips would use transit and 7051 would travel by auto. Using data from the same sources, it was further estimated that of those traveling by auto 75 percent would drive alone and 25 percent would carpool. Under these conditions the average auto occupancy for work trips would be 1.153, and the number of home-work vehicle trips would be 6114 per day.

The number of trips estimated for the other trip purposes is derived as the difference between the estimate of total daily trips and the number of home-work trips. That is, of

TABLE II

EVERETT HOMEPORT

TRIP GENERATION

Military Units	Personnel Assigned	Trip Gen. Rate	Daily Vehicle Trips
Previous Estimates(1)			
Homeport (CBG)	8191	2.46	20,150
Destroyer Tender (AD)	1800	1.72	3100
Carrier Air Wing	1500	1.72	2580
TOTAL	11,491	--	25,830
Current Estimates(2)			
Homeport (CBG)	7610	2.46	18,720
Destroyer Tender	1800	1.72	3100
TOTAL	9410	--	21,820

SOURCE: See Table I

(1) Personnel estimates and trip generation rates used to forecast traffic for the "Access Report," August 1985

(2) Navy Personnel Loading Plan for Everett, January 1986

the 21,820 daily vehicle trips generated by the facility 6114 are home-work trips and 15,706 are trips for all other purposes. Average vehicle occupancy for the latter is much higher than for work trips.

TRIP DISTRIBUTION

Trip distribution in this case refers to the location of the off-base end of the trip. Home-work trips were distributed geographically in relation to the location of off-base housing. The method of estimating the location of housing (place of residence) for personnel living off-base is described in the PSCOG report, "Everett-Navy Impact Study," January 1985. The geographic distribution of off-base housing and of the home end of journey-to-work trips of Homeport employees is shown in Table III. The breakdown in by major area within Snohomish and King Counties with totals for Island and Skagit Counties.

Trips grouped in the "other" category were distributed geographically using the PSCOG's regional transportation planning models. These models use the gravity principle to estimate the probable distribution of trips taking into account the location of activities, often referred to as "attractors" which fulfill the objective of the trip, and the relative travel times to alternative destinations. Estimates developed from the modeling process were then adjusted to reflect special characteristics of the proposed facility, such as its connections to Naval Station Seattle (Sandpoint). Distribution of the other vehicle trips is also shown in Table III.

In order to create a trip table suitable for assignment to the computer coded highway network the trip distribution was carried to the level of traffic analysis zones. Two trip tables were created, one for home-work trips and the other for all "other" trips. These data are included as Appendix A.

PEAK HOUR TRAFFIC

The calculation of volume-capacity (V/C) ratios and of lane requirements on routes affected by Homeport traffic requires the estimation of design hour volumes (DHV). Both A.M. and P.M. Peak Hour Volumes were estimated for this purpose although the DHV is usually determined by the P.M. peak since background traffic is greater in the evening peak hours.

Peaking characteristics of traffic generated by an employment activity are directly influenced by the beginning and ending times of the workday. From available information it was assumed that duty hours of personnel at the Homeport would be as follows:

TABLE III

DISTRIBUTION OF TRIPS GENERATED BY

EVERETT NAVY HOMEPORT

Area	Workers	Home-Work Person Trips Transit	Home-Work Person Trips Auto	Vehicle Trips Home-Work	Vehicle Trips Other Purposes
1. Arlington, Marysville, Stanwood, Granite Falls	653	10	1166	1040	1292
2. Snohomish, Lk. Stevens, Monroe, Sky Valley	481	51	816	742	1388
3. Everett-Central/North	570	87	937	852	4278
4. Everett-South/S.W.	324	64	519	471	3355
5. Paine Fld/Alderwood Mall	603	36	1049	945	1479
6. Edmonds, Lynnwood, Mountlake Terrace	419	14	740	607	1027
7. North Creek, Maltby, Cathcart, Mill Valley	365	20	637	554	923
8. Shoreline/Bothell	109	—	196	170	129
9. Eastside	91	--	164	131	262
10. North Seattle	179	--	322	239	662
11. Central Seattle	96	--	173	128	384
12. Other King Co.	10	--	18	12	151
13. Kitsap Co.	22	--	40	28	31
14. Island Co.	57	--	103	74	161
15. Skagit Co. (I-5 North)	94	--	169	121	184
TOTAL	4073	281	7049	6114	15,706

Total vehicle trips per day 21,820

- Shipboard personnel will be assigned 50 percent to day shift and 25 percent each to swing and graveyard shifts.
- All shore based personnel work day shift.
- In order to distribute traffic flows more evenly during the peak period, work hours of major units on the base will be staggered.

Since the above conditions are substantially the same as those which prevail at the Mayport station, data from 1983 traffic counts at that facility were analyzed to determine peaking characteristics. A summary of the traffic count data and of the peak hour factors calculated from these data are shown in Appendix B. The data indicate conditions for two levels of activity at the station, one with the Aircraft Carrier Saratoga and its 5000 person crew in port and one without. The A.M. and P.M. Peak Hour volumes as a percent of daily volumes and the directional split are as follows:

	P.M. Peak Hr.	A.M. Peak Hr.
With the Saratoga		
Peak Hour Factor	11.0%	10.4%
Directional Split	80/20	84/16
Without the Saratoga		
Peak Hour Factor	11.4%	10.6%
Directional Split	80/20	85/15

Considering potential differences in operation between the Everett station and the Mayport station, there is reason to expect that traffic peaking characteristics at Everett during periods of maximum activity will be similar to those at Mayport without the Saratoga in port. From the Mayport traffic data it is evident that with more ships in port, especially the aircraft carriers, the peak hour traffic decreases as a percent of the daily traffic. As indicated in the above table, the peak hour factor is lower with the Saratoga in port than without. It is very likely that this is caused by the unique duty schedule for shipboard personnel at the Mayport station. The percentage of personnel assigned to the swing and graveyard shifts, presumably an accommodation to the subtropical climate at that location, is much larger than what is typical at most Navy facilities.

At Everett it is reasonable to expect that the duty schedule will be more in line with conventional Navy practice, that is, about 80 percent on day shift and 10 percent each on swing and graveyard shifts. In terms of its effect on traffic peaking characteristics this would correspond more closely to the Mayport situation without the Saratoga in port. Thus, for the P.M. Peak Hour it was assumed that the two directional volume would be 11.4 percent of the 24 hour volume with a directional split of 80 percent outbound and 20 percent inbound. For the

A.M. Peak Hour the assumptions are 10.6 percent with an 85/15 directional split.

Applying these peak hour factors to the daily volumes and considering the duty schedule and other circumstances affecting trip purpose percentages, the traffic breakdown for the "worst case" condition is as follows:

	Daily	A.M. Peak Hour Out/B	A.M. Peak Hour In/B	P.M. Peak Hour Out/B	P.M. Peak Hour In/B
Vehicle trips					
Home-Work	6114	210	1570	1495	280
"Other"	15706	135	395	495	220
Total	21820	345	1965	1990	500

COMPARISON WITH PREVIOUS STUDIES

To provide a reference for evaluating the reasonableness of the traffic forecasts developed in this study, the estimates of Homeport generated traffic reported in previous studies are shown for comparison. All of the forecasts are intended to represent a "worst case" condition.

	Vehicle Trips Daily	Vehicle Trips P.M. Peak Hr.
FEIS, June 1985	20,162	2091
PSCOG, for the Access Report, August 1985	25,800	3100
PSCOG, Current Study	21,820	2490

IV. TRAFFIC IMPACT

TRAFFIC ASSIGNMENT

Traffic assignment is the process of estimating traffic flows on a network for a given set of travel desires. In this analysis the objective is to determine the paths that the Homeport generated traffic would use on trips to and from the proposed base. In previous studies traffic assignments and the traffic impact assessment covered a more extensive area because of the need to evaluate alternative highway access improvements. In this study the emphasis is on the south access and the impact of traffic using W. Marine View Drive and the major arterials through the central part of Everett.

Procedures and Assumptions

The traffic flow pattern throughout an urban network tends toward an equilibrium in which traffic using competing routes is balanced in relation to the level of service on those routes. Normally drivers choose the route having the minimum travel time. Where there are alternative routes having only small differences in travel time, as is the case in Everett, the traffic will distribute itself with some percentage using each route. As additional traffic is added to the network from a new traffic generator such as the proposed Homeport, the level of service is affected and congestion may occur on one or more of the alternative routes. When this happens, relative travel times of the alternate routes may also change thus affecting the drivers choice of routes and in the aggregate traffic flows on the arterial network.

Computer models have been developed to estimate the effect on traffic flows of these interrelated factors, that is, the imposition of additional traffic on the network, changes in the level of service (increased congestion and disutility) resulting from the additional traffic and its effect on drivers' choice of routes. For the previous studies the PSCOG regional traffic model was used. This model provided traffic assignments in sufficient detail to be adequate for the evaluation of alternative highway access improvements to the Homeport site. For the current study, however, it was necessary to develop a more detailed model. The procedures and assumptions involved in this process are as follows:

- The PSCOG regional traffic model was enhanced in the Everett area to provide capability for detailed traffic analysis. The number of traffic zones in Everett were increased four-fold and all designated arterials were included in the network. Speeds and travel times on the arterial network were refined based on existing conditions.

- Homeport generated traffic in the form of trip tables, as described in the previous chapter, were assigned to the network. The assignment was reviewed in relation to the level of service that would exist with the background traffic.

- A further assignment was then made using a multi-path assignment technique. This is a fine tuning technique which distributes traffic among alternative paths having small differences in travel time. It was necessary to use this technique to assign trips between the Homeport site and points east and south of Everett because of the alternative paths available through the arterial grid system in Everett.

- Because of the unique characteristics of the arterial grid system which affect traffic flows several additional assumptions were made for the traffic assignment:

    1. Given approximately equal travel times on alternate paths, traffic would use the path requiring the least number of turns.

    2. Some traffic would follow a path requiring more than one left turn if it offered a perceptibly better level of service than paths with only one left turn.

    3. Although in actuality some traffic will not use the same path on their outbound trip from the Homeport as they used inbound, for purposes of the impact assessment all traffic has been averaged and balanced directionally.

Travel Time Comparisons

Observed data on speeds and travel times for alternative routes to and from the Homeport on the existing system and estimates for the preferred alternative (with improvements) were shown in the previous PSCOG report, "Everett Navy Traffic Impact-Highway Access Alternatives," June 1985.

With the preferred alternative all regional traffic between the Homeport and points served by I-5 South will use the south access to the site except for trucks which will be signed to use Marine View Drive around the north end of Everett. The north route is 4.0 miles and 3.0 minutes longer than the minimum path south route under existing traffic conditions.

The minimum path route between the Homeport site and I-5 south is via W. Marine View Dr., Pacific Avenue and Broadway. Alternatives are via Rucker or Colby and 37th Street and via the Pacific Avenue interchange with I-5. Some traffic is expected to divert to the alternates as the level of service decreases on Pacific and Broadway due to the added traffic.

Also, with the preferred alternative virtually all regional traffic between the Homeport and SR-2 east will use the south access to the site. Only trucks and a few auto drivers are expected to use the route via Marine View Drive around the north end of Everett. The north route is 3.2 miles and about one minute longer than the route across town on Hewitt or Everett Avenues.

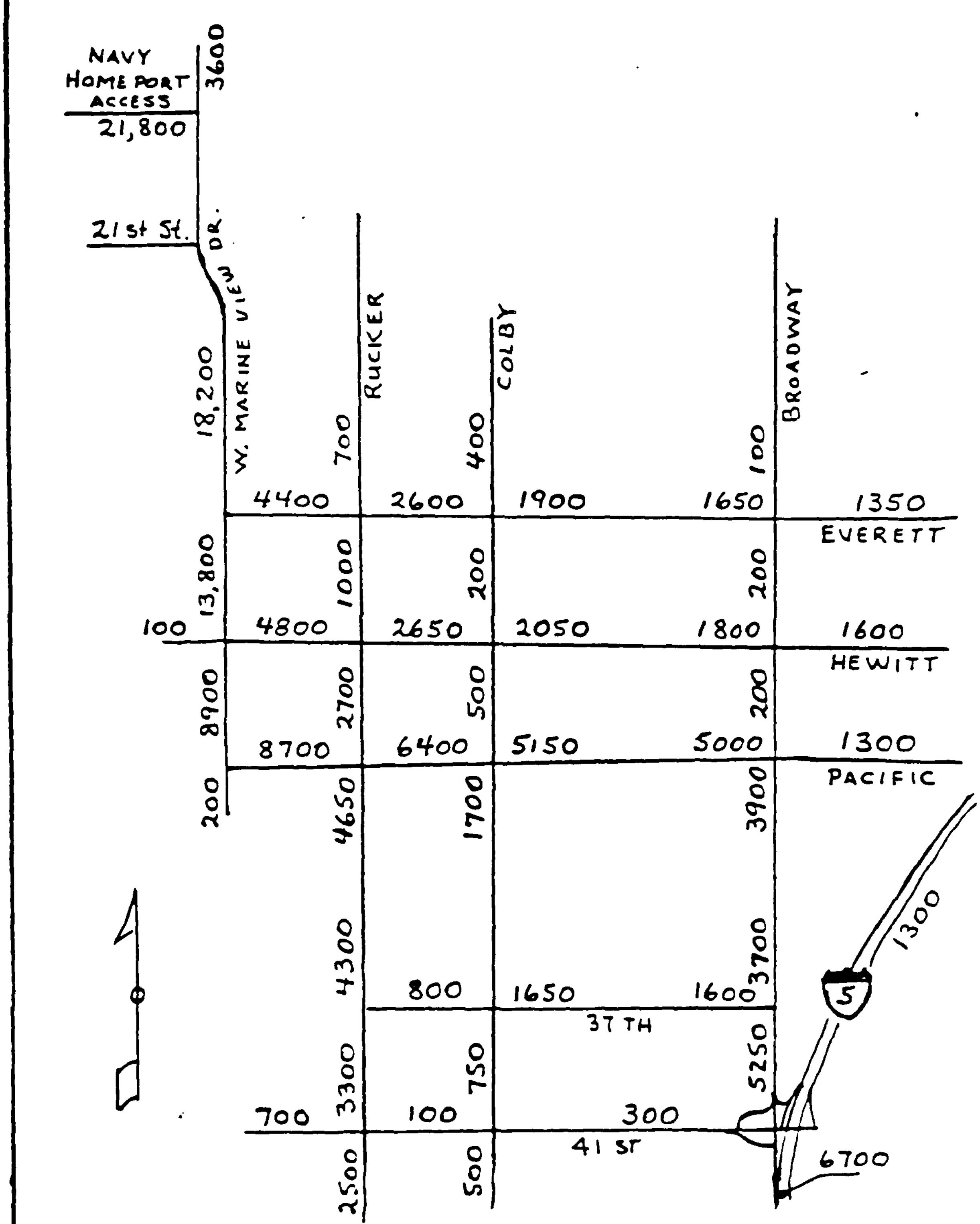
Traffic Flow

The distribution of Homeport generated traffic on the arterial streets in Central Everett, the area of primary impact, is shown in Figures 3 and 4. Daily volumes for the "worst case" condition as shown in Figure 3, represent the combined total of the home-based work trip table and the "other" trip table. The P.M. Peak Hour volumes as shown in Figure 4, were obtained by assigning 29 percent of the home-work trip table and 4.6 percent of the "other" trip table. These are the percentages of the respective trips expected to occur during the evening peak hour.

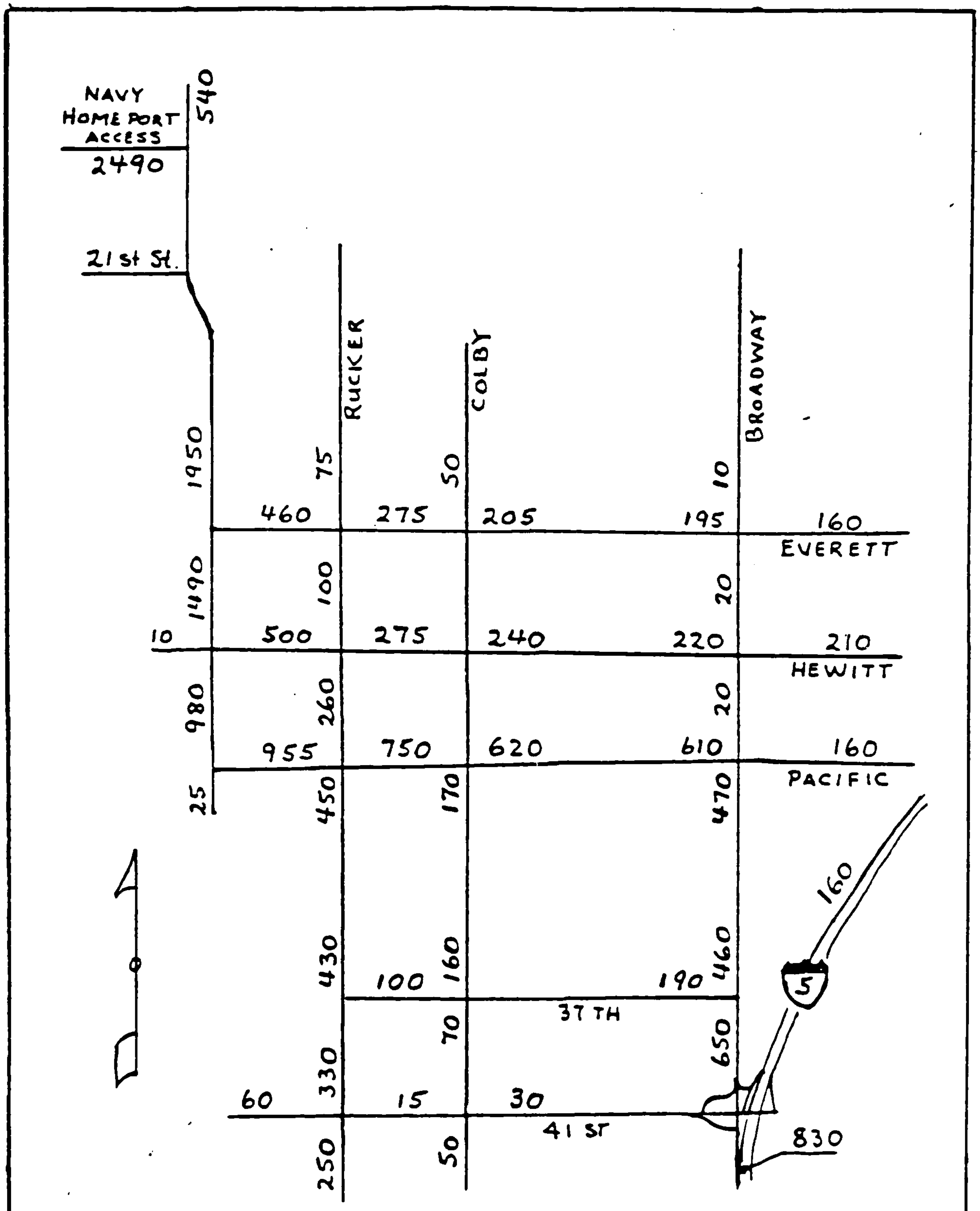
It is important to note that the north-south orientation of peak hour traffic differs from that for daily traffic. Although about 84 percent of the daily traffic is oriented to the south, only 78 percent of peak traffic is so oriented. This is because most of the peak hour traffic consists of home-work trips and these trips form a higher percentage of the traffic oriented to the north than that oriented to the south.

Intersection Volumes

For all practical purposes capacities within an arterial grid system are determined by capacities at the intersections. It was necessary, therefore, to develop forecasts of the 1990 design hour volumes at major intersections of the arterial system for the traffic impact assessment and the analysis of lane requirements. From the traffic assignment forecasts described above, estimates were made of the peak hour flows of Homeport generated traffic through the major intersections of Everett's arterial system. A.M. Peak Hour volumes are shown in Figure 5, and P.M. Peak Hour volumes in Figure 6.

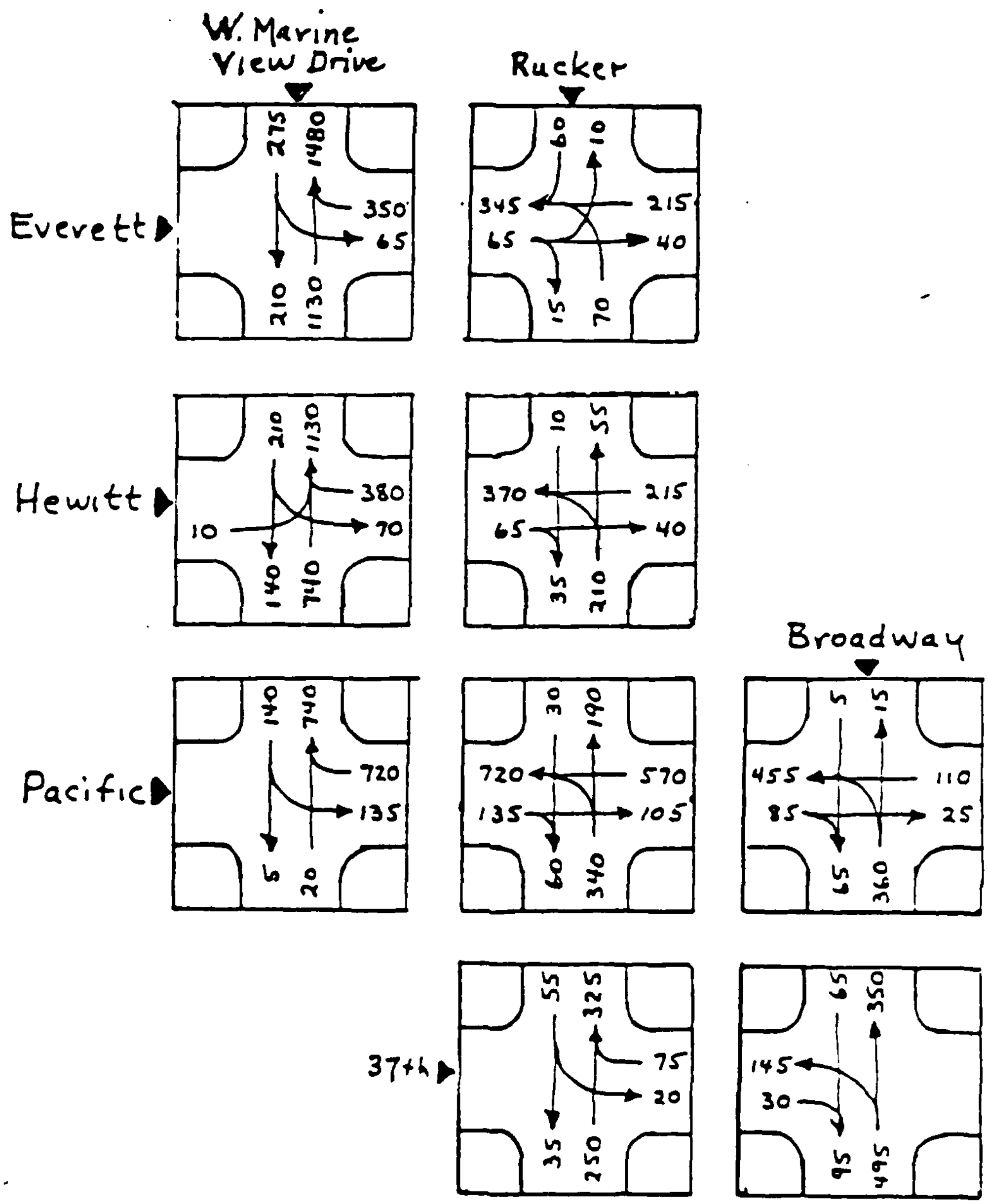


PSCOG	HOMEPORT GENERATED TRAFFIC DAILY VOLUMES	FIGURE 3



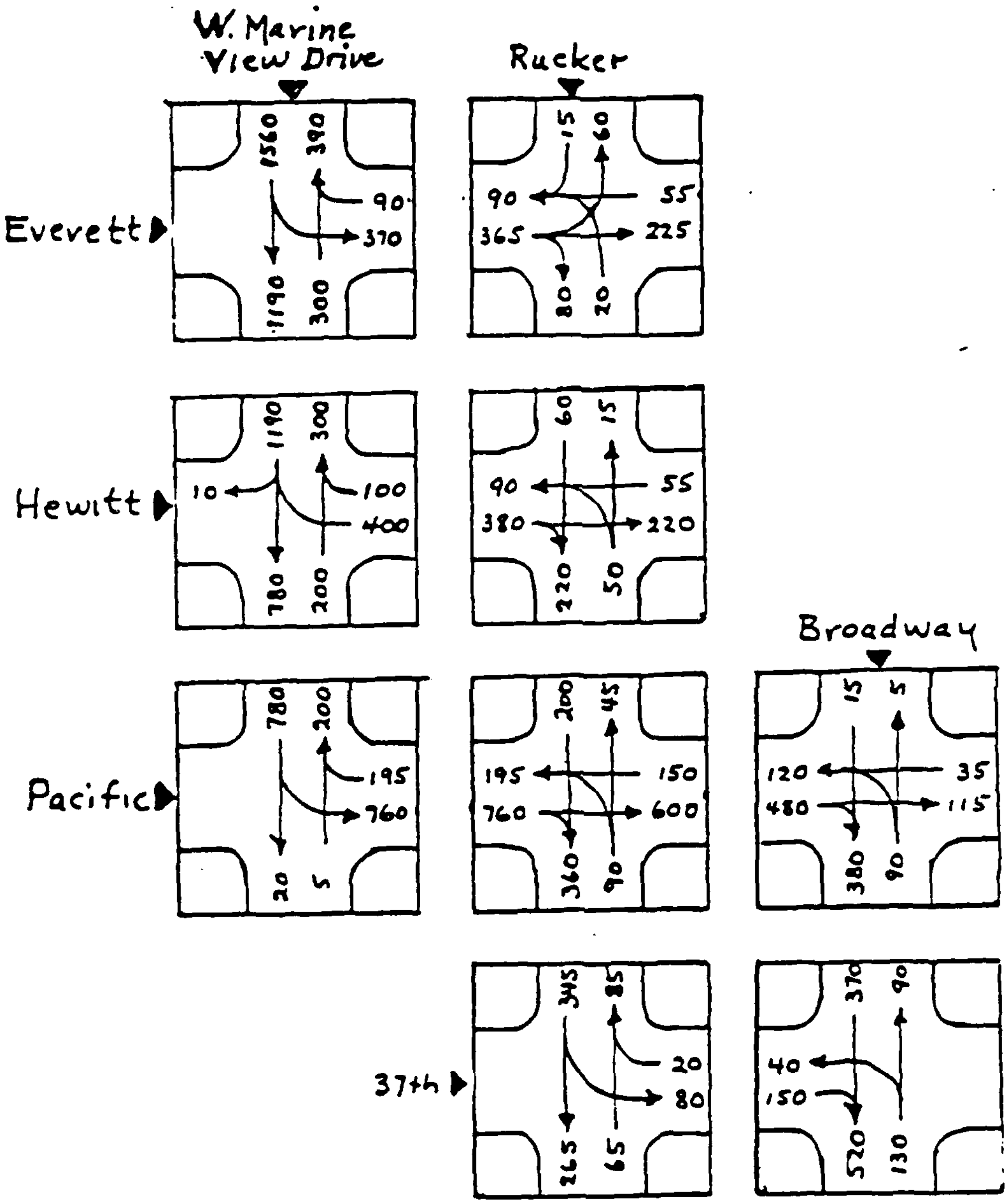
PSCOG	HOMEPORT GENERATED TRAFFIC P.M. PEAK HOUR VOLUMES	FIGURE 4

Homeport Traffic



PSCOG	INTERSECTION VOLUMES A.M. PEAK HOUR	FIGURE 5

Homeport Traffic



PSCOG	INTERSECTION VOLUMES P.M. PEAK HOUR	FIGURE 6

Finally, to provide the data required for the impact assessment, intersection flow diagrams were prepared showing the background 1990 traffic and total traffic including that generated by the Homeport. Two of these diagrams showing the A.M. and P.M. Peak Hour volumes at the intersection of the Navy access road with W. Marine View Drive are shown as Figures 7 and 8. Diagrams for the remaining intersections are included as Appendix C.

TRAFFIC IMPACT ASSESSMENT

The assessment of traffic impacts attributable to the proposed Everett Homeport under "worst case" conditions with the Carrier Battle Group at full strength and the Destroyer Tender in port consists of the following:

1. Identification of those arterial segments and intersections where 1990 traffic will be increased by 100 percent or more with the addition of Homeport generated traffic. This measure of impact referred to as the "doubling effect," relates to eligibility for Federal funding of highway access improvements as provided by 23 U.S.C., Sections 210, 315 and 49 CFR 1.48(b). (1)

2. Determination of the Volume/Capacity (V/C) Ratio and Level of Service (LOS) at affected intersections in Everett using intersection geometry and control conditions as they presently exist. The analysis involves application of Critical Movement Analysis as described in Transportation Research Circular 212.

3. Identification of feasible mitigating measures (changes in intersection geometry and control) for those intersections determined from the preceding calculation, to have unacceptable operating conditions (LOS E or F) and,

4. Recalculation of the V/C and LOS for such intersections with the mitigating measures in place.

Traffic Volume Impact

The impact of Homeport generated traffic on segments of the arterial system, expressed as the average percent increase in 1990 traffic volumes for the heavily impacted segments is as follows:

---

(1) Funding criteria are explained in "Federal-Aid Highway Program Manual, Volume 6, Chapter 9, Section 5. - Defense Access Roads."

TRAFFIC IMPACT – 1990

A.M. Peak Hour

Location W. Marine View Drive / Navy Access Rd.

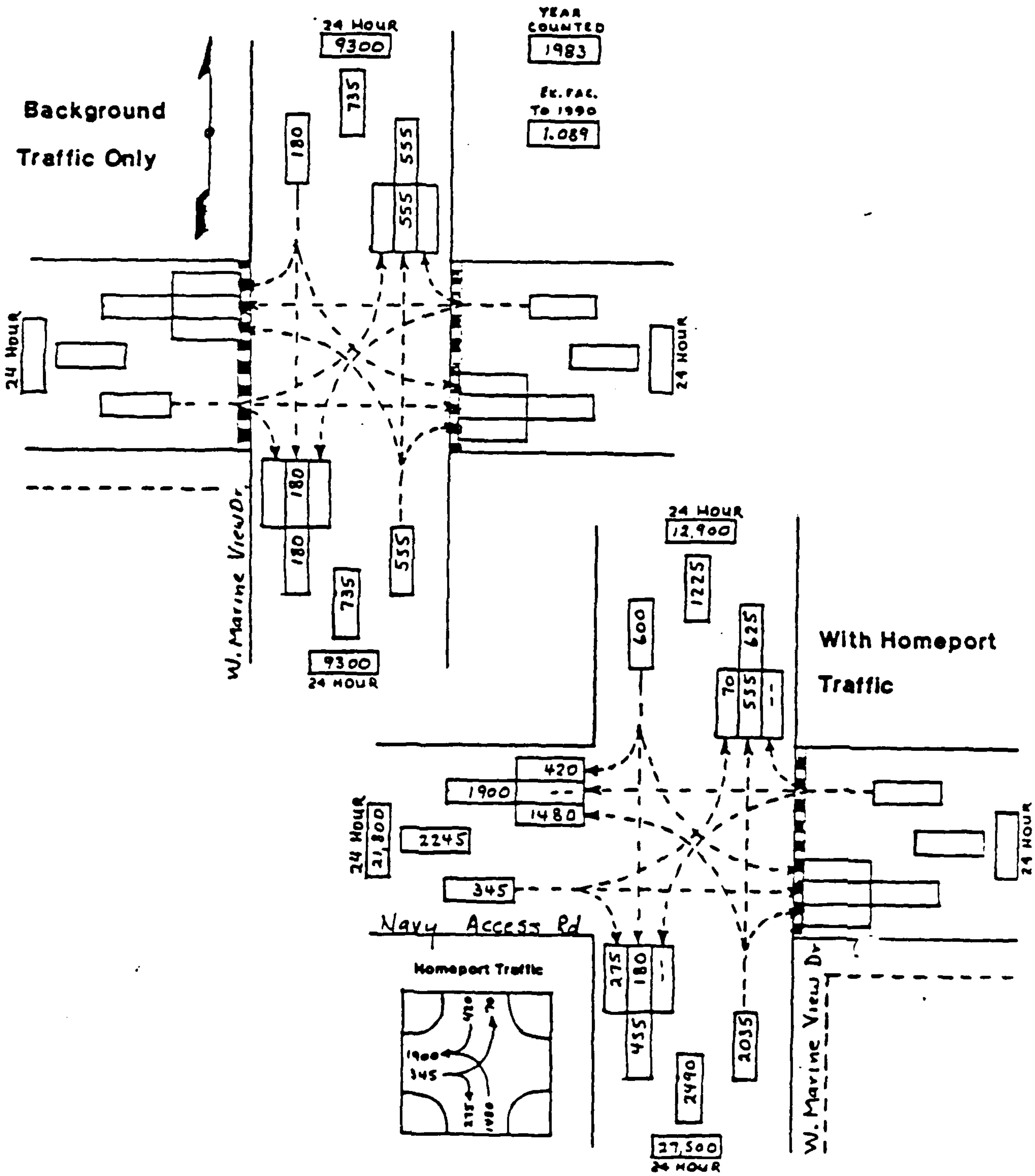


Figure 7

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. Marine View Drive / Navy Access Rd.

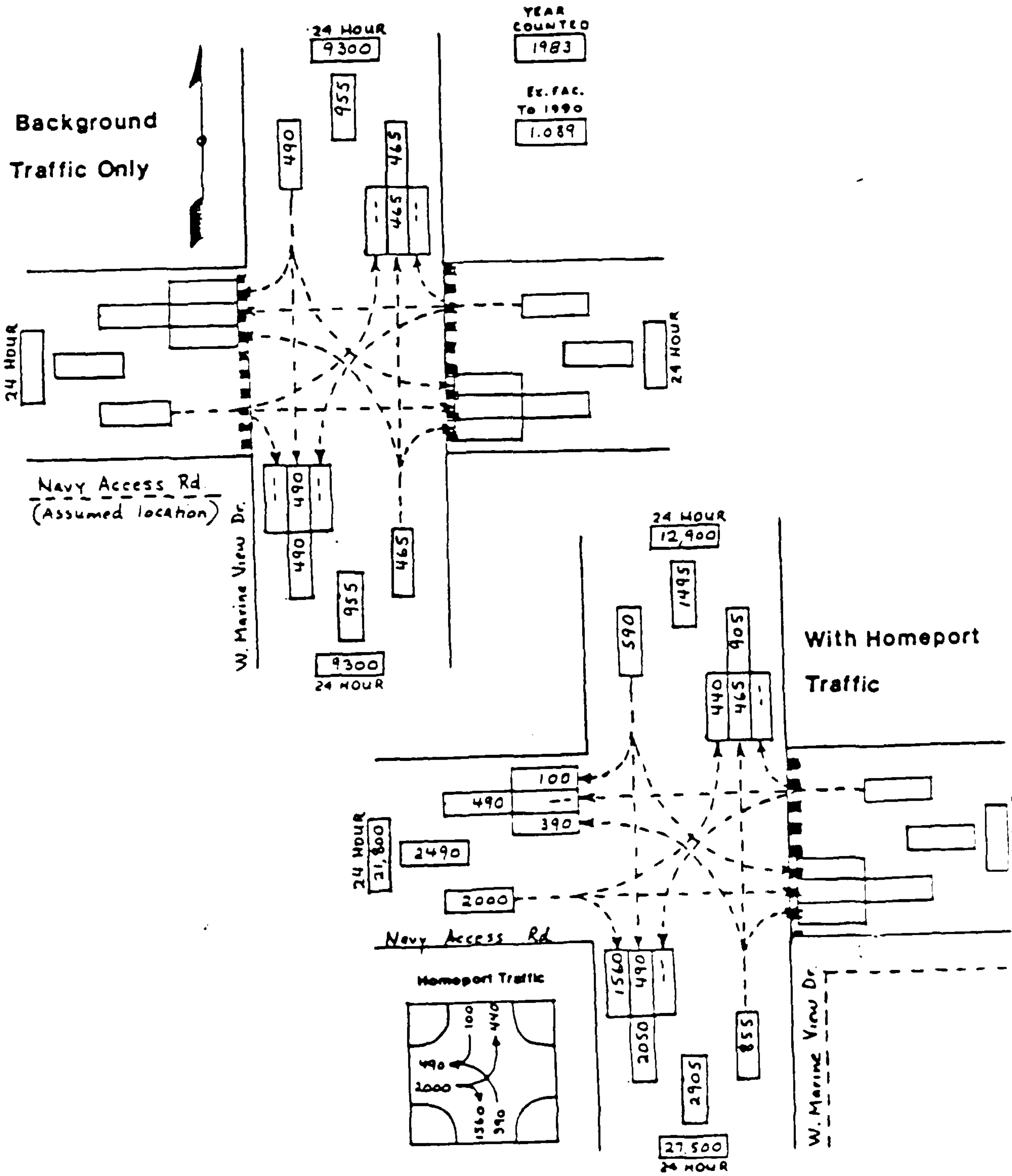


Figure 8

W. Marine View Drive	
Navy access road to Everett Avenue	191%
Everett to Hewitt	163%
Hewitt to Pacific	126%
North of the Navy Access Road	39%

Pacific Avenue	
W. Marine View Drive to Rucker	93%
Rucker to Colby	63%
Colby to Broadway	41%

Everett Avenue	
W. Marine View Drive to Rucker	136%
Rucker to Colby	42%
Colby to Broadway	18%

Hewitt Avenue	
W. Marine View Drive to Rucker	112%
Rucker to Colby	42%
Colby to Broadway	22%

Rucker Avenue	
Everett to Hewitt	10%
Hewitt to Pacific	20%
Pacific to 37th	23%
37th to 41st	18%

Broadway	
Pacific to 37th	15%
37th to I-5 Interchange	20%

37th Street	
Rucker to Colby	30%
Colby to Broadway	25%

From the above it may be seen that the extent of the traffic "doubling" effect is fairly clear. Segments affected include W. Marine View Drive from the Navy access road to Pacific Avenue and short segments of both Everett and Hewitt Avenue between W. Marine view Drive and Rucker Avenue.

Intersection Capacity Analysis

The intersection capacity analysis was made using Critical Movement Analysis, a procedure which allows for capacity and level of service determination for signalized intersections. The procedure incorporates the effects of geometry, traffic signal operation and traffic characteristics in determining the volume of traffic that can be accommodated through an intersection. The analysis produces a level of service determination for the intersection as a whole.

The technique is based on the fact that at each signalized intersection there is a combination of conflicting movements which must be accommodated. For each combination of conflicting movements, that set with the largest combined volume represents the critical movement. The sum of the critical movements provides the measure for relating volume to capacity and thus the measure for determining the level of service expected at the intersection.

Critical Movement Analysis is based on "per lane" volumes. Key to the analysis are the assumptions made regarding the maximum number of vehicles per lane that can be accommodated at an intersection per hour of green. The determination of this value proceeds from the observation that a discharge rate of 2000 passenger cars per hour of green is a theoretical maximum. Because of time lost due to queue start up and signal change intervals, the maximum discharge of a single lane at signalized intersections typically varies from 1500 to 1800 passenger cars per hour of green. The values recommended for use in Circular 212 are at the low side of this range since they take into account other factors which reduce capacity such as buses and trucks in the traffic mix, impedances due to left turns, pedestrian traffic, parking activity and bus stops and the assumption of a 15 percent peaking characteristic (PHF = .85) within the peak hour.

The values used in this analysis for determining level of service (LOS) from the maximum sum of critical volumes are in terms of ranges for each LOS. The meaningful number in establishing these ranges is the volume (in vehicles per hour of green) assumed as the upper limit of LOS E, in this case 1500 vehicles per hour for two phase signals, 1425 for three phase, and 1375 for four or more phases. These values are recommended for planning applications of the technique.

The results of the intersection volume/capacity and LOS analysis are shown in Table IV. The first column shows expected conditions with 1990 background (non-project) traffic given the existing geometry and lane configurations at intersections. Traffic would be accommodated at LOS A at all intersections except those on Broadway.

When the Navy traffic is added, there is a reduction in level of service at all intersections along the primary routes of travel. At five of the intersections, the reduction in level of service results in an unacceptable condition, that is, LOS E or F. At these intersections improvements in the form of additional lanes or reconfiguration of lane designations are needed to increase capacity. Potential changes in geometry and traffic control at these intersections are described in Table V along with the revised level of service calculated for each intersection with the changes in effect.

TABLE IV

INTERSECTION LEVEL OF SERVICE
EXISTING GEOMETRY

Intersection	Peak Hour	1990 Background Traffic V/C	1990 Background Traffic LOS	1990 Traffic W/Navy V/C	1990 Traffic W/Navy LOS
Marine View Drive					
at Navy access	(am)	--	--	1.31	F
at Navy access	(pm)	--	--	0.93	E(1)
at 21st	(am)	--	--	0.69	B
at 21st	(pm)	--	--	0.72	C
at Scott Paper	(pm)	--	--	0.74	C
at Everett	(am)	0.22	A	0.90	D
at Everett	(pm)	0.26	A	1.16	F
at California	(pm)	0.19	A	0.59	A
at Hewitt	(pm)	0.23	A	0.82	D
at Pacific	(pm)	0.43	A	0.94	E
Pacific Avenue					
at Rucker	(pm)	0.48	A	0.78	C
at Colby	(pm)	0.59	A	0.79	C
Broadway					
at Everett	(pm)	0.77	C	0.83	D
at Pacific	(am)	0.44	A	0.73	C
at Pacific	(pm)	0.83	D	1.07	F
at 37th	(am)	0.44	A	0.60	A
at 37th	(pm)	0.82	D	1.07	F
Rucker					
at Everett	(pm)	0.36	A	0.49	A
at Hewitt	(pm)	0.40	A	0.57	A
at 37th	(pm)	0.44	A	0.53	A

(1) Assumes 3-lane exit from the base with one left turn and two right turn lanes.

TABLE V

POTENTIAL CHANGES IN INTERSECTION GEOMETRY AND TRAFFIC CONTROL AND REVISED LEVEL OF SERVICE

Intersection	Potential Changes	1990 Traffic W/Navy V/C	1990 Traffic W/Navy LOS
Marine View Drive at Navy access	Add NB left turn lane; permit left turns from inside through lane	0.82	D
Marine View Drive at Everett	Add SB left turn lane; install three phase signal	0.62	B
Marine View Drive at Pacific	Change lane designations of SB approach to provide an exclusive left turn lane with all movements permitted from right lane	0.68	B
Broadway at Pacific	Add eastbound to south-bound right turn lane	0.87	D
Broadway at 37th	Provide three lanes from from 37th eastbound; left turn, through/right and right turn only. Add right turn lane southbound to eastbound.	0.87	D

From the intersection volume/capacity analysis it may be concluded that; (1) a five-lane configuration on West Marine View Drive with turning lanes as proposed at the intersections with Everett and Pacific Avenues would operate at LOS B, thus providing a substantial reserve capacity for future growth, (2) if only one intersection is provided for Navy Access, it would operate at LOS D/E, and (3) elsewhere within Everett the Navy generated traffic can be accommodated with the existing arterial system and intersection geometry at no worse than LOS C, except on Broadway where additional turning lanes will be needed at the intersections of Broadway with Pacific Avenue and 37th Street. With added lanes for the critical turning movements these intersections will operate at an acceptable level of service (LOS D) but with little capacity for future growth.

The projected condition on Broadway suggests that more traffic may actually divert to alternate routes than was indicated by the assignment. The available alternates are via the Pacific Avenue interchange with I-5 or via Rucker/Colby and 41st Street. These routes have adequate capacity to accommodate more of the Homeport generated traffic.

Sensitivity

The issue of sensitivity involves the question of how much of a change there would have to be in the traffic forecasts (or calculated capacity) to change the conclusions regarding the impact of Navy traffic.

Homeport traffic generation. The method of estimating daily and peak period Homeport traffic has been somewhat of an issue. In the current study, for instance, there was a question as to whether the Destroyer Tender personnel should be included in the base for estimating the trips generated at the Everett facility. Because of this issue, the initial intent was to prepare traffic estimates with and without the Destroyer Tender personnel assumed in the calculation. As it turns out, however, there is only a six percent difference in peak hour traffic between the two calculations. The small difference in the peak hour traffic estimates is due to the fact that the Destroyer Tender personnel will not make home-work trips. The difference, which is within the range of forecasting accuracy, was not enough to affect any of the traffic impact findings.

A more relevant indication of sensitivity is provided by comparing the findings of this study with the projected impact of a Homeport traffic generation scenario of 25,800 vehicles per day as was assumed in the most recent previous study. This estimate assumed a 15 ship Battle Group (instead of 13). The "worst case" traffic estimates assumed the Battle Group at full strength prior to deployment on sea duty, the Destroyer Tender in port and the Marine Air Wing quartered on the Carrier.

Again, the difference in peak hour traffic (comparing the major direction of flow) is much less than the difference in daily traffic. While daily traffic would be 24 percent greater with the 24,800 vehicles per day scenario, the peak hour peak direction is only 9 percent greater. This is beacuse the Destroyer Tender and Marine Air Wing, since they are homeported elsewhere do not generate home-work trips while at the Everett facility. As for the traffic impact, with the 24,800 vpd scenario the level of service on Marine View Drive with the proposed five-lane configuration would be no worse than LOS C, except at Navy Access Road where it would be D/E.

Background traffic. The analysis is even less sensitive to the potential underestimation of background traffic. Assuming that the background traffic has been underestimated by a third, that is, it will actually turn out to be 50 percent greater than what has been forecasted with the improvements as indicated. The V/C ratio at the intersection of W. Marine View Drive and Everett would increase from .62 to .73 and at W. Marine View Drive and Pacific from .68 to .82. This would result in LOS C at the former intersection and LOS D at the latter.

Considering the sensitivity of the analysis to changes in the traffic estimates as indicated above, it is reasonable to conclude that the findings regarding intersection capacities and lane requirements on West Marine View Drive are valid with a sizeable margin for error in the traffic estimates.

V. SUMMARY OF FINDINGS

BACKGROUND TRAFFIC

- Comprehensive traffic count data covering existing conditions in the City of Everett were made available for this study.
- 1990 background traffic (projected conditions without the Homeport) was estimated for the area included in the analysis. Traffic growth to 1990 is expected to be modest on those arterials serving mainly local traffic in Everett. Higher growth rates (16 to 25 percent between 1983 and 1990) are expected on the regional highways such as I-5 and SR-2 in the general area. Intermediate rates of growth are expected on Everett arterials connecting with the regional highway system.
- Peak hour traffic volumes in Everett are generally 9 to 10 percent of average daily traffic. The directional split is typically 55/45.

HOMEPORT TRAFFIC

- The Navy's current ship berthing/personnel loading plan for Everett provides for 13 ships and 6740 personnel assigned to the Carrier Battle Group (CBG). Shoreside personnel permanently assigned to the Homeport would include about 870 military and 475 civilian employees.
- A Destroyer Tender with 1800 assigned personnel will spend one month per quarter at the Everett facility.
- It is estimated that 21,800 vehile trips per day will be generated by the Homeport under "worst case" conditions, that is, when the CBG is preparing for deployment and the Destroyer Tender is in port. The estimate is developed using a trip generation rate of 2.46 vehicle trips per day for the 7610 military personnel assigned to the CBG and 1.72 vehicle trips per day for the 1800 personnel on the Destroyer Tender.
- About 4070 of the military and civilian employees assigned to the Homeport will live off-base. During periods of maximum activity these personnel are expected to generate about 6100 home-work vehicle trips per day.
- It is estimated that 2490 vehicle trips, 11.4 percent of daily traffic, will occur during the P.M. Peak Hour and 2310 vehicle trips, 10.6 percent of daily traffic during the A.M. Peak Hour. About 71 percent of P.M. Peak Hour traffic and 77 percent of A.M. Peak Hour traffic consists of home-work trips.

- Estimates of Homeport traffic developed in this study are about 8 percent higher than what was estimated for the FEIS (June 1985), but about 15 percent lower than the previous PSCOG estimates (August 1985).

TRAFFIC IMPACTS

- About 16 percent of daily traffic generated by the Homeport is expected to use the north access corridor and 84 percent the south access corridor. For the P.M. Peak Hour the respective shares are 22 and 78 percent respectively.

- Almost a third of the Navy traffic will use cross-town routes to access I-5 South. The minimum time path for this traffic is via W. Marine View Drive, Pacific Avenue and Broadway. Not all traffic will use this route since alternative routes with only marginal differences in travel time are available.

- Generally, the Everett arterial system can accommodate 1990 background (without Navy) traffic at Level of Service (LOS) A, except on Broadway where LOS C/D can be expected at major intersections during the P.M. Peak Hour.

- The addition of Homeport traffic as estimated for the "worst case" condition will have the following impacts:

  - Traffic will increase by 100 percent or more on Marine View Drive between the Navy access and Pacific Ave. and also on Everett and Hewitt Avenues between Marine View Drive and Rucker Ave.

  - There will be a reduction in LOS at virtually all intersections on primary routes of travel.

  - With existing geometry and traffic control, intersection capacities will be exceeded at four locations; on Marine View Drive at Everett Avenue and at Pacific Avenue and on Broadway at Pacific Avenue and at 37th Street.

LANE REQUIREMENTS

- At the four intersections identified above, additional lanes or reconfiguration of the existing roadways will be required to provide an acceptable level of service. A five-lane roadway on W. Marine View Dr. would provide the additional lane required at the critical intersections plus adequate queuing space in advance of the intersections. With such an improvement all of the intersections on W. Marine View Drive, including those at Everett and Pacific Avenues, would operate at level of service B with the Navy traffic.

- If only one gate is provided at the Navy facility, there would be a requirement for three lanes outbound at the intersection with W. Marine View Dr. to accommodate the P.M. peak. There would also be a requirement for at least three lanes northbound on Marine View Dr. to accommodate the A.M. peak. With this geometry the intersection would operate at level of service D/E during the respective peaks.

TABLE A-1
DISTRIBUTION OF VEHICLE TRIPS BY ZONE

Arlington, Marysville, Stanwood, Granite Falls and Arlington

New TAZ	Old TAZ	Workers	Home-Work Person Trips Transit	Home-Work Person Trips Auto	Vehicle Trips Work	Vehicle Trips Other
440	286	25	--	45	43	106
436	287	25	--	45	42	30
	288	49	--	88	81	113
437	289	105	5	184	169	405
438	290	147	5	260	240	320
439						
442	291	52	--	94	85	120
441	292	20	--	36	33	40
443	293	90	--	161	139	43
497	303	90	--	161	139	50
498	304	17	--	31	24	15
500	305	129	--	230	166	234
TOTAL		749	10	1335	1161	1476

Snohomish, Lake Stevens, Monroe, Sky Valley

New TAZ	Old TAZ	Workers	Home-Work Person Trips Transit	Home-Work Person Trips Auto	Vehicle Trips Work	Vehicle Trips Other
409	276	5	--	9	9	25
408	277	6	--	11	11	30
423	278	61	11	99	92	140
424	279	100	18	162	150	283
435	280	91	12	152	141	450
410	(1)	117	10	201	187	250
496	302	101	--	182	152	210
TOTAL		481	51	816	742	1388

(1) Includes Monroe which was formerly outside the old TAZ structure and a part of external station 302.

TABLE A-1 (Continued)

Everett-Central North

New TAZ	Old TAZ	Workers	Home-Work Person Trips Transit	Home-Work Person Trips Auto	Vehicle Trips Work	Vehicle Trips Other
427						
428	281	125	20	205	186	2430
429						
431	282	65	15	102	93	418
430						
433	283	180	30	294	267	780
432	284	130	20	214	195	510
434	285	70	4	122	111	140
TOTAL		570	89	937	852	4278

Everett-South Southwest

New TAZ	Old TAZ	Workers	Transit	Auto	Work	Other
415	271	60	10	98	89	850
418	272	30	4	50	45	460
419						
420	273	70	15	111	101	760
425						
426	274	100	25	155	141	1050
421						
422	275	64	10	105	95	235
TOTAL		324	64	519	471	3355

Paine Field, Alderwood Mall

New TAZ	Old TAZ	Workers	Transit	Auto	Work	Other
404	260	30	--	54	49	50
405	261	80	9	135	121	530
411	265	68	--	122	110	140
412	266	255	15	442	398	480
413	267	170	10	296	267	279
TOTAL		603	36	1049	945	1479

Island County

New TAZ	Old TAZ	Workers	Transit	Auto	Work	Other
501	306(2)	57	—	103	74	161

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(2) Mukilteo Ferry Terminal

TABLE A-1 (Continued)

Edmonds, Lynnwood, Mountlake Terrace

New TAZ	Old TAZ	Workers	Home-Work Person Trips Transit	Home-Work Person Trips Auto	Vehicle Trips Work	Vehicle Trips Other
382						
383	248	25	--	45	37	20
384						
385	249	35	--	63	52	40
386						
388						
387	250	105	--	189	155	120
394	254	35	--	63	52	180
395						
396	255	30	--	54	44	60
399						
400	256	30	--	54	44	40
397						
401	257	34	10	51	42	150
398	258	45	--	81	66	40
402	259	80	4	140	115	377
TOTAL		419	14	740	607	1027

North Creek, Maltby, Cathcart

New TAZ	Old TAZ	Workers	Transit	Auto	Work	Other
389						
390	251	40	10	62	54	40
391	252	50	--	90	78	60
392	253	30	--	54	47	40
403	262	45	5	76	66	150
407	263	25	--	45	39	53
393	264	40	--	72	63	50
414	268	45	5	76	66	200
406	269	45	--	81	71	250
416						
417	270	45	--	81	71	250
TOTAL		365	20	637	554	9[illegible]3

Kitsap

New TAZ	Old TAZ	Workers	Transit	Auto	Work	Other
	307(3)	22	--	40	28	31

(3) Edmonds Ferry Terminal

TABLE A-1 (Continued)

Area	Imputed TAZ	Workers	Home-Work Person Trips Transit	Home-Work Person Trips Auto	Vehicle Trips Work	Vehicle Trips Other
Shoreline	241	57	--	103	89	69
Bothell	178	52	--	92	81	60
Eastside	167	91	--	164	131	262
North Seattle	233	179	--	322	239	662(4)
Central Seattle	194	96	--	173	128	384
Other King Co.	146	10	--	18	12	151

(4) Includes about 80 one-way shuttle bus trips.

APPENDIX B

TABLE B-1
TRAFFIC CHARACTERISTICS DATA - MAYPORT NAVAL STATION, FLORIDA

1. Vehicle counts with the Saratoga in port.

Outbound	Daily	P.M. Peak Hr.	A.M. Peak Hr.
Main Gate	7350	922	246
Seminole Gate	2525	742	63
Mayport Gate	350	106	29
	-----	-----	-----
Total	10225	1770	338
Inbound			
Main Gate	8400	409	1185
Seminole Gate	970	3	514
Mayport Gate	500	19	43
	-----	-----	-----
Total	9870	431	1742
Both Directions	20095	2201	2080
Percent of Daily	100.0	11.0	10.4
Directional Split	--	80/20	84/16

2. Vehicle Counts without the Saratoga in port.

Outbound	Daily	P.M. Peak Hr.	A.M. Peak Hr.
Main Gate	5850	811	185
Seminole Gate	2325	683	58
Mayport Gate	300	68	29
	-----	-----	-----
Total	8475	1562	272
Inbound			
Main Gate	7500	367	1019
Seminole Gate	890	3	485
Mayport Gate	260	19	43
	-----	-----	-----
Total	8650	389	1547
Both Directions	17125	1951	1819
Percent of Daily	100.0	11.4	10.6
Directional Split	--	80/20	85/15

Source: Military Traffic Management Command, "Traffic Engineering Planning Study Naval Station, Mayport, Florida," Feb. 1984 Data derived from Figures 3, 5, 6; and Tables 2, 3, 4.

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. Marine View Dr. / 21st St.

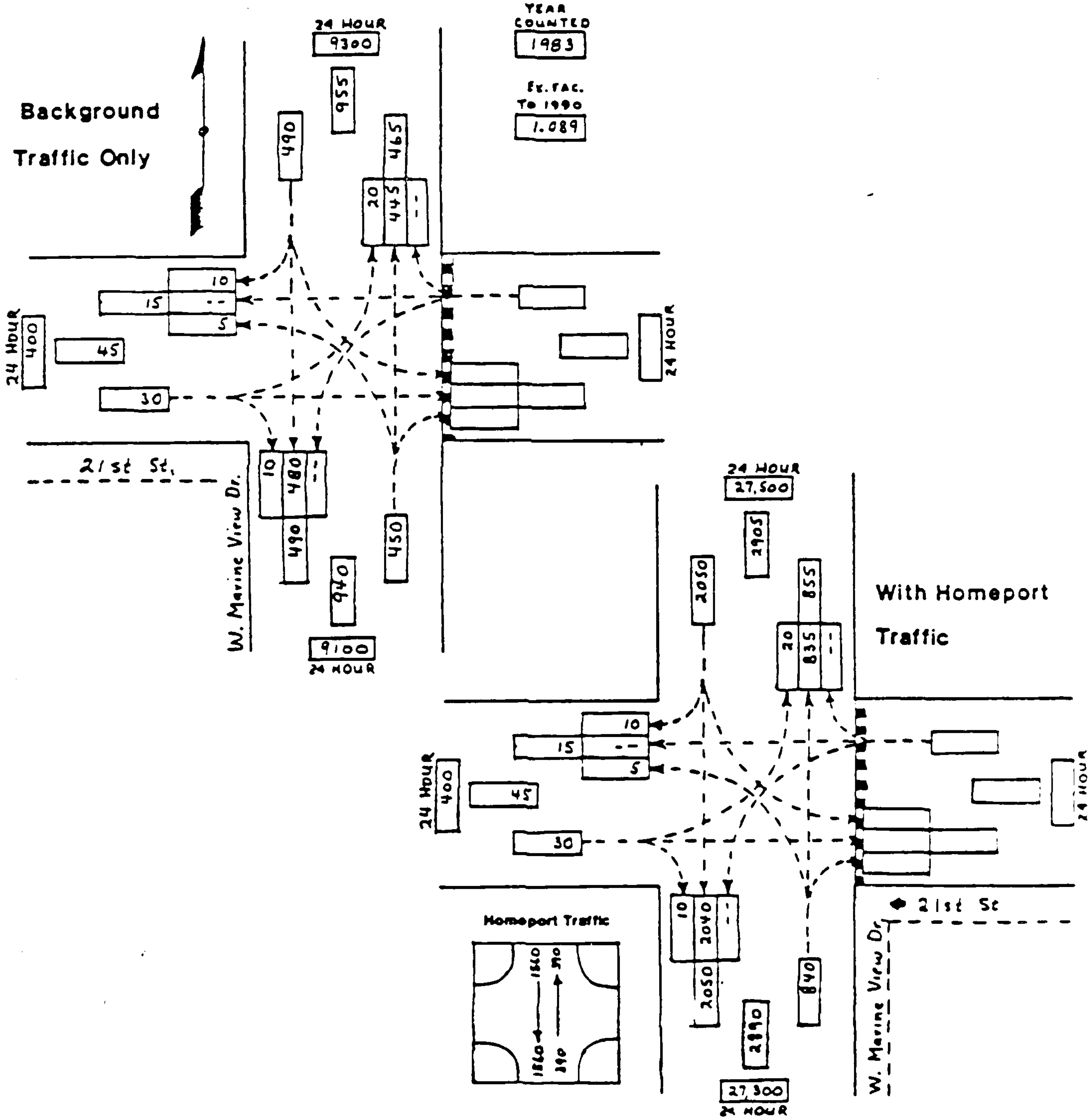


Figure C-1

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. MARINE VIEW DR / SCOTT PAPER CO. ENTR. (25TH ST.)

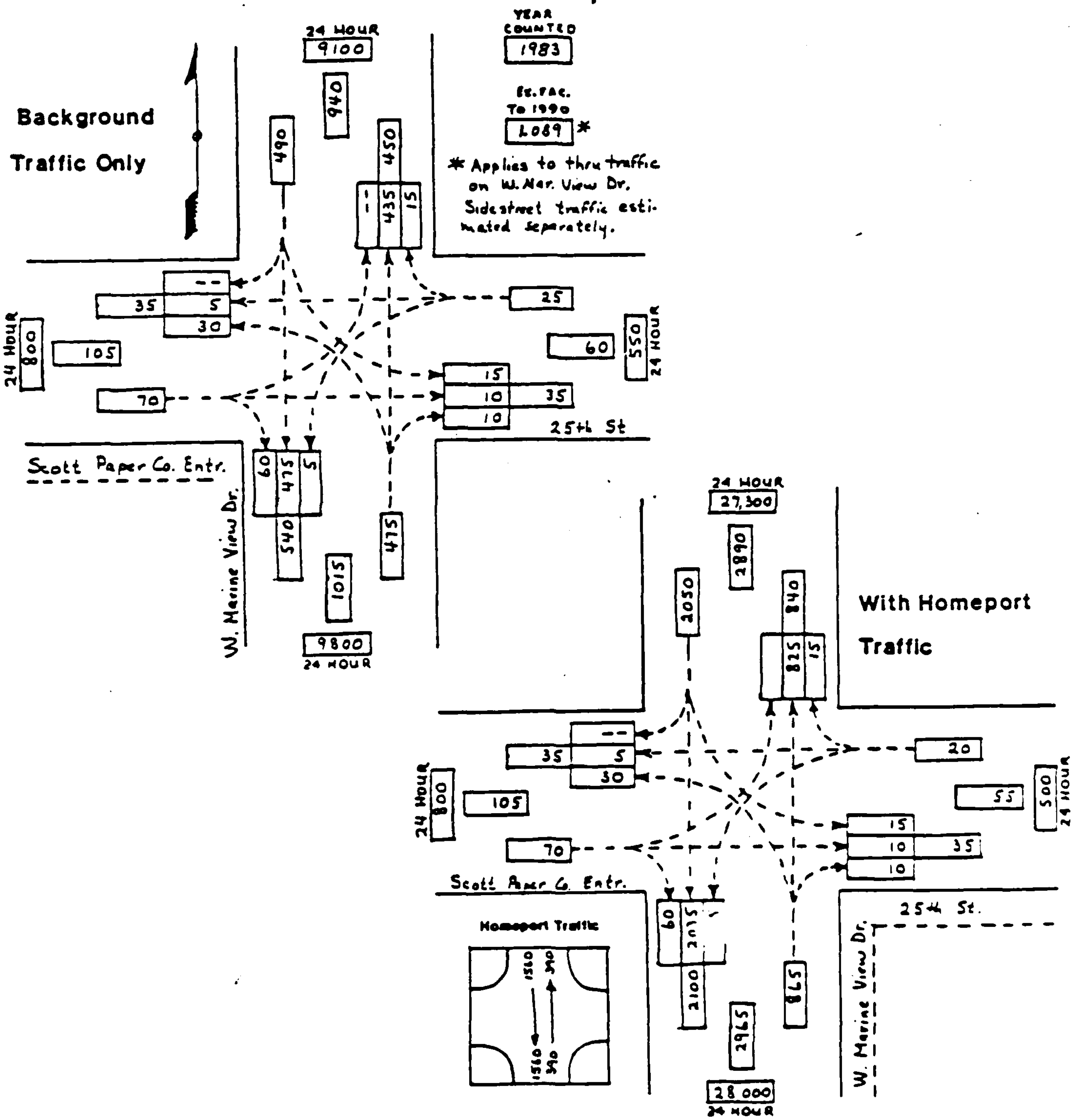
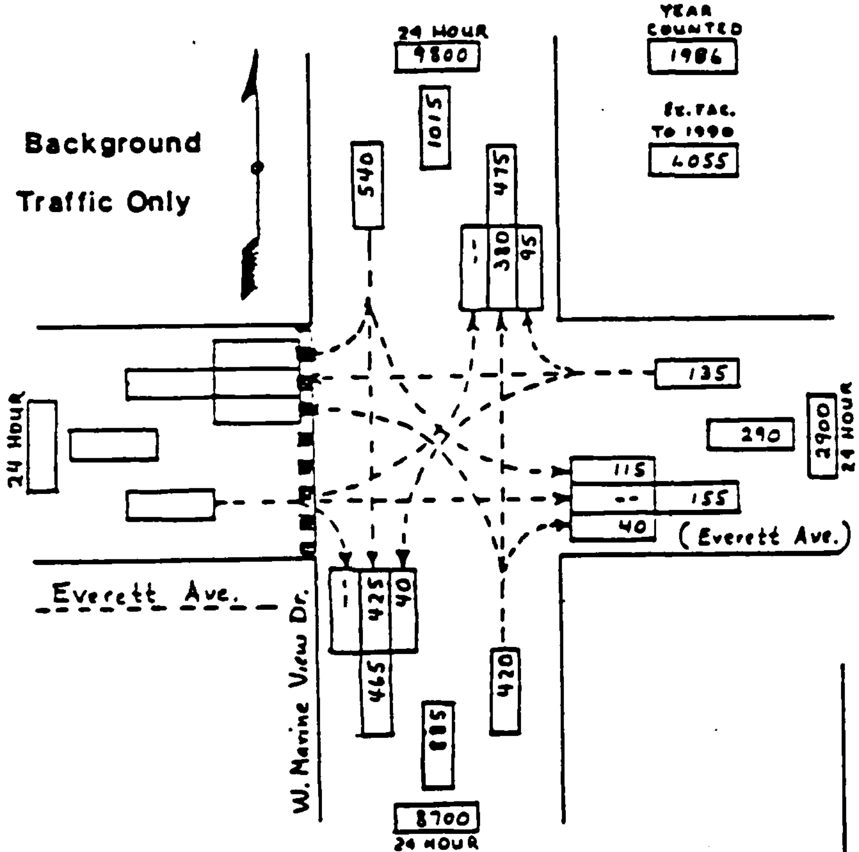


Figure 6-2

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. MARINE VIEW DR. / EVERETT AVE.



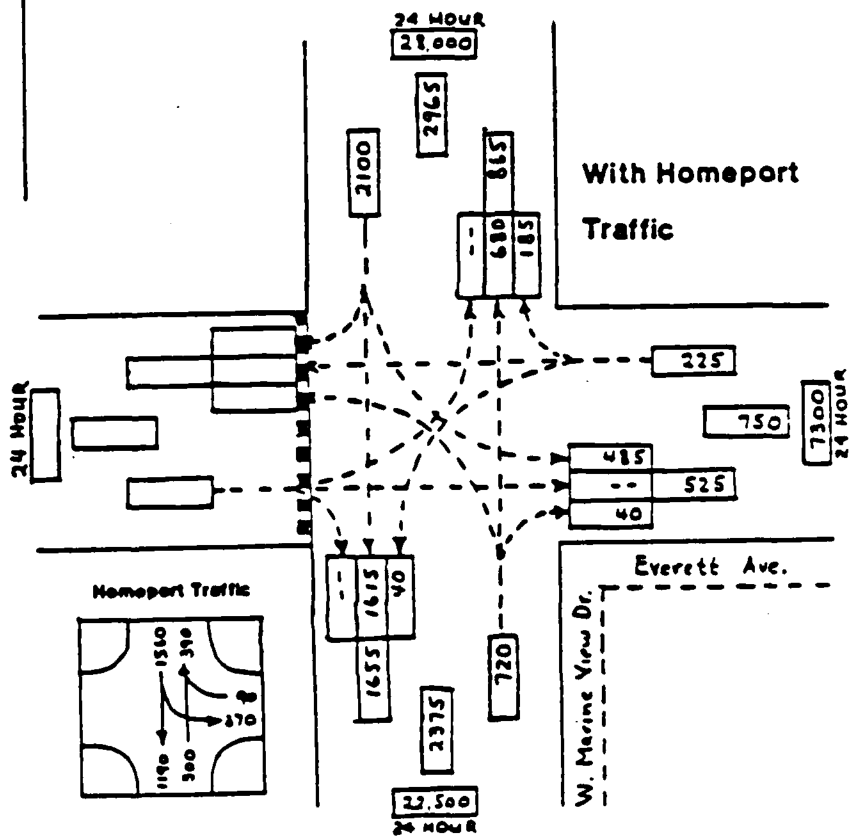


Figure 6-3

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. MARINE VIEW DR./CALIFORNIA AVE.

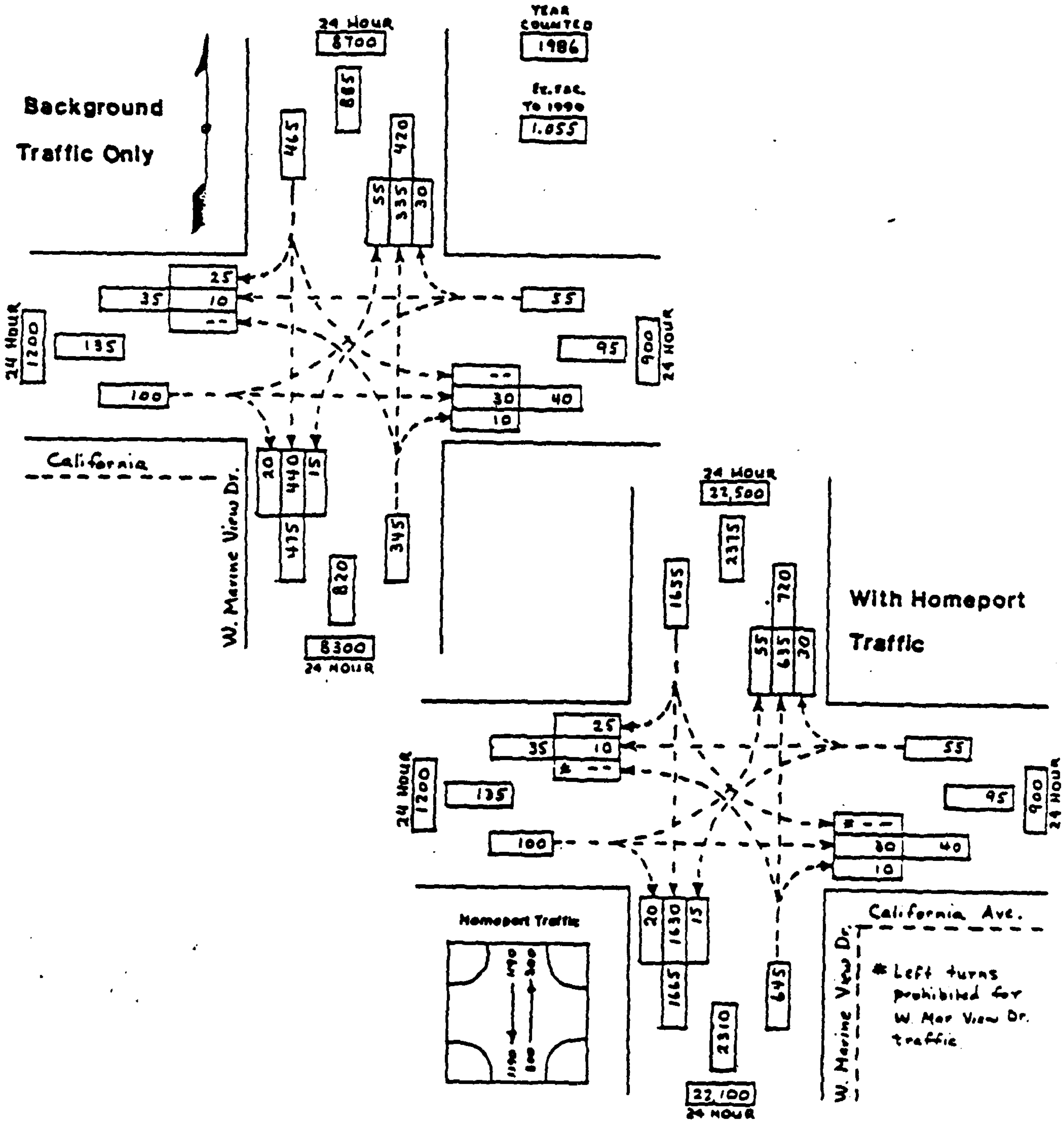
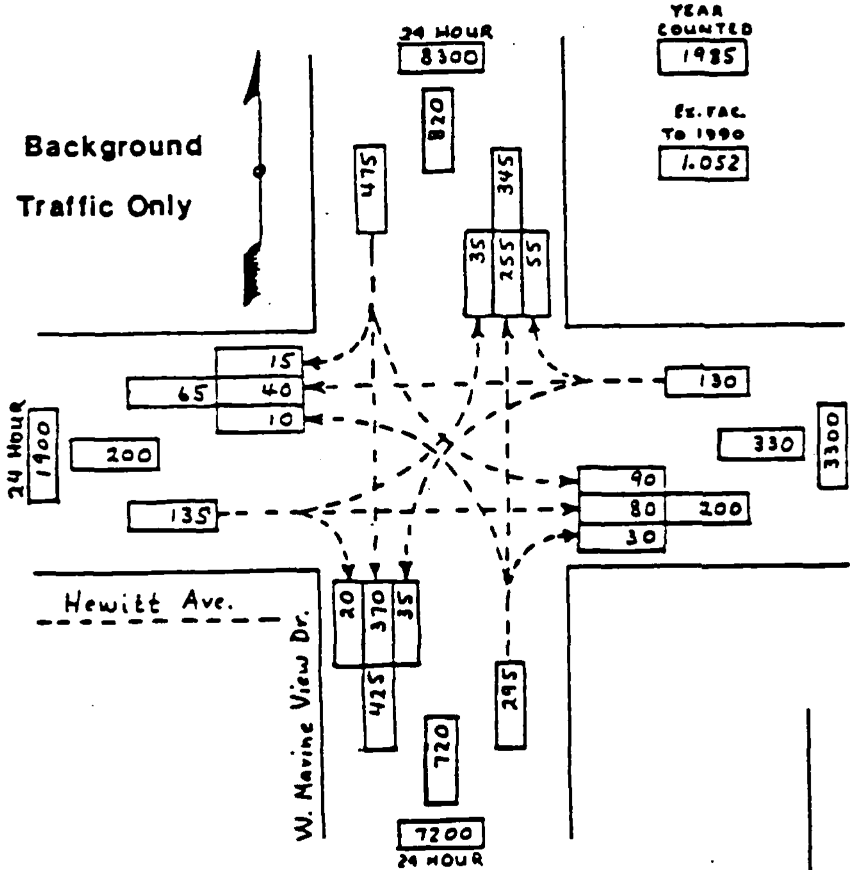


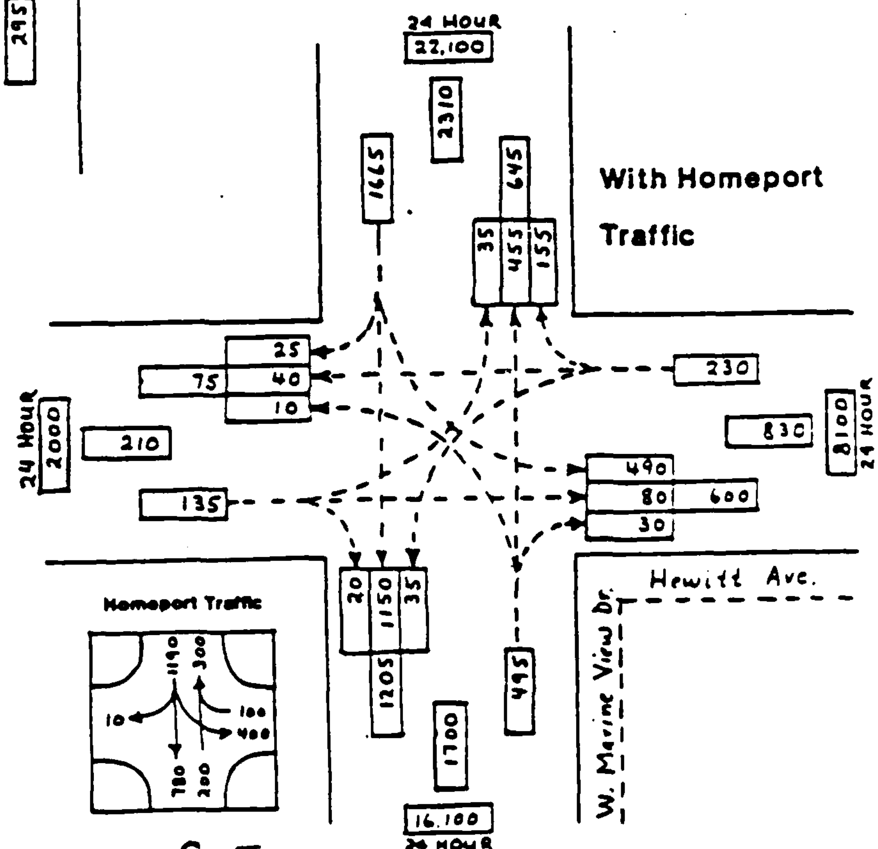
Figure C-4

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. MARINE VIEW DR. / HEWITT AVE.





TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location W. MARINE VIEW DR. (NORTON) / PACIFIC AVE

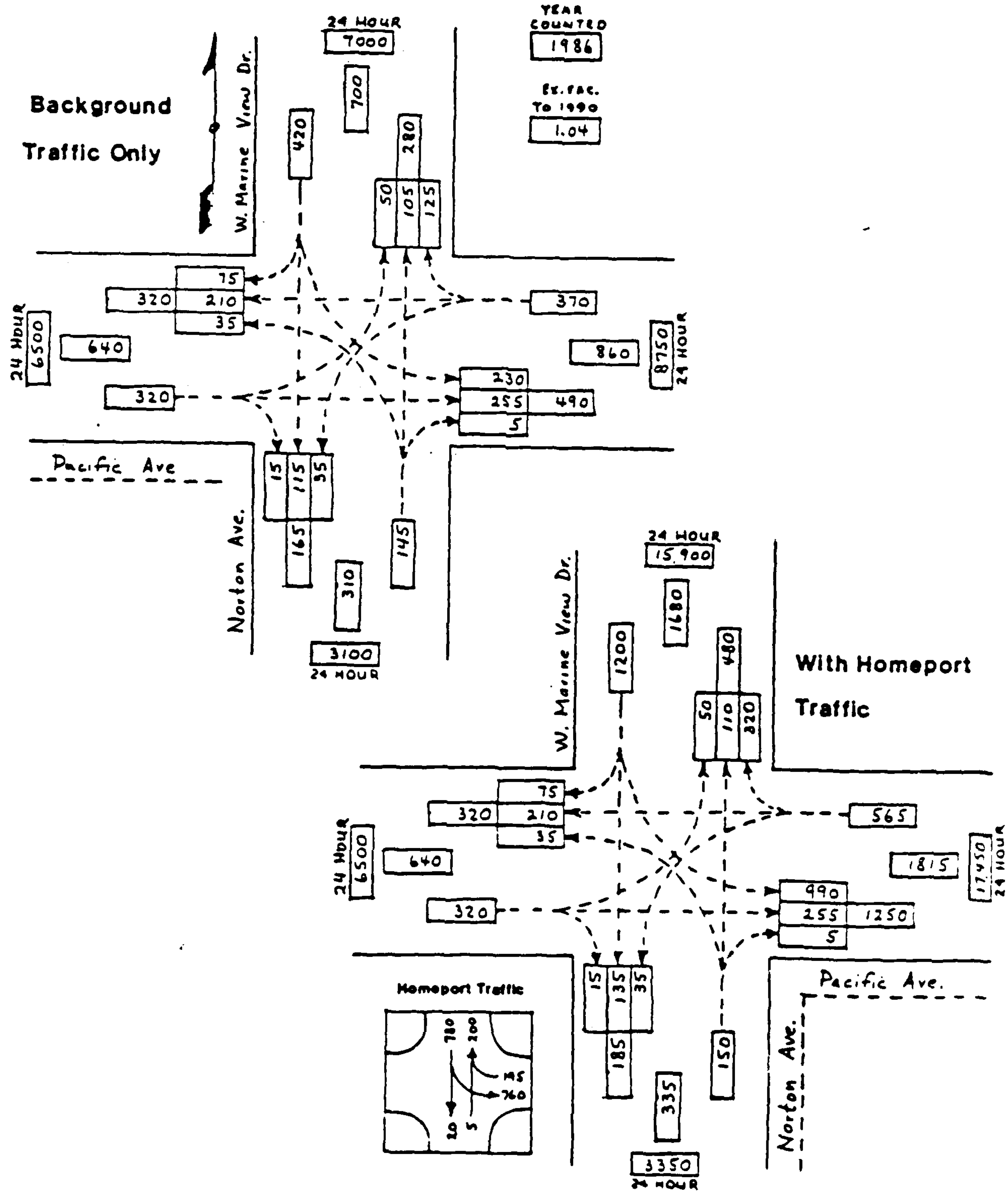


Figure C-6

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location RUCKER / PACIFIC AVE.

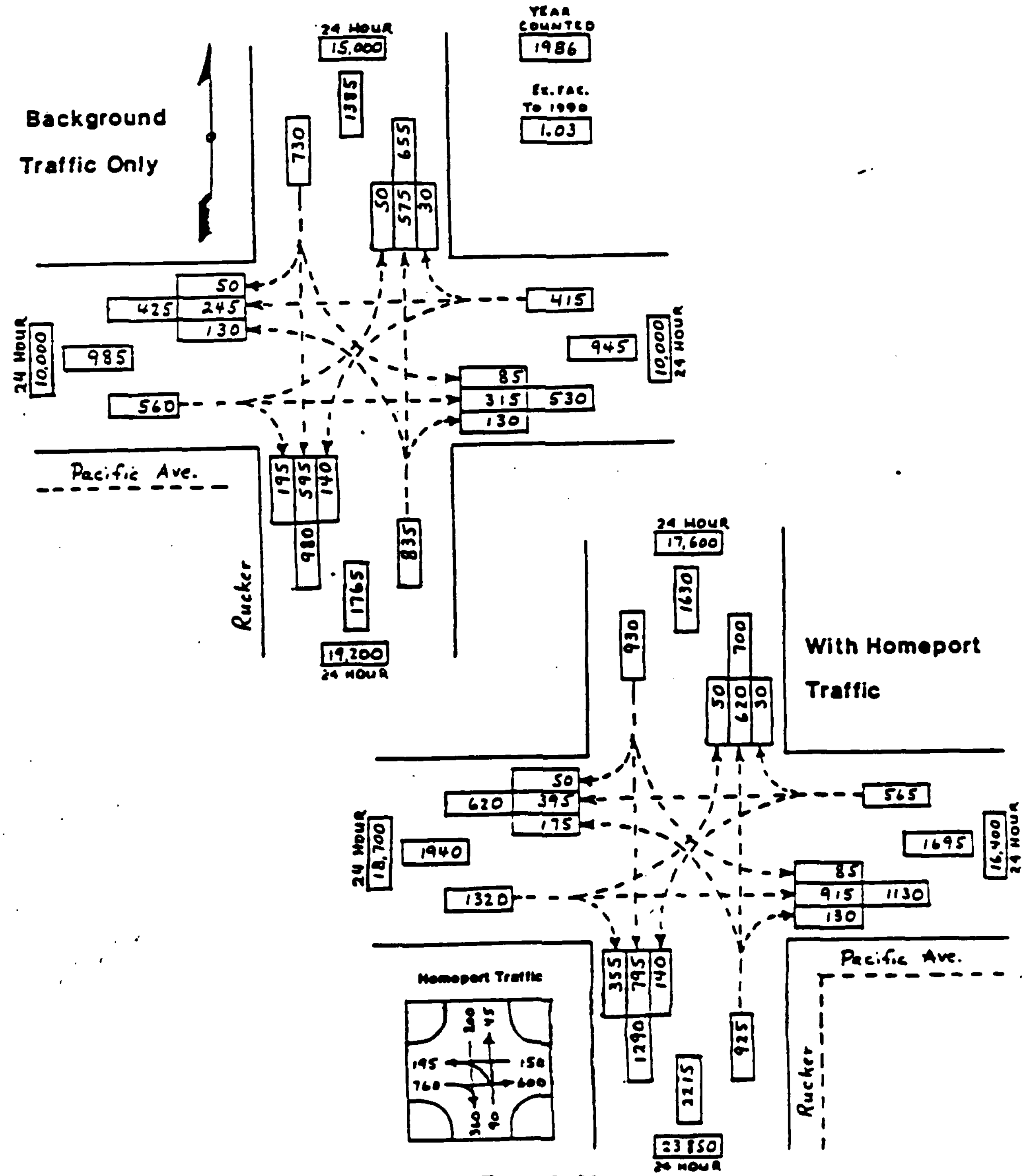


FIG. C-7

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location COLBY/PACIFIC AVE.

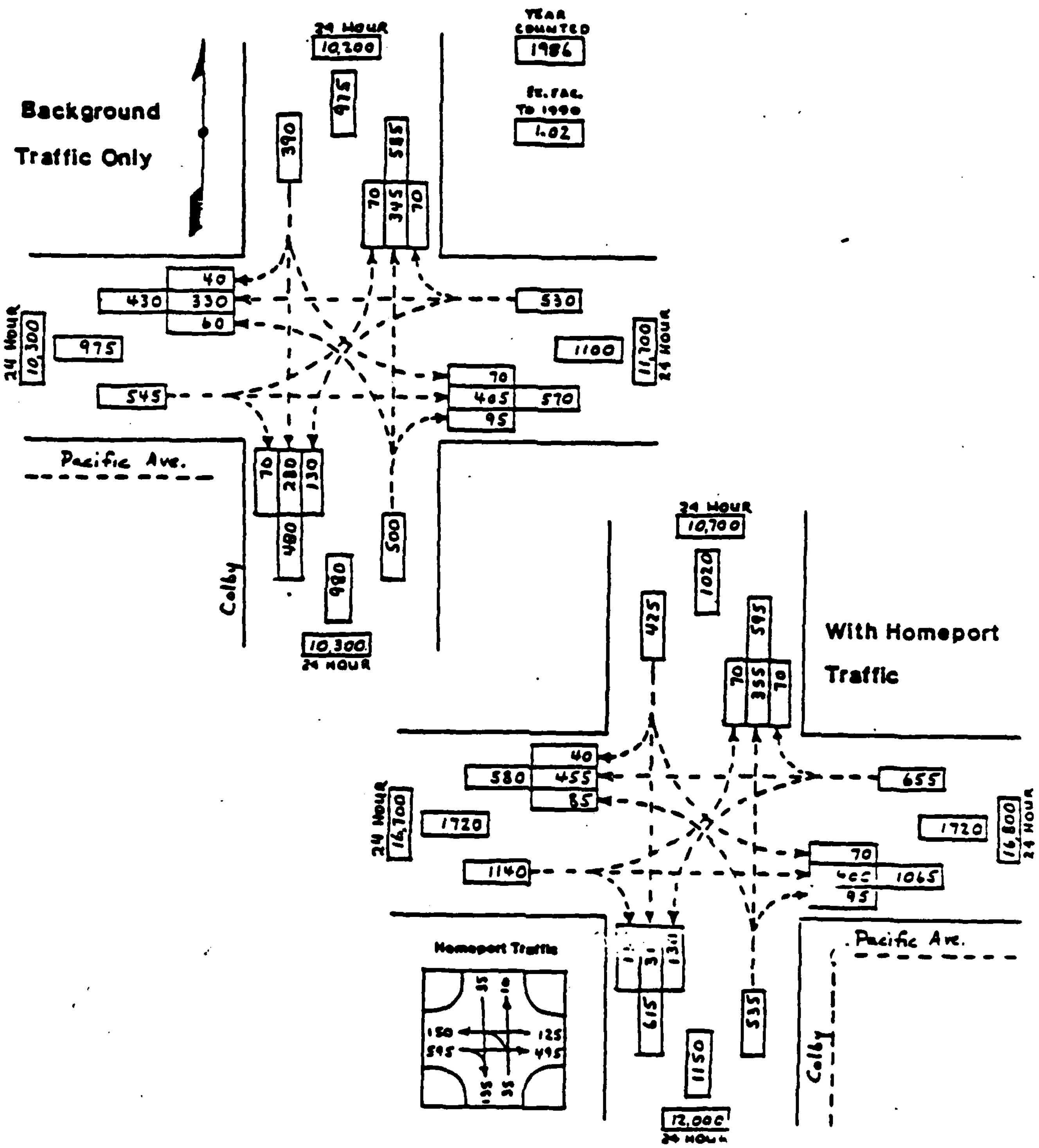


Figure 6-8

TRAFFIC IMPACT - 1990

P.M. Peak Hour

Location BROADWAY / PACIFIC AVE.

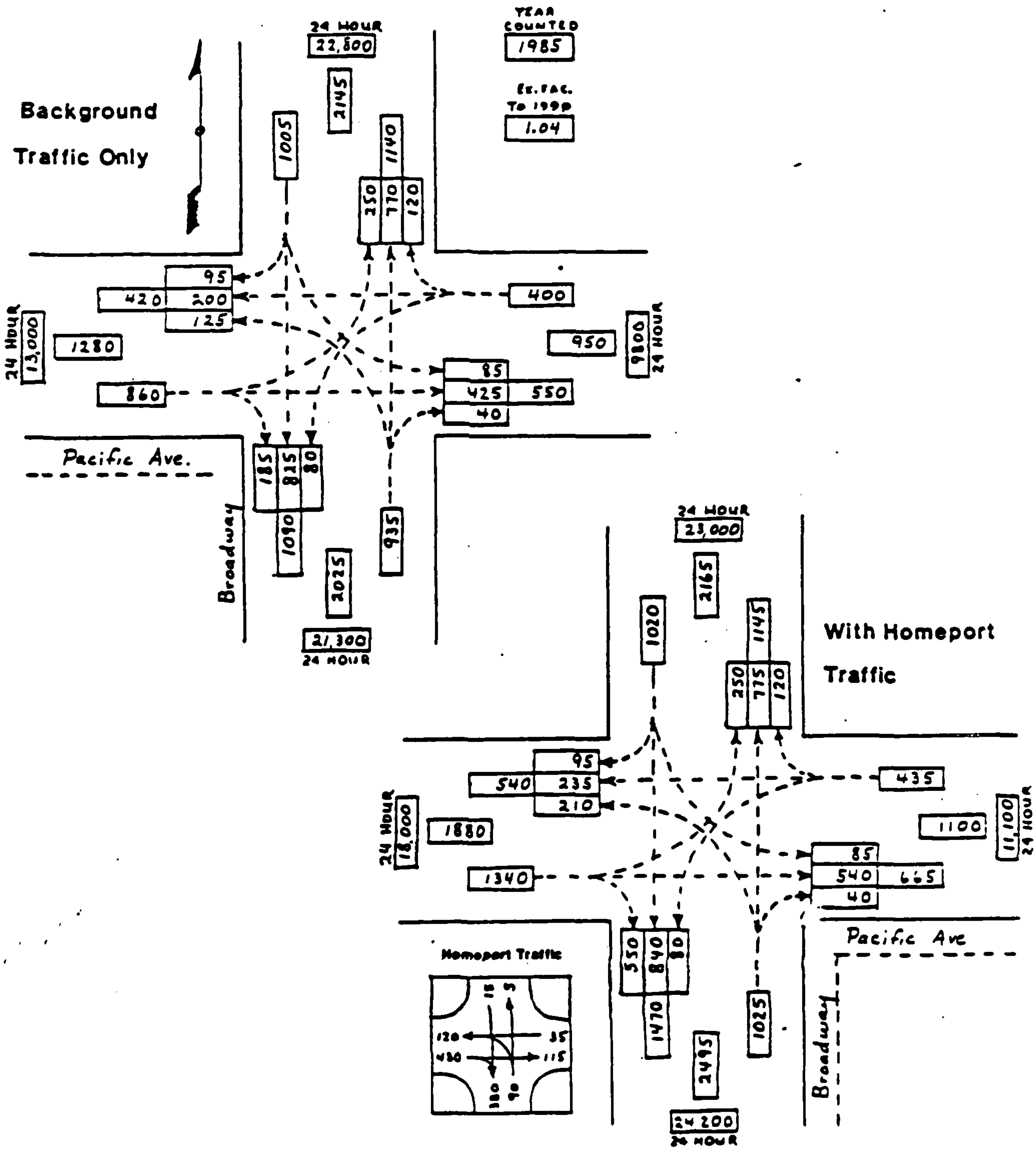


Figure C-9

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location BROADWAY / 37TH ST.

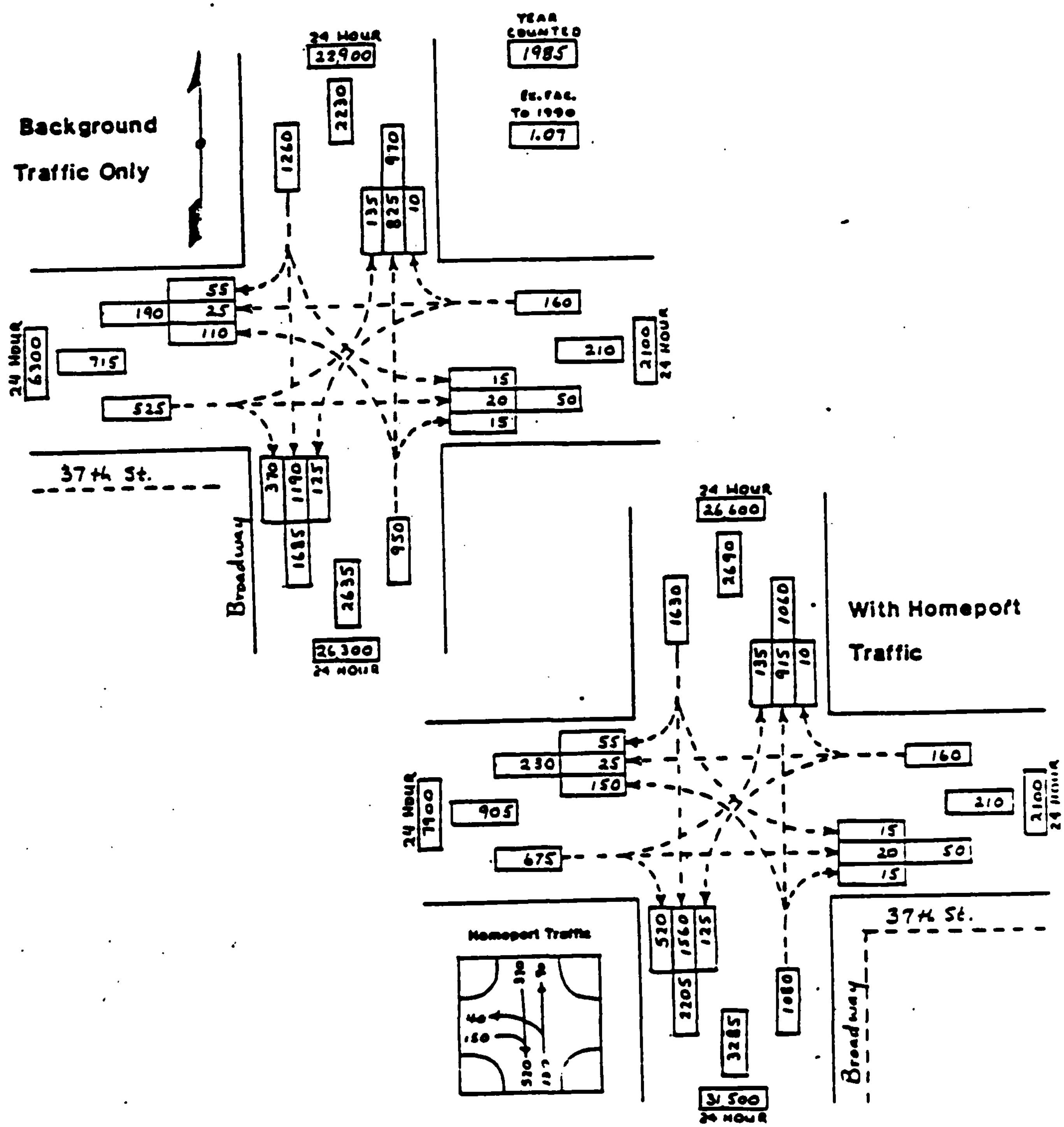


Figure C-10

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location RUCKER / EVERETT AVE.

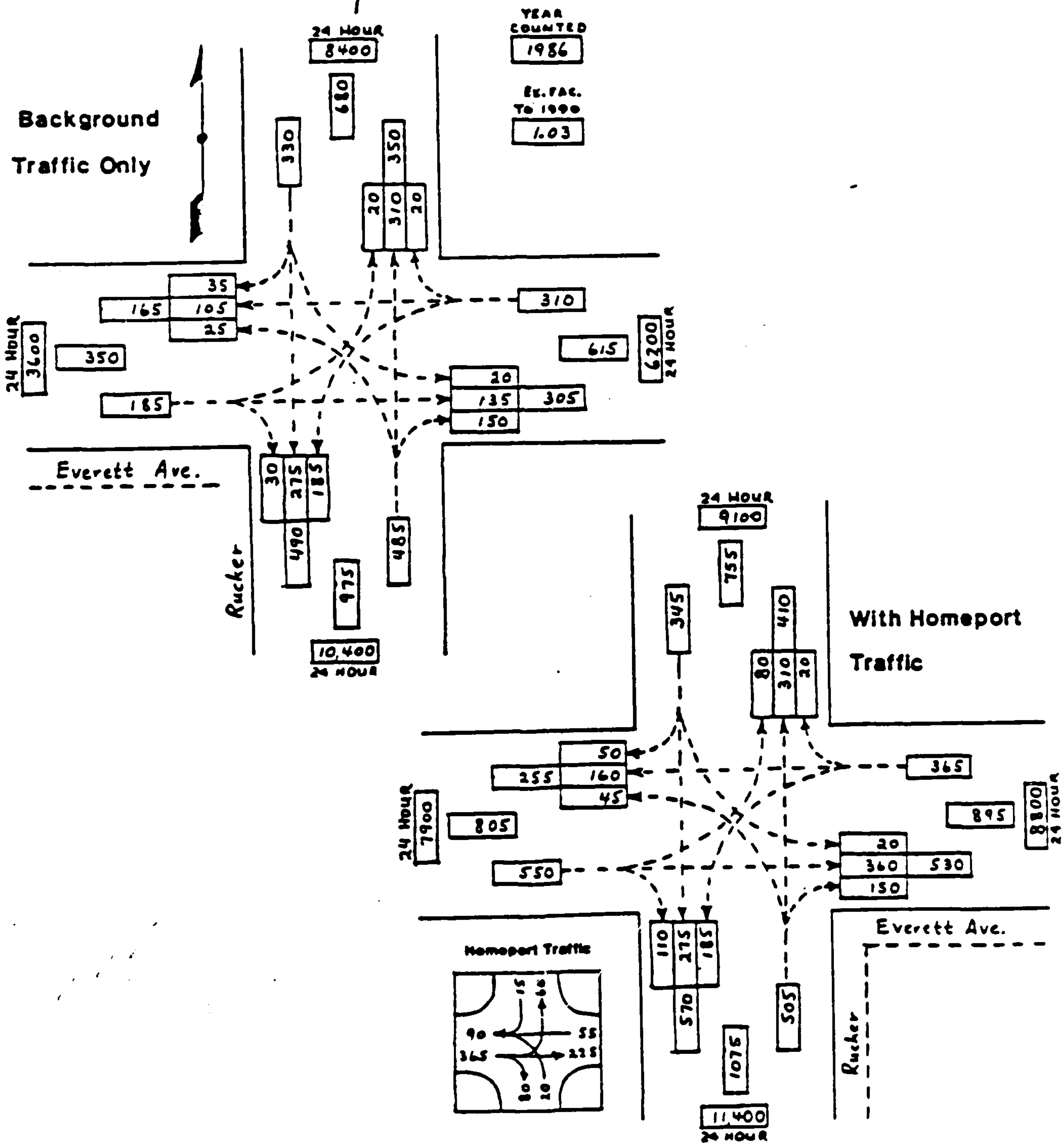


Figure C-11

TRAFFIC IMPACT - 1990

P.M. Peak Hour

Location RUCKER / HEWITT AVE.

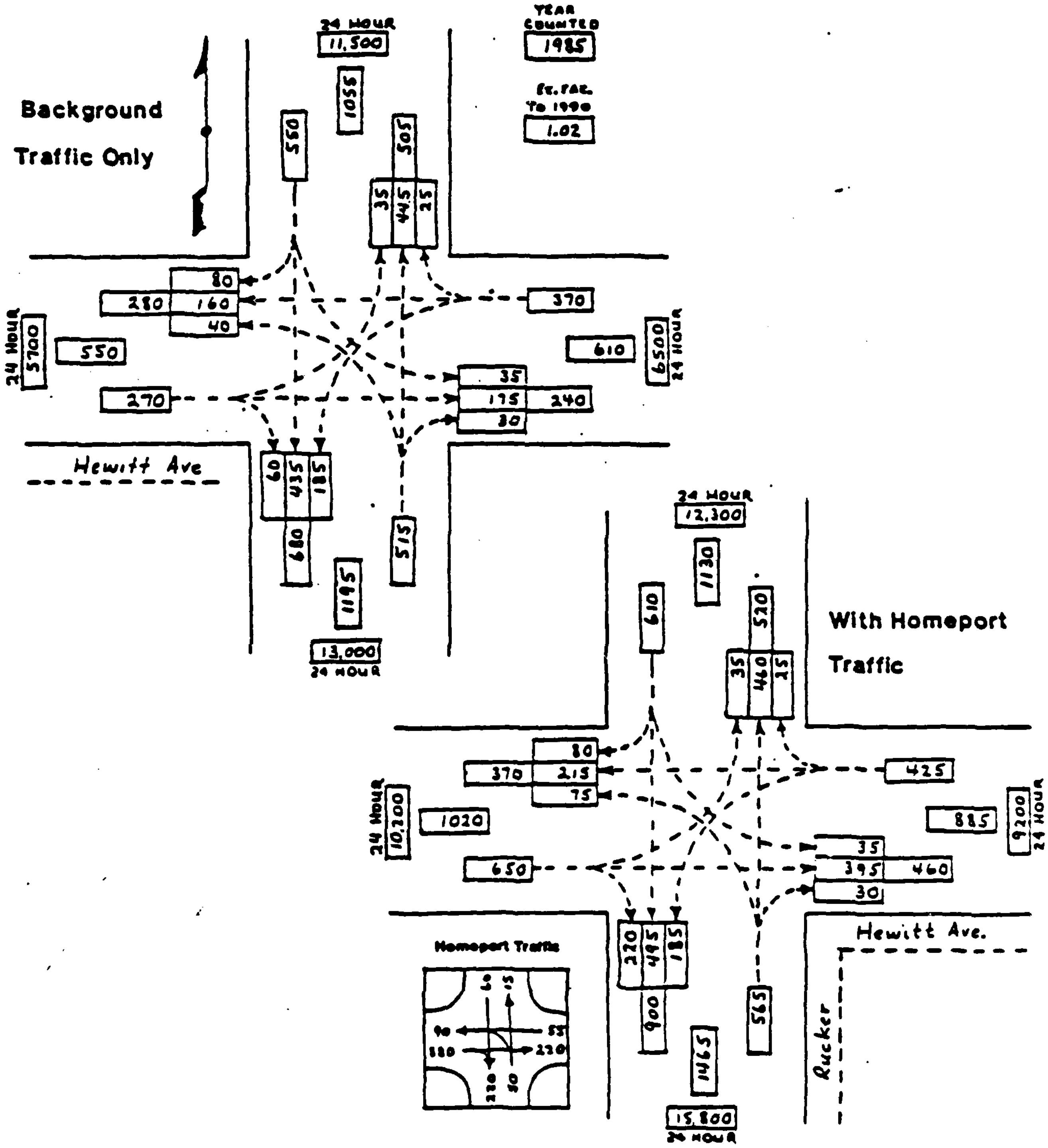


Figure C-12

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location RUCKER / 37TH ST.

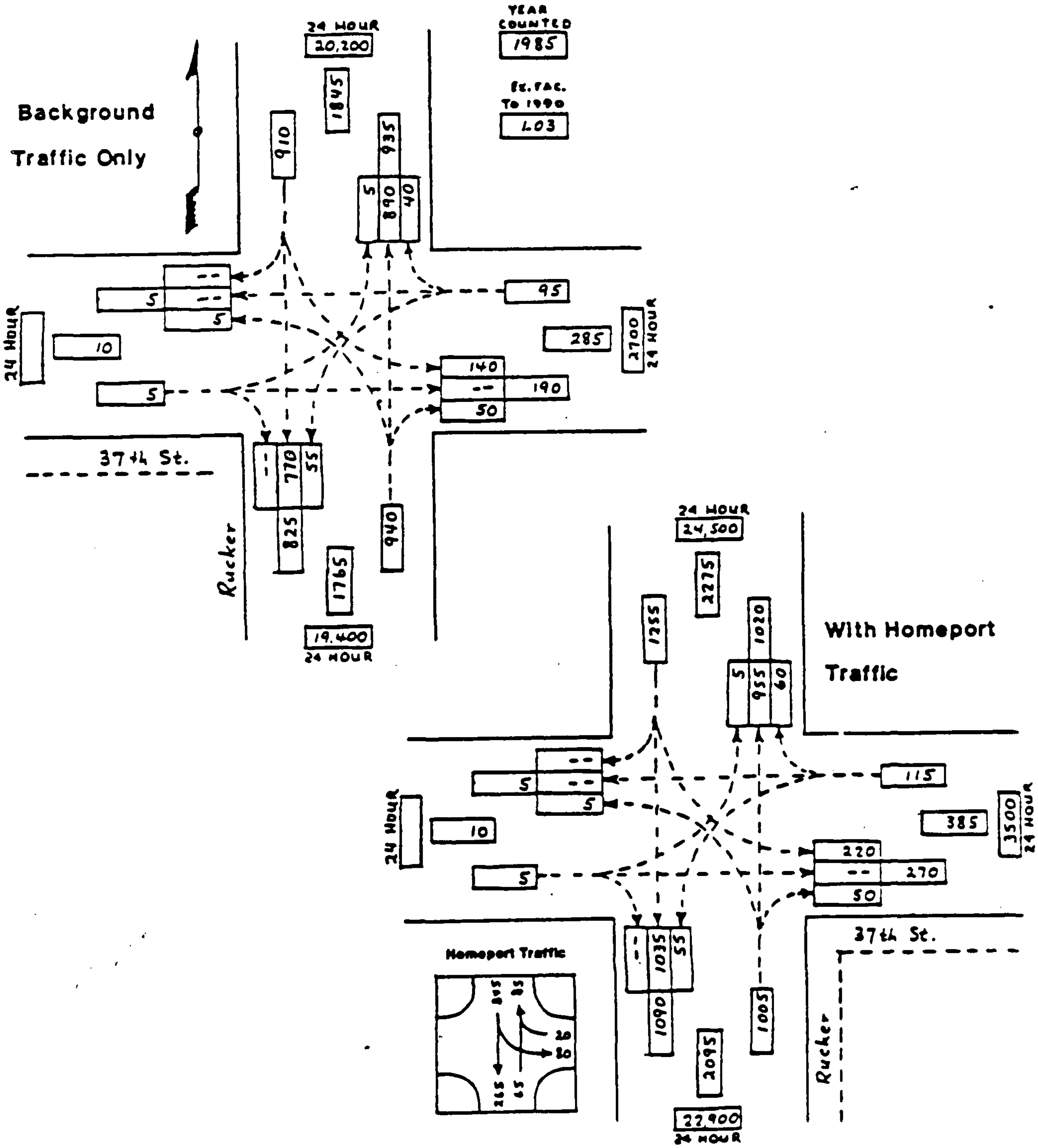


Figure C-13

TRAFFIC IMPACT – 1990

P.M. Peak Hour

Location BROADWAY/EVERETT AVE.

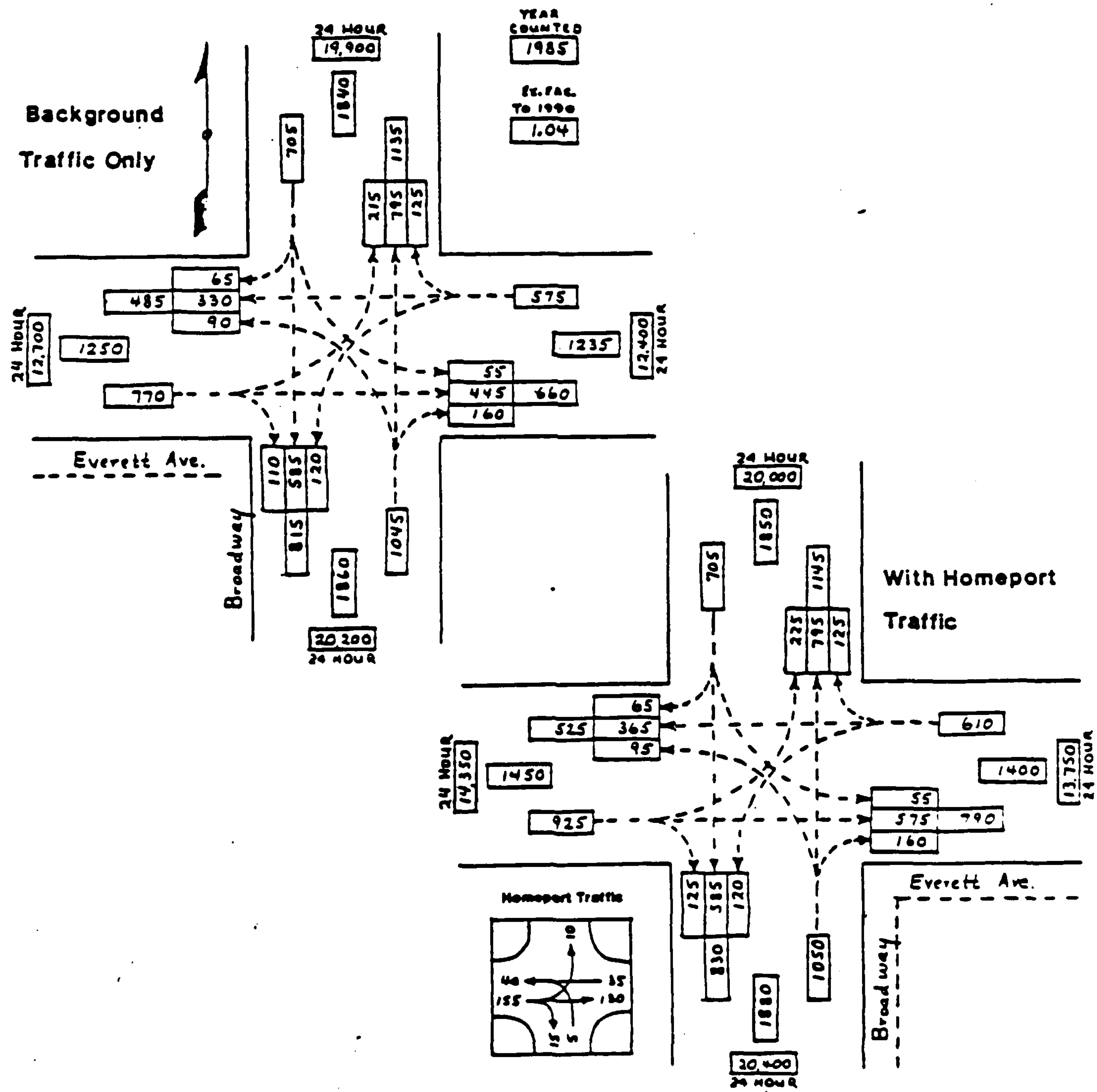


Figure C-14

TRAFFIC IMPACT - 1990

A.M. Peak Hour

Location W. MARINE VIEW DR. / EVERETT AVE.

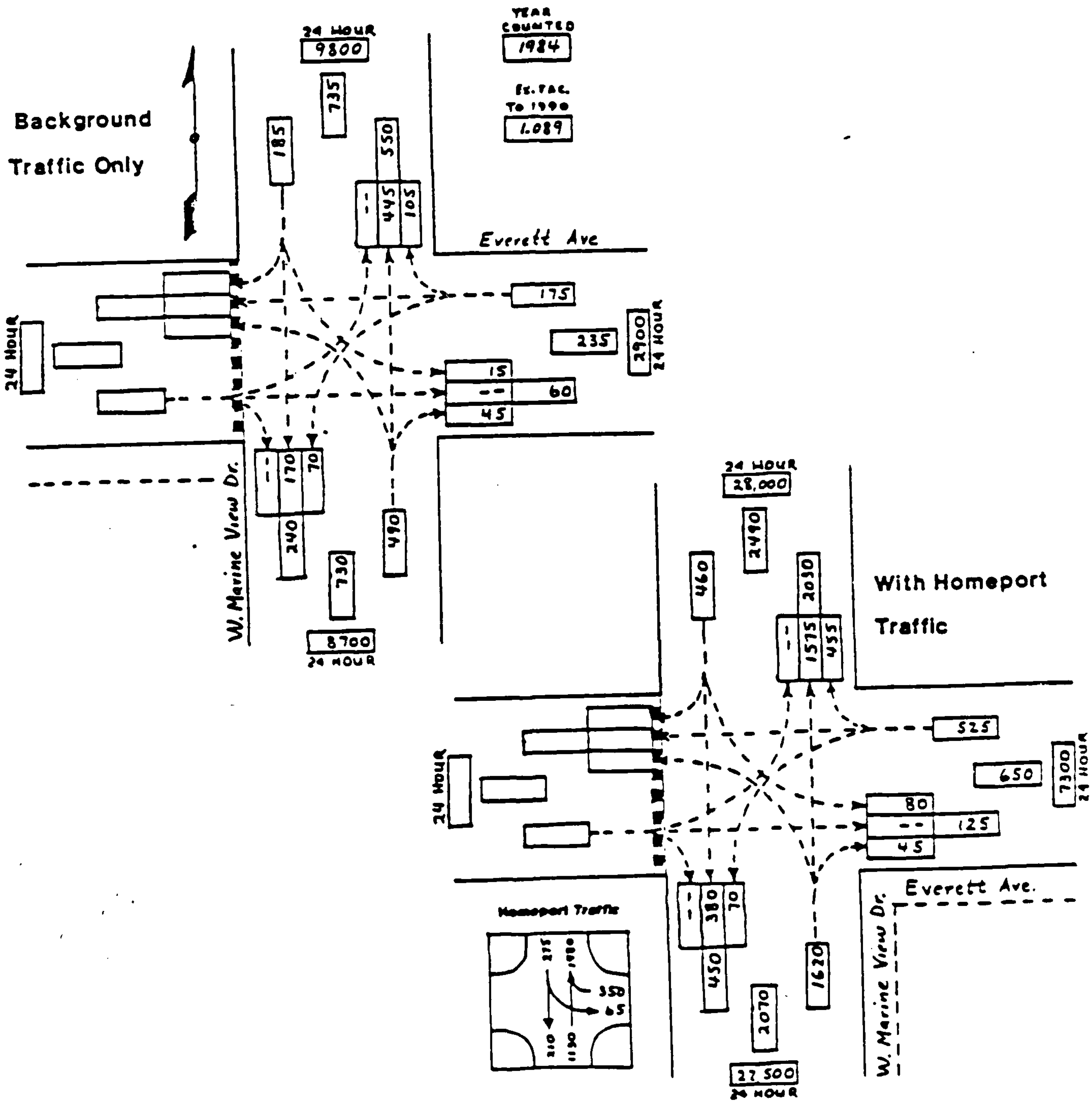
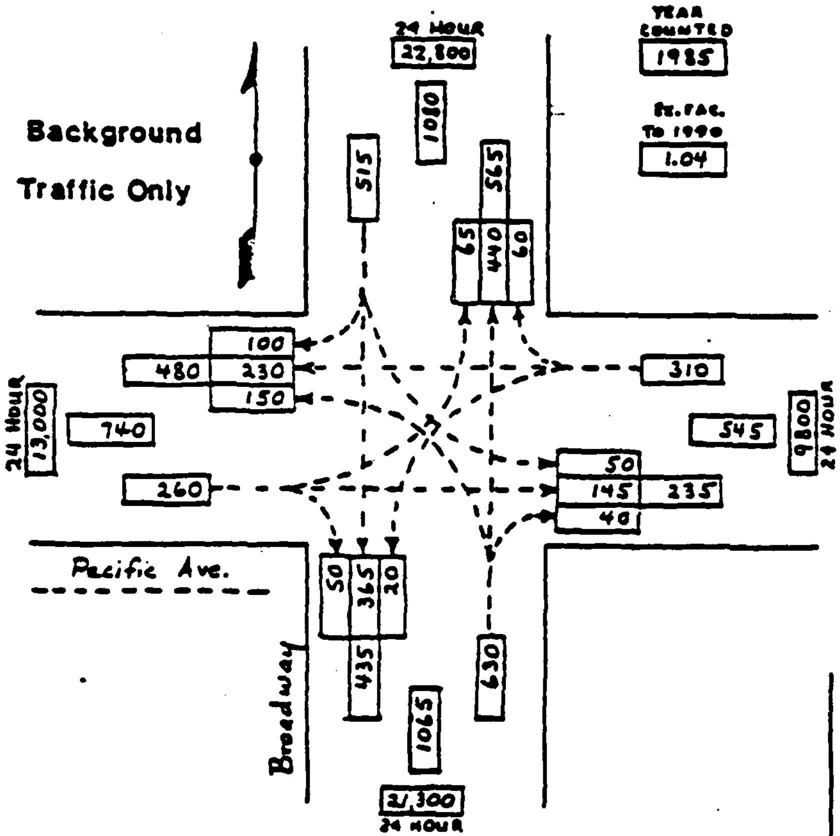


Figure C-15

TRAFFIC IMPACT – 1990

A.M. Peak Hour

Location BROADWAY / PACIFIC AVE.



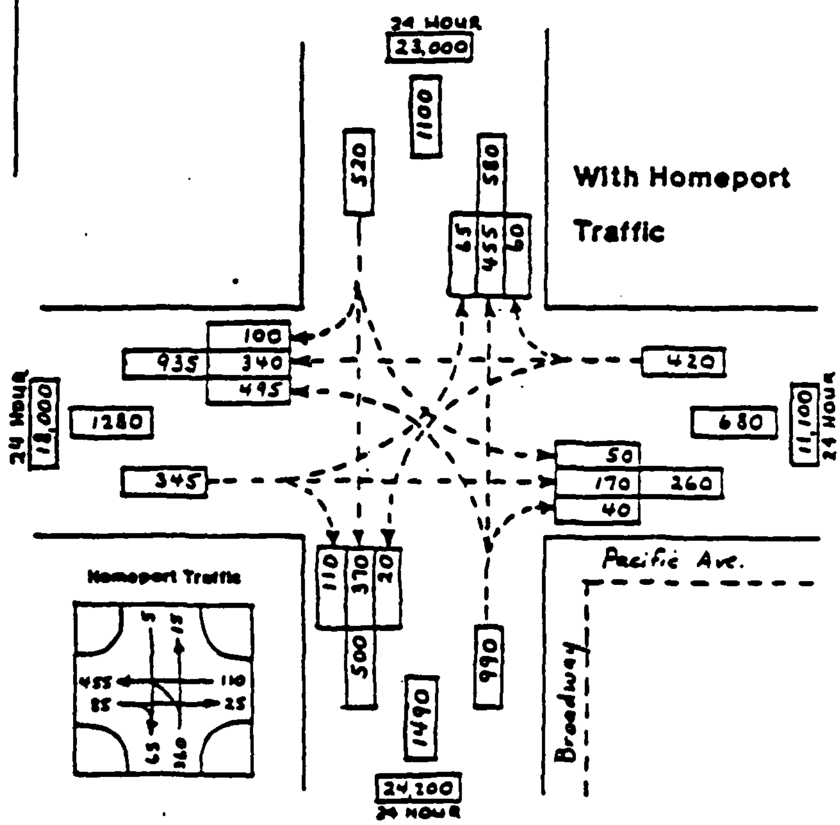


Figure C-16

TRAFFIC IMPACT – 1990

A.M. Peak Hour

Location BROADWAY / 37TH ST.

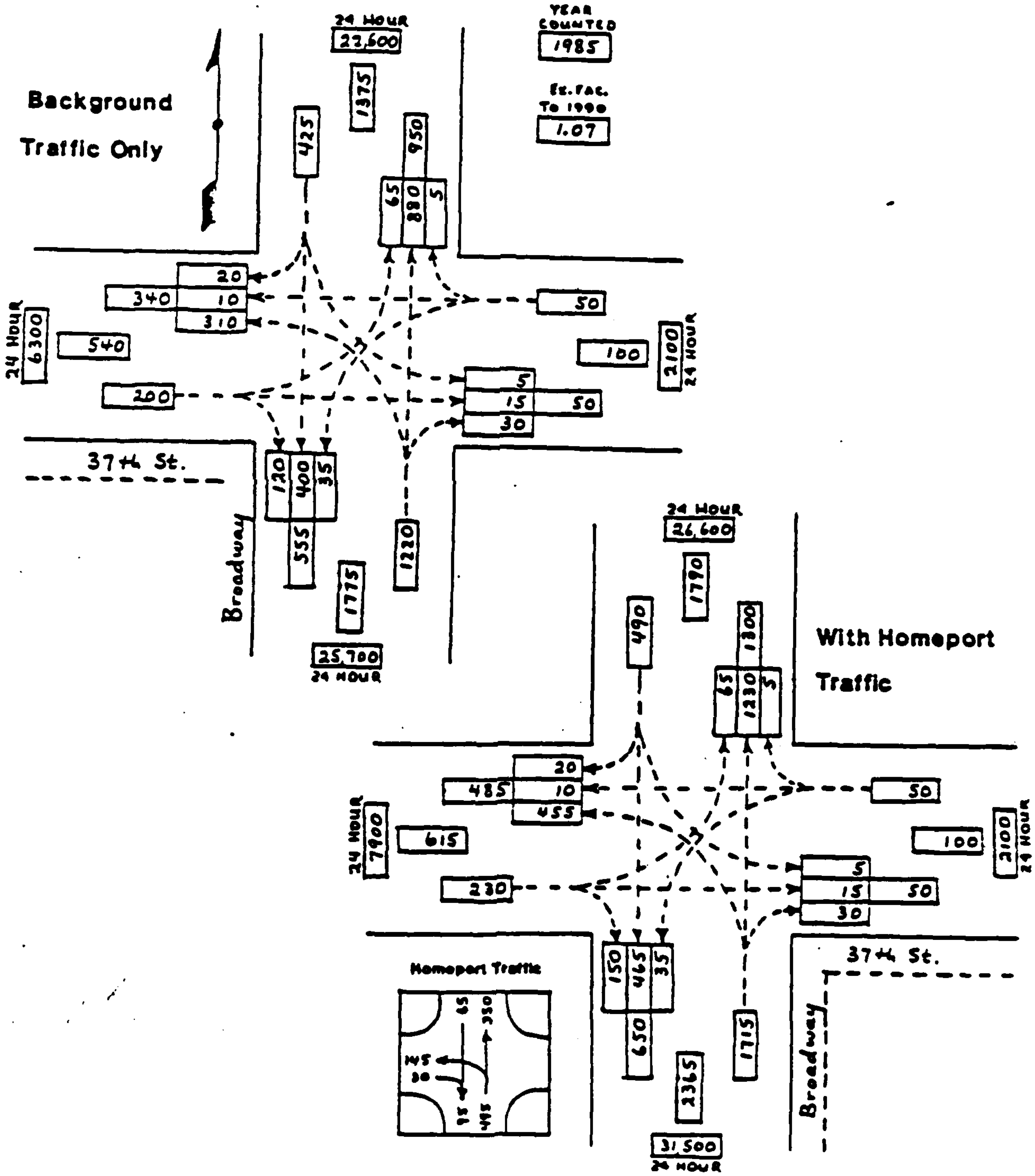


Figure C-17

APPENDIX B

TECHNICAL SUPPLEMENT TO SEDIMENT TESTING AND DISPOSAL ALTERNATIVES EVALUATION

U.S. NAVY CARRIER BATTLE GROUP HOMEPORT

EVERETT, WASHINGTON

TECHNICAL SUPPLEMENT

TO

SEDIMENT TESTING AND DISPOSAL ALTERNATIVES EVALUATION

PREPARED FOR:

DEPARTMENT OF THE NAVY

WESTERN DIVISION

NAVAL FACILITIES ENGINEERING COMMAND

PREPARED BY:

US Army Corps
of Engineers
Seattle District

SEPTEMBER 1986

U.S. NAVY CARRIER BATTLE GROUP HOMEPORT FACILITY
EVERETT, WASHINGTON

TECHNICAL SUPPLEMENT

TO

SEDIMENT TESTING AND DISPOSAL ALTERNATIVES EVALUATION

PREPARED FOR

DEPARTMENT OF THE NAVY
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Prepared by:
U.S. Army Corps of Engineers
Seattle District

September 1986

PREFACE

The U.S. Navy has proposed to homeport a Carrier Battle Group, consisting of 11 to 13 ships, in Puget Sound at Everett, just north of Seattle, Washington. A total of 3.3 million cubic yards of material would be dredged from East Waterway to provide berthing depth. Approximately 928,000 cubic yards of that total is contaminated. The proposed plan includes mechanical dredging of the contaminated sediment and contained aquatic disposal (CAD) at an average depth of 350 feet in Port Gardner. Capping of the contaminated material would be by hydraulic dredging the remaining approximately 2.4 million cubic yards of cleaner, underlying sediments.

This Technical Supplement report is an addendum to the Corps of Engineers June 1986 report and presents information and analyses on sediment testing and numeric dump modeling studies performed by the Corps' Waterways Experiment Station (WES), site investigations and tests performed by other Corps' contractors, and pertinant information from other Puget Sound studies which have become available since June 1986. The report provides project-specific evaluation to assist the Navy in meeting the requirements of NEPA, the Clean Water Act, and other appropriate Federal laws.

This report was prepared by the Seattle District, U.S. Army Corps of Engineers, Engineering Division. Principal author is Mr. John F. Malek, Assistant Project Manager, Planning Branch. Project Manager for the U.S. Navy Homeport Technical Assistance is Mr. Walter L. Farrar, Assistant Chief, Planning Branch. Technical input, review, and comment were provided by Mr. Keith E. Phillips, Assistant Study Director, Puget Sound Dredged Disposal Analysis, Planning Branch; Mr. A. David Schuldt, Chief of Tidal Hydraulics Unit, Civil Projects Section, Planning Branch; and Mr. Eric E. Nelson, Hydraulic Engineer, Civil Projects Section, Planning Branch.

The report was prepared under the general supervision of Mr. Dwain F. Hogan, Chief of Planning Branch; Mr. Richard P. Sellevold, Chief of Engineering Division; and Major Franz E. Koch, Deputy Commander - Military.

District Engineer of the Seattle District is Colonel Roger F. Yankoupe.

TECHNICAL SUPPLEMENT

to

SEDIMENT TESTING AND DISPOSAL ALTERNATIVES EVALUATION

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to

SEDIMENT TESTING AND DISPOSAL ALTERNATIVES EVALUATION

PART 1: BACKGROUND

Purpose and Scope. The U.S. Navy has proposed to site a Carrier Battle Group (CVBG) Homeport at Puget Sound in the East Waterway of Everett Harbor, Washington (figure 1). Construction of the Homeport facility will involve dredging and disposal of contaminated and uncontaminated sediments from the East Waterway. This report is one component of a technical assistance program to aid the Navy and its Architect-Engineers (A-Es) in design of dredging and disposal features for the project.

This report describes supplemental information and analyses which have become available since mid-May 1986 and is intended to be used in combination with the "Sediment Testing and DIsposal Alternatives Evaluation" report, dated June 1986. Changes in conclusions, as appropriate, resulting from new data generated or evaluated are provided.

Project Description. The dredging and disposal component of the proposed Homeport continues to evolve. Although CAD remains the Navy's preferred disposal alternative, the proposed site has shifted from the Deep Delta CAD site to a Southwest CAD site, and presently to a Revised Application Deep (RAD) CAD site. The RAD CAD site is located in the same general area in Port Gardner as the Deep Delta and Southwest CAD sites, but at a greater depth to minimize adverse impacts to Dungeness crab resources. In addition, the U.S. Navy is evaluating use of an upland site located on Smith Island. These sites are located on figure 2.

Corps of Engineers' Technical Assistance. Submittal of this Technical Supplement completes documentation of Phase III efforts as specified in the approved work plan for Seattle District techncial assistance to the U.S. Navy. Previous reports to the U.S. Navy include the "Sediment Testing and DIsposal Alternatives Evaluation" report, dated June 1986, and the "Dredging and Disposal Design Requirements" report, dated March 1986. Remaining technical assistance efforts contained in the work plan and which are scheduled for completion in January 1987 are:

- o complete on-going contracts;

- o continue project and contract management and coordination; and

- o publish technical reports for technology transfer.

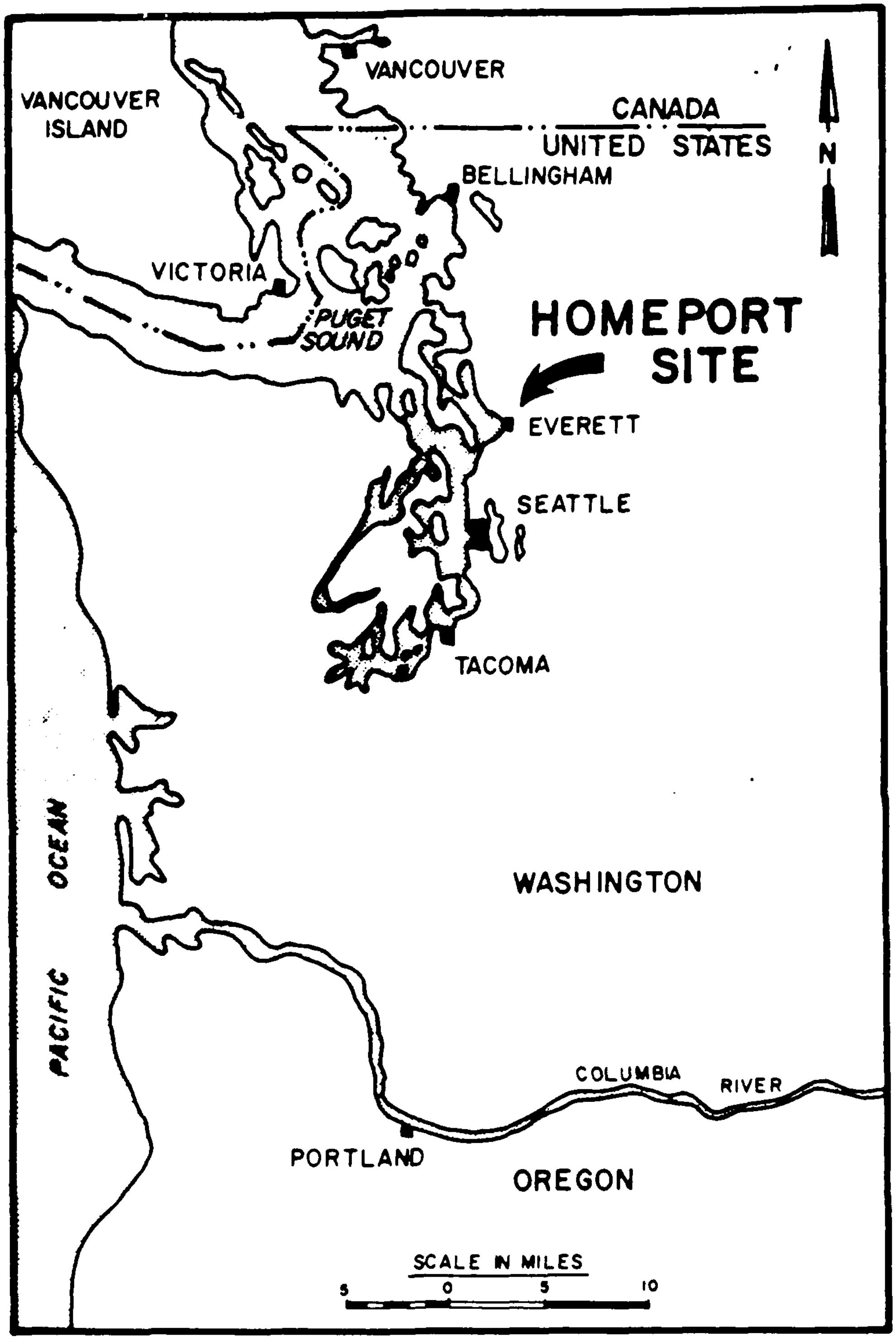
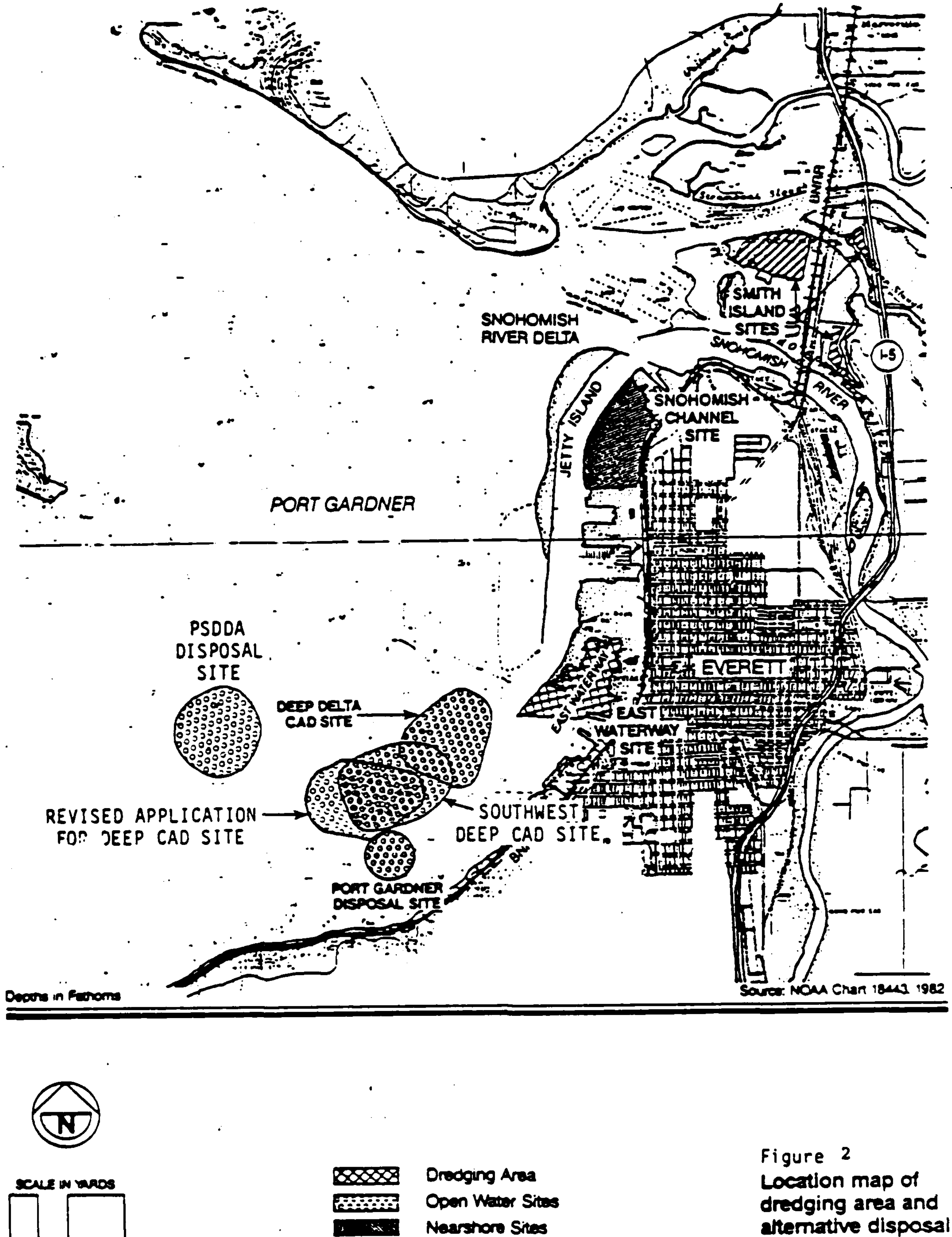


FIGURE 1. Location Map



Dredging Area
Open Water Sites
Nearshore Sites
Upland Sites

Figure 2
Location map of dredging area and alternative disposal sites.

PART II: DESCRIPTION AND RESULTS OF DREDGE AND DISPOSAL ALTERNATIVES

Smith Island Upland Disposal Site. The Navy final environmental impact statement identified several upland sites located on Smith Island. Two sites, designated as Smith Island 2 and Smith Island 4 (ABAM, 1986), were considered by the Navy to have the best potential for disposal of East Waterway sediments. These Smith Island sites could be excavated to allow placement of most of the contaminated sediments below the ground water table where they would remain anaerobic or they could be diked and used as a conventional upland site where the sediments would become aerobic.

Smith Island has been evaluated under the National Flood Insurance Program as part of the Snohomish County Flood Insurance Study, dated September 5, 1983, and is identified as a flood hazard area. The 100-year flood elevation at Smith Island is 9 feet above National Geodetic Vertical Datum (NGVD). Existing levees at Smith Island are inadequate to protect against seeping and overtopping during a 100-year frequency flood. Studies would be necessary to determine ground water levels as well as directions and velocities of underground flow.

The testing results described in the Corps' June Disposal Alternatives report and the supplemental results contained in this report are directly applicable to evaluation of an upland site. There are insufficient technical data presently available on the Smith Island site to determine if its use is feasible based uupon environmental and engineering factors. Preliminary cost estimates indicate that use of Smith Island would cost more than CAD. Until site configuration and additional data on site conditions are obtained, a site-specific evaluation for upland disposal similar to those performed in the June report cannot be performed.

PART III: DESCRIPTION AND RESULTS OF STUDIES AND TESTS

Sediment Testing.

Mass Release Performance Goal. A performance goal of 5 percent for total mass release for contaminants from both dredging and disposal was specified as a means to evaluate the efficiency of performances of conventional dredging equipment and return parthways (e.g., effluent, disposal discharge, etc.). The 5 percent goal does not consitute a standard to be met in any regulatory or contractural sense nor does it have any direct application to environmental impact. All mass release estimates were made based on the best current information and all tend to be conservative. For example, the 2 percent resuspension during clamshell dredging was assumed to be completely lost for purposes of performance evaluation. This overestimates dredging mass release, as a significant percentage of the suspended material will resettle in the dredge area and be removed in the next dredging pass. The mass release performance goal allows a manager to compare performances of hydraulic versus mechanical dredges or of individual disposal sites. This evaluation can suggest also that controls could be useful to reduce mass releases via a particular return pathway (e.g., effluent return). The appropriateness and need of additional control is a separate regulatory decision.

Comparison of East Waterway Sediment Values to Preliminary Puget Sound Guidelines. The results of chemical and biological tests conducted in 1984-1985 (COE, 1985a & 1985b) on East Waterway sediments were interpreted using available interim criteria for dredged material proposed for discharge at the Fourmile Rock and Port Gardner disposal sites. (The Port Gardner interim criteria are essentially identical to the Puget Sound Interim Criteria.) These interim criteria, developed by Region 10, Environmental Protection Agency (EPA) and the Washington Department of Ecology (WDE), were the only ones available for regulatory purposes in Puget Sound and are expected to govern through completion of the proposed Navy project. New disposal guidelines are presently being developed by the Puget Sound Dredged Disposal Analysis (PSDDA). Expected to be available in late 1987, the new disposal guidelines will eventually replace the interim criteria. They will be applicable primarily to the multi-user sites designated and managed by the Washington De artment of Natural Resources (DNR) for unconfined, open-water disposal of dredged material in Puget Sound.

A comparison of East Waterway contaminated surface composite (using PNL data from the Phase III testing results) with the August 1986 proposed PSDDA guidelines indicates that East Waterway material would be labelled as Category 4. Due primarily to the high levels of polynuclear aromatic hydrocarbons (PAH's) and the bioassay responses, East Waterway contaminated material could not be discharged unconfined in Puget Sound. Confined disposal (either aquatic, land or shore) would be required.

Sea Surface Microlayer (SSM). The SSM consists of the top 100 microns of the sea surface where large numbers of bacteria, phytopplankton, and animal eggs and larvae have been shown to occur. In addition, the SSM often concentrates materials that are not very soluble, are lighter than water, and/or are adhered to floatable matter. Recent testing of the Everett Harbor contaminated sediments (appendix E) indicate that the fraction of the sediment metals and extractable contaminants found in the microlayer in experiments designed to simulate the dredging and disposal sediment disturbances varied between 0.01 and 0.02 percent. The less soluble contaminants, such as PCB's and pesticides, were not released in measurable quantities. Though additional biological testing is still under analysis, these data suggest that the bulk of the sediment contamination will remain associated with the sediment particles, and that SSM for the East Waterway contaminated sediments would not be a significant loss.

Environmental and Engineering Tests.

Leachate Test. Aerobic leachate tests have been completed and data and interpretations are contained in appendix C to appendix A. The fraction of metals that was resistant to anaerobic leaching was generally greater than 90 percent of the bulk sediment concentration. Under aerobic conditions, over 85, 65, and 49 percent of the Zn, Ni and Cd was mobilized in the tests. This higher metal release observed in aerobic testing is related to pH: the pH in aerobic testing was lower than the pH in anaerobic testing. Recently available data from the leachate tests confirm earlier assessments, as shown in Table 1.

The table shows that Cr and Pb predicted leachate qualities for the anaerobic disposal environment slightly exceed drinking water standards. In aerobic disposal environments, Cd, Cr and Pb would exceed standards by a substantive amount. Though the application of drinking water standard as criteria for the design of an upland site may not be appropriate for sites not in proximity to potable ground water, these data clearly suggest that potential leachate losses would need to be addressed for upland disposal.

TABLE 1

CONTAMINANT LEACHING CONCENTRATIONS
(mg/1)

Contaminant	Anaerobic	Aerobic	Federal/State Drinking Water Standards
As	.039	<0.005	0.05
Cd	.010	0.034	0.010
Cr	.080	2.27	0.05
Cu	.096	0.023	1.0
Ni	.052	0.449	NA
Pb	.058	0.210	0.05
Zn	.181	3.5	5.0
PCB	.00036	0.00176	NA

Consolidation Test. A consolidation test was conducted using the composited contaminated sediment to provide data for evaluation and settlement rates for confined sites. The test results, contained in appendix G of appendix A, are applicable for evaluation of both nearshore and upland sites. The physical properties of the contaminated and native sediments are similar and consolidation behavior for the two sediments would be comparable on a qualitative basis. WES has made predictions of consolidation behavior of capping material for the CAD alternative. Results indicate that the assumption of 50 percent consolidation of the cap is very conservative.

Mounding Evaluation. An evaluation of mounding characteristics for the CAD design was made (appendix A). This evaluation replaces the evaluation made in the Disposal Alternatives Report and utilizes results of WES Hydraulics Laboratory dump modeling and data from existing disposal mounds. The evaluation by WES did not include placement of a berm, which is considered to be an additional conservative measure. The mounding configuration described indicated that sufficient capping material is available to place the required one meter cap over the contaminated mound. Monitoring should define the final configuration of the contaminated mound and the applied cap thickness after initial placement and consolidation.

Dump Model Studies. A technical supplement report has been prepared by WES Hydraulics Laboratory and is provided as appendix B. These data and evaluations were included in the Disposal Alternatives Report in summary form. Results of the 400-foot model run were provided to the Navy as supplemental information.

Disposal Site Biological Investigations. Appendices C and D contain the Summer Trawl Report (June trawls) and Autumn Trawl data (September trawls) provided by the University of Washington School of Fisheries and Fisheries Research Institute. The Autumn Trawl data include Dungeness crab catchs only. An Autumn Trawl Report is scheduled for submittal in October 1986. This completes Phase III disposal site investigations in Port Gardner.

Dungeness crab. Results of the June and September trawls confirm earlier conclusions that Dungeness crab are present in significant numbers throughout the year in the area of the Deep Delta CAD. Crab catches were sharply reduced in the September trawls and greater movement of crabs into deeper water was noted. Relocation of the CAD site to deeper water (RAD CAD) places it at the Control 1 site defined for this study. Crab abundance has been consistently low throughout the study at this location.

Shrimp. Average shrimp densities in Port Gardner remained low for June. September trawl catches have not been processed. The highest shrimp densities were off Mukilteo. Unpublished data have been obtained and are being analyzed to provide perspective on the relative importance of shrimp in Port Gardner.

Bottomfish. Bottomfish patterns for abundance and biomass in June were similar to previous trawls. Results continue to support the conclusion that the Deep Delta CAD area may be a nursery area for juvenile Pacific hake.

PART IV: EVALUATION OF DREDGING AND DISPOSAL ALTERNATIVES

Disposal Alternatives Analysis. Appendix F presents the relative advantages and disadvantages of disposal alternatives that have been considered for disposal of East Waterway sediments. A comparison of alternatives is presented, noting the important issues and tradeoffs associated with each disposal alternative. Three basic types of disposal are typically considered for contaminated dredged material: contained aquatic (CAD), nearshore (intertidal), and upland. Summaries of pertinent information are as follows:

Contaminant Pathways. The key contaminant pathways that require consideration for Everett Harbor sediments are:

CAD: deposited mound
near-bottom mass release

Upland: effluent releases
leachate releases

For CAD, current estimates of the mass release for the combined dredging and disposal are around 4.1 percent, split evenly between the dredging and disposal sites. Though estimated mass release for upland depends on the specific site involved, releases for the nearshore sites in the Everett Harbor area were calculated to vary from 4.3 to 5.5 percent. The primary differences between CAD and upland mass releases is the potential for using effluent treatment to reduce contaminant losses. Given the unknown fate of the releases, proper siting of the disposal site and reasonable management practices (including design and performance goals) are the primary tools for addressing mass releases. The fact that the bulk of the contamination still remains with the deposited sediments is also salient.

Control and Treatment Options. Primary control and treatment options to restrict contaminant migration address:

- resuspension at the dredge site
- pathways at the CAD
- contaminant migration through pathways of:
  - -surface water
  - -leachate/ground water
  - -plant/animal uptake
  - -air

Remedial Action Techniques. For CAD, the placement of additional or different capping materials is the primary method for remediation. Possible reasons for failure of the original cap include:

- incomplete original capping (or inadequate thickness)
- unexpected animal or human bioturbation
- unexpected physical erosion or geologic disturbance
- through-cap diffusion of chemicals
- ebullition (gas formation) and cap disruption

Of these five possibilities, the first three are more likely than the latter two. These three are effectively addressed by adding more cap material. Through-cap diffusion is a very slow process. This diffusion rate can be easily monitored via cap coring and analysis (most caps are self-healing after coring). More cap material continues to effectively prevent release of the contamination. Ebullition can result in gas-transported contaminant loss, but is greatly reduced in anaerobic environments relative to aerobic ones. Any physical cap disruption can be repaired by more cap material. In addition, different cap materials can be brought to the site to improve thickness, provide resistance to erosion, reduce permeability, etc., as needed.

Remedial response at upland sites is much more diverse. Once the site has been filled, typical monitoring includes leachate and runoff quality measurements. Assuming runon controls and surface covers are in place, and gas formation is not a major issue, the emphasis in the long-term is ground water and surface water seeps. Sites can be designed to include second liner systems and leachate collection drains, though these types of designs are usually specified for more dangerous and hazardous waste. With these systems, leachate can be monitored, collected and treated, as necessary.

Disposal Site Tradeoffs. In general, disposing of contaminated sediments in a chemical environment as close as possible to their in situ state favors retention, especially of metals. Geochemical changes associated with air and oxygen in upland and nearshore sites can change sediment pH (mobilizing metals) and alter (dissolve, degrade, or volatilize) sediment organic carbon (mobilizing organics). Based on this, many contaminants would tend to stay bound to sediments better in an open-water, capped site than a nearshore or upland site.

Open-water sites, especially those in deep water, have fewer transport mechanisms (e.g., air is absent) than upland sites. Nearshore sites have the most transport routes available and are located in a very active environment; therefore, nearshore disposal generally is the least preferred method for long-term confinement of contaminants.

In terms of controlling contaminant release, open-water disposal allows for very few controls of releases other than cap thickness. However, increasing cap thickness is a relatively simple and effective control method. Upland disposal, on the other hand, allows for the greatest control through design features, monitoring capabilities, backup contaminant intercept systems, and treatment facilities.

CAD allows higher short-term mass releases, but has opportunities for longer-term control due to lower mobility of chemical contamination. Upland disposal has less short-term mass releases, but greater long-term concerns due to mobilized contamination and the active physical forces that can move contamination. Nearshore, generally a more dynamic environment than either CAD or upland, shares advantages and disadvantages of both the other alternatives.

PART V: CONCLUSIONS

General. Any disposal operation involving contaminated sediments must be considered a complex engineering and construction activity due to potential risks to the environment in the event of error and/or failure. Although there is greater familiarity with design and construction of nearshore and upland confined disposal sites, the need for sound engineering and construction techniques applies equally to these options as for the Navy's preferred alternative, contained aquatic disposal (CAD). While it is true that CAD has not yet been attempted in over 100 feet of water, the field work of Yale University found the same placement processes occurred in depths ranging from 60 to 220 feet. The same physical parameters of sediment settling occur at depths of 300 to 400 feet, therefore, CAD at these depths is more an extension of existing technology than new technology. Corps' sediment disposal evaluations have been made using a Management Strategy based on 15 years of intensive research on dredging and disposal and employing the best available technical approaches, including testing protocols designed especially for dredged material and disposal modeling. Nevertheless, there is no way to predict with absolute certainty what will occur during construction. The monitoring plans presented have been developed to compensate for this uncertainty and to determine the effectiveness of performance. Continuity between design and construction must be recognized and reflected in contract flexibility that permit quick response to monitoring results and necessary adjustments to dredging or disposal operations.

Dredging. Conclusions presented in the June 1986 Disposal Alternatives Report have been reviewed and updated as appropriate. The specific conclusions for mechanical and hydraulic dredging remain effective. Supplemental conclusions are presented below:

o Debris removal and sediment dredging should occur as concurrent, but separate, activities. Debris removal should be by orange peel or similar equipment onto a separate barge for subsequent upland disposal. Large, solid debris removed incidental to sediment dredging should be transferred to the debris barge. Soft or small debris removed incidental to sediment dredging can be handled and disposed with the dredge contaminated material.

o Dredging of the dredge contaminated material in the inner harbor (P-112 and P-905) should occur beginning at the north end of the waterway and proceeding south to the extent practicable.

o Material to be used for berm construction should come from the area of the breakwater. The top two feet (average depth) of sediment to be dredged in fiscal year 1987 (P-111) at the carrier pier and around the outside of the mole is contaminated. Dredging of this material should occur in two lifts. The first lift should remove at least the top two feet with disposal of this material on top of or with the dredge contaminated sediments. This lift can be accomplished by mechanical or hydraulic dredge. The remainder of the sediment from this area can be removed during the second lift as a single unit.

Disposal. Conclusions presented in the June 1986 Disposal Alternatives Report have been reviewed and remain effective. Supplemental conclusions are presented below:

o Results of the June and September trawls by the University of Washington School of Fisheries confirm earlier conclusions that Dungeness crab are present throughout the year in the area of the original Deep Delta CAD site. The relocated RAD CAD site is virtually the Control 1 site which will lessen adverse impacts to the crab and bottomfish resource.

o Accurate placement of the contaminated sediment by surface discharge from bottom-dump barges is considered feasible and environmentally acceptable provided (1) point dumping can be assurred and (2) the barge is completely stopped during discharge. Control of the barges during surface discharge of the contaminated sediment must be maintained, e.g., taut-wire moored bouy, short hawser, and opening the doors only when close aboard the disposal bouy(s). Should monitoring reveal that the contaminated material is mounding too steeply, the discharge point should be adjusted to control mound formation to design dimensions.

o A single model run was made for bottom-dump discharge of contaminated material at a 400-foot depth. These results indicate 3.6 percent of the material remains in suspension after 1800 seconds. Deposition patterns for the 400-foot run showed little change over the 265-foot runs. This indicates that the "bottom footprint" used for mounding evaluation of the 265-foot Deep Delta CAD would be approximately the same for a 400-foot depth. No model runs for hydraulic placement of the capping material have been made for the 400 feet depth condition. However, it is believed that results would be similar to those generated for the 265 feet depth.

o Consolidation tests indicate that hydraulically-placed capping material will consolidate less than one foot following placement. This indicates that the 50 percent consolidation estimate used in design is very conservative and that the cap will exceed the one meter operational requirement.

o Results of aerobic leachate tests confirm potential leachate problems with certain heavy metals (i.e., Pb, Cr, Cd) and with PCB 1254. This is an important design criteria for upland disposal site(s).

Monitoring. Monitoring of CAD performance is critical. A detailed monitoring plan for CAD is provided in appendix I of the WES report. This plan should be finalized based on final project designs and the "parameters of success" to be developed by the State of Washington. Evidence of effective capping during the first year (FY 1987) is especially important.

Conclusions presented in the June 1986 Disposal Alternatives Report have been reviewed and remain effective. Supplemental conclusions are presented below:

o The Navy and State of Washington should convene an advisory panel of "staff level" experts familiar with Puget Sound to review final monitoring plans relative to the parameters of success upon which the first year disposal will be judged. Ideally, the panel would meet before the Navy commits to the parameters of success. The purpose of the panel would be to advise the Navy of potential problem areas, application of data, etc.

o Monitoring to determine the performance of CAD should be a separate activity and task from construction contractor performance monitoring. Although there is some opportunity for overlap, this detailed monitoring program must be conducted by a fully qualified group or firm with experience in data collection, analysis, and interpretation.

Management. These supplemental conclusions have been added to emphasize the importance of continuity between CAD design and construction:

o The Navy and construction contractor should understand that the first year of dredging and disposal will require extraordinary attention, flexibility, and coordination to allow adjustments to the construction as dictated by the results of the monitoring program. The Navy should consider option clauses in the construction contract for changes in items such as volumetric dumps or discharges, disposal point locations, etc. based upon monitoring results.

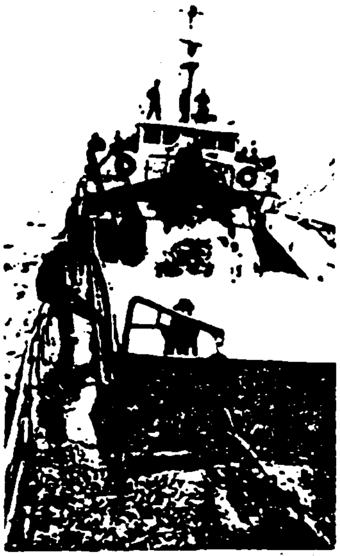
o Adjustments to the dredging and disposal operation should be anticipated and reflected in plans and specifications.

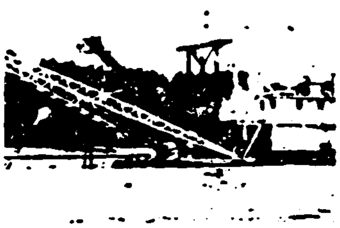
o Continuity of key members of the design team through construction is essential. This would include design A-E services during construction for review of monitoring data, consultation, etc. Lacking complete understanding of the basis of certain design requirements, on-site modifications may be made that violate the integrity of the design objective.

o The Navy should consider designation of a specific office or individual to oversee the monitoring and to coordinate the monitoring results into ongoing construction inspection and decisionmaking.

APPENDIX A

US Army Corps of Engineers





TECHNICAL SUPPLEMENT TO EVALUATION OF DREDGED MATERIAL DISPOSAL ALTERNATIVES U.S. NAVY HOMEPORT AT EVERETT, WASHINGTON

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

by

M. R. Palermo, J. M. Brannon, T. E. Myers, R. A. Shafer, S. A. Adamec, D. M. Griffin, Jr.

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Prepared for
U.S. Army Engineer District, Seattle
P.O. Box C-3755, Seattle, Washington 98124-2255

PREFACE

This report describes supplemental information regarding an evaluation of dredging and disposal alternatives for the proposed U.S. Navy Homport at Everett Washington. The U.S. Army Engineer District, Seattle is assisting the Navy in preparing a dredging plan for approximately 928,000 cubic yards of contaminated sediments which require dredging as a part of the project. The report is based on current results of sediment testing and disposal modeling being conducted by the U.S. Army Engineer Waterways Experiment Station (WES) for the Seattle District. WES prepared a report describing design requirements for the project in March 1986, and a report on evaluation of disposal alternatives in June 1986, based on the project description, sediment testing, and modeling conducted through those dates. This report is an addendum to the June 1986 report and is intended to provide information in support of the Corps permit evaluation for the project under Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act as amended.

The report was prepared by the following personnel of the Environmental Engineering Division (EED) and Ecosystem Research and Simulation Division (ERSD) of the WES Environmental Laboratory (EL), and Estuaries Division (ED) of the WES Hydraulics Laboratory (HL): Dr. Michael R. Palermo, Mr. Rick Shafer, Mr. Tommy E. Myers, and Dr. D. M. Griffin, Jr., EED; Dr. James M. Brannon, ERSD; and Mr. Steven A. Adamec, ED. Technical review and comment on various portions of the report was provided by Dr. Robert M. Engler, Manager, Environmental Effects of Dredging Programs, EL; Mr. Norman R. Francingues, and Mr. M. John Cullinane, EED; Dr. Thomas L. Hart and Dr. Charles R. Lee, ERSD; Dr. Billy H. Johnson, Hydraulic Analysis Division, HL; and Mr. John Malek of the Seattle District.

The report was prepared under the general supervision of Dr. Raymond L. Montgomery, Chief, EED, Mr. Donald L. Robey, Chief, ERSD, Mr. William H. McAnally, Chief, ED, Dr. John Harrison, Chief, EL, and Mr. Frank Herrmann, Chief, HL.

Director of WES was COL Allen F. Grum, CE. Technical Director was Dr. Robert W. Whalin.

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APPENDICES*

Appendix C: Leachate Testing

Appendix G: Consolidation Testing

Appendix I: Monitoring Plans

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* Other appendices are contained in the parent report to this technical supplement.

AD-A175 114 CARRIER BATTLE GROUP (CVBG) HOMEPORTING IN THE PUGET SOUND AREA WASHINGTON STATE TECHNICAL APPENDICES(U) CORPS OF ENGINEERS SEATTLE WA SEATTLE DISTRICT NOV 86 2/7

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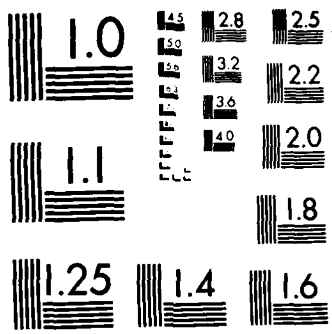
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INTRODUCTION

Background

The US Navy has proposed to homeport a carrier battle group at Everett, WA. Development of the homeport will involve dredging and disposal of approximately 928,000 cubic yards of contaminated sediments from the East Waterway, Everett Harbor. An additional 2,377,000 cubic yards of uncontaminated native material must also be dredged. The Navy has requested the Seattle District provide technical assistance in developing a dredging and disposal plan for these sediments from the East Waterway. In addition, the Seattle District must act in its role as permitting agency under Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act. The Seattle District has requested the Waterways Experiment Station (WES) to provide support for testing and evaluations required for its technical assistance role for the Everett project.

Purpose and Scope

The purpose of this report is to provide supplemental information which has become available since June 1986 regarding evaluation of dredging and disposal alternatives for the Everett Homeport project. Information is provided on leachate testing, consolidation testing, applicability of modeling results to alternate contained aquatic disposal (CAD) sites, mounding characteristics for the CAD alternative, applicability of sediment testing results to the upland disposal alternative and monitoring plans.

Sequencing of WES Reports

WES prepared a report entitled "Dredged Material Disposal Design Requirements for U.S. Navy Homeport at Everett, Washington" (Palermo, et al 1986) and submitted the report to the Seattle District in March 1986. For simplicity, that report is referred to herein as the "Design Requirements" report. WES prepared a second report entitled "Evaluation of Dredged Material Disposal Alternatives for U.S. Navy Homeport at Everett, Washington" (Palermo et al

1986b) and submitted the report to the Seattle District in June 1986. That report is referred to herein as the "Disposal Alternatives" report. The Disposal Alternatives report provided site specific evaluations of selected alternatives and was intended to support the Supplemental Environmental Impact Statement to be prepared by the Seattle District to support the Navy's permit application. The report was based on testing and modeling conducted as of 1 May 1986. This report supplements the Disposal Alternatives report and contains the results of testing and evaluations to 1 September 1986. This report is intended to complete technical information in support of the evaluation for the project.

This report is not intended to be used as a stand-alone document. Rather, it is a technical supplement to the Disposal Alternatives report. Background information and interrelationships between the various parts of this report are found in the Disposal Alternatives report. Changes in conclusions, as appropriate as a result of new data generated or evaluated since the Disposal Alternatives report are provided herein.

PART II: SEDIMENT SAMPLING AND TESTING

Leachate Prediction Tests

(This section replaces the corresponding section in the Disposal Alternatives Report.)

Procedures

When contaminated dredged material is placed in a confined nearshore or upland disposal facility, the potential exists to generate leachates having adverse impacts on groundwater and surface water quality. Subsurface drainage and seepage through dikes may reach adjacent surface and ground waters, resulting in contamination of ground water and deterioration of surface water quality.

At present, there is no routinely applied laboratory testing protocol capable of predicting leachate quality from confined dredged material disposal sites. Newly-developed testing procedures to predict leachate quality are, therefore, being used to evaluate the confined disposal alternative for Everett Harbor dredged material. These leaching techniques have only been used once before, therefore, the procedures are in an early stage of development and results have been interpreted with caution. When properly applied, these techniques should allow determination of the potential impacts of using a nearshore or upland site. This information is needed to develop cost effective site designs.

Appropriate testing procedures were evaluated and applied for estimating leachate contaminant levels from Everett Harbor sediment for the nearshore and upland disposal alternatives. Laboratory leaching tests used for predicting short-term and long-term leachate quality included sequential batch leaching tests and permeameter testing, a modified form of column leaching. Results from these tests were combined with a mass transport equation to provide an integrated approach for predicting contaminant concentrations from a CDF. Details of the integrated approach and its application to Everett Harbor sediment are provided in Appendix C.

Results

Batch Testing. The intrinsic release characteristics of Everett Harbor dredged material for As, Cd, Cr, Cu, Ni, Hg, Pb, Zn, PAHs, and PCBs were determined using sequential batch leaching tests. Tests were also conducted to determine shaking time required to reach steady-state concentration values, the proper liquid-solids ratio at which to conduct batch tests, and the effects of varying salinity on metal concentrations in leachate.

Desorption isotherms were developed using data from the sequential batch leaching tests. The sequential batch leaching tests involved shaking sediment with successive inputs of fresh distilled-deionized water and analyzing the leachate. Procedures used in the anaerobic sequential batch leaching tests are described in Appendix C. From the desorption isotherms, the mass of contaminant leached and where possible distribution coefficients, K_d, were obtained. The desorption isotherms for metals and organics fall into four distinct groups. These groups consisted of (1) desorption isotherms with leachate values that were near the detection limit for the parameter, (2) desorption isotherms that produced a linear relationship between steady-state sediment and leachate concentrations, (3) desorption isotherms that showed a double-valued relationship between steady-state sediment and leachate concentrations, and (4) desorption isotherms that did not show a well-defined relationship between steady-state sediment and leachate concentrations.

Desorption isotherms for anaerobic metals fit into all four of these categories. Hg was not detected in any of the leachates and fell into category (1). Cu and Pb fell into category (2). As and Ni fell into category (3), and Cd, Cr, and Zn fell into category (4). For aerobic sequential leaching, Hg and As fell into category (1). Ni and Zn fell into category (2), and the remainder of the metals fell into category (4).

Releases of organic contaminants from anaerobic sediment were measurable for only 8 of 33 compounds analyzed during sequential leaching. Compounds that were detected fell into category (1), as all were near the detection limit. This can be expected if the distribution coefficient is large. Distribution coefficients for organic contaminants were calculated by computing the average from all the point estimates provided by the data from the sequential batch leach tests.

Permeameter Testing. Continuous flow column leaching studies were conducted in divided flow stainless steel permeameters using anaerobic and aerobic sediment. Column effluent was analyzed for As, Cd, Cr, Pb, Zn, and the organic compounds listed in Table C3. The specific details of permeameter loading and operation are presented in Appendix C. Data from the anaerobic columns show concentrations of As below detection limits. Concentrations of Cd, Cr, Pb, and Zn were at or above detection limits. Metal leachate concentrations from aerobic columns were generally higher and showed greater variation than metal leachate concentrations from anaerobic columns. Leachate concentrations of PCBs from anaerobic and aerobic columns were low and no PAHs were detected.

Integrated Approach. Application of the integrated approach to anaerobic leaching of PCBs from Everett Harbor sediment showed that predicted values agreed well with observed values and that because of the high distribution coefficients for PCBs, pore water concentrations in the field can be predicted using a simple equilibrium equation. The integrated approach was not applied to the leaching of metals from anaerobic Everett harbor sediment because most of the metal desorption isotherms fell into categories (1), (3), and (4). Unless a metal desorption isotherm is a category (2) isotherm, the mass transfer equation developed thus far cannot be used to predict column elution curves. Therefore, an approximate method, based on equating liquid-solids ratios in batch and column tests, was developed and used to predict column leachate concentrations using batch leaching data. Using the approximate method, the general shape of column elution curves was well predicted for anaerobic leaching of As, Cd, and Zn. Less agreement was observed for Cr and Pb. Comparison of predicted to observed values was limited because of the small region of overlap between batch and permeameter data.

The integrated approach was not used to predict elution curves for aerobic metals. Previous work with sediment from Indiana Harbor has demonstrated that leaching conditions in aerobic batch tests and aerobic column tests are not comparable. Therefore, there is no basis for prediction. Additional discussion is provided in Appendix C.

Summary. The intrinsic contaminant release characteristics determined in batch and column leaching tests for Everett Harbor sediment indicate that mobility of metals and organic contaminants is low under anaerobic conditions. Low mobility under anaerobic conditions is consistent with previous experience with anaerobic sediments. Under aerobic conditions some metals are mobilized in large quantities. The fraction of metals that was resistant to anaerobic leaching in batch tests was generally greater than 90 per cent of the bulk concentration. Under aerobic conditions, over 85, 56, and 49 percent of the Zn, Ni, and Cd was mobilized in batch tests. The higher metal release observed during aerobic testing is related to the pH reached under test conditions.

Differences were also noted between the pH values observed in the aerobic batch testing (3.5 to 4.8) for Everett Harbor sediments were lower than those reported from runoff testing. Theoretically, the pH of the sediment in the surface runoff tests should reach pH levels similar to that reached in the aerobic batch leaching tests once the sediment reaches a comparable oxidation level. However, the sediment in the surface runoff test is in a static, unmixed state and a longer time will be required to reach an oxidation status comparable to that observed in the batch testing.

There are potential groundwater problems with PCBs in both anaerobic and aerobic leachates. Other organic contaminants should pose no problems since they were not consistently measured in both the batch and column leachates as were PCBs. Restrictions due to PCB release from Everett Harbor sediment would need to be imposed if the attenuation capacity of the underlying soil was exceeded, an evaluation that could be conducted only following site selection. Site specific factors will determine the type of leachate control strategy, if any, that is appropriate. Table 1 provides a summary of leachate contaminant concentrations for use in computing flux. The use of these concentrations for predictions of contaminant release in leachates is discussed in Part IV.

Consolidation Tests

A consolidation test was conducted using the composite sample of contaminated sediment to provide data for evaluation of filling and settlement rates for confined sites. The test results are applicable for evaluation of both intertidal and upland sites. The tests were conducted using standard odometers and procedures developed specially for soft sediments (Cargill 1983). If a confined site is selected for disposal, the test results can be used to determine the fill surface elevation as function of time. This information will be useful in determining the appropriate timing for placement of a surface cap of cleaner material and the surface elevation behavior of the capped disposal site. The test results are presented in Appendix G.

The physical properties of the contaminated and native sediments are similar and consolidation behavior for the two sediments would be comparable on a qualitative basis. Predictions of consolidation behavior of capping material for the CAD alternative were made based on this assumption. The predictions were made assuming a 9 foot thickness of material deposited at a void ratio of 4.5. This corresponds to the assumed void ratio for deposited cap material in the Disposal Alternatives report. The results are tabulated below and show that the ultimate cap thickness would be approximately 8.4 feet, corresponding to a settlement of only 0.6 feet. These results indicate that the assumption of 50% consolidation in the Disposal Alternatives report is very conservative.

Time (years)	Cap Thickness (feet)
0	9.0
1	8.8
5	8.5
ultimate	8.4

Table 1.

Contaminant Leachate Concentrations (mg/1) For Flux Analysis

Contaminant	Drinking Water Standards (mg/ℓ) Federal	State	Anaerobic	Aerobic
As	.05	.05	0.039	<0.005
Cd	.01	.01	0.010	0.034
Cr	.05	.05	0.080	2.27
Cu	-	-	0.096	0.023
Ni	-	-	0.052	0.449
Pb	.05	.05	0.058	0.210
Zn	5.0	5.0	0.181	3.5
PCB	-	-	0.0036	0.00176

PART III: EVALUATION OF CONTAINED AQUATIC DISPOSAL

Modeling Results for Alternate CAD Sites

The CAD Deep Delta site, identified as the Navy's preferred site, is located in approximately 265 feet of water. Detailed modeling runs were made for conditions at this site, and results are given in the Disposal Alternatives report. Alternate sites in deeper water are now being considered for CAD to offset potential impacts to biological resources. One tentative site at a water depth of approximately 325 feet is being considered as are other sites in even deeper water.

Use of an alternate site at deeper depth would mean a proportionally higher sediment mass remaining in suspension. Model runs for the Deep Delta site at depth of 265 feet indicate 1.9% of the material remains in suspension after a time period of 1800 seconds (conservatively considered a mass release). A single model run has also been conducted for a surface dump of contaminated material in a 400 foot depth. These results indicate 3.6% of the material remains in suspension after a time period of 1800 seconds. Interpolation for a 325 foot depth yields approximately 2.5% remaining in suspension. It should be noted that all these figures are essentially at the accuracy limit of the currently available models.

Deposition patterns for the 400 foot run showed little change over the 265 foot runs. This would indicate that the "bottom footprint" used for the mounding evaluation as described below would be approximately the same for the 400 foot depth.

No model runs for hydraulic placement of the capping material have been made for the 400 depth conditions. However, it is anticipated that results would be similar to those generated for the 265 foot depth, i.e. discrete particle settling behavior. The processes governing the gradual build-up of the cap would therefore be the same for the deeper depth.

Additional model runs for a range of depth conditions up to 800 feet have been conducted for the Puget Sound Dredge Disposal Analysis (PSDDA). Since the conditions for the Everett study area are similar to those used in the PSDDA study, the generic model runs performed for PSDDA can be used to qualitatively evaluate material behavior at deeper water sites being considered for the Everett project.

Analytical Evaluation of Mounding Characteristics

(This section replaces the corresponding section in the Disposal Alternatives Report.)

General

An evaluation of mounding characteristics is an essential part of CAD design. The purpose of this evaluation is to generate a conservative estimate of the extent of spread or occupied surface area of the mound and to determine if sufficient capping material is available to place the design thickness over the occupied surface area. It is recognized that the Navy design for the CAD site is still evolving and that other configurations for the mound are feasible from a design standpoint.

The modeling described in the Disposal Alternatives report and in the above paragraphs delineates the area of deposition of one 4000 cubic yard barge load of contaminated material and the short term deposition characteristics of hydraulically dredged cap material. However, the model is not capable of simulating the effects of mounding or settlement after a large volume of material from multiple dumps has been deposited. Therefore, an evaluation of mounding characteristics was made based on existing data at other disposal sites.

Two major processes must be evaluated in estimating mounding behavior: the tendency of the material to flow due to momentum transfer during placement and the tendency of the material to form a stable angle of repose. Both processes are influenced by the method and rate of dredged material placement and the mechanical condition of the material resulting from the dredging. The tendency to flow will largely be offset by the tendency of the material to mound. The 1V on 50H bottom slope at Port Gardner is not great enough to induce gravity flow of the disposed material. There would be some tendency for successive impacts of the contaminated material to spread previously placed material, but bottom friction forces would quickly dampen the spread. Naturally-occurring bottom undulations and clumps within the disposed material characteristic of clamshelled material would also inhibit the tendency for the material to flow.

A major factor in estimating mound configuration is the slope or angle of repose taken by the contaminated material and cap. No analytical method has been developed for prediction of mound size or slopes in a subaqueous condition. Some insight can be gained by examining data on existing mounds. However, data on mound slopes exists for only a few sites. The change in void ratio due to entrainment of water and the subsequent settlement of mounds due to consolidation are also major considerations. As with the slopes, no analytical method has been developed for prediction. Therefore, conservative assumptions for this behavior were made for this evaluation.

The tendency for clamshelled material to remain in clumps and the nature of the existing bottom at the CAD site are factors which would cause the material to mound and would reduce the need for lateral confinement. The modeling runs for this project and experience with capping projects to date indicate that mechanically dredged, reasonably cohesive material can be placed into discrete mounds using carefully controlled and monitored, but otherwise conventional equipment and techniques (Semonian 1983, Bokuniewicz et al 1978, and Truitt 1986). Clamshelled material will exhibit significant clumping and cohesion, adding to stability. Under these conditions, local differences in the slope of mounds should be expected. The assumption of clumping and cohesion for clamshelled material is a major consideration in this evaluation and is based on the assumption that the material will be dredged in essentially its present in-situ condition and will not be significantly disturbed during debris-removal (i.e., only large logs evident by surface probing will be removed prior to dredging and the bottom will not be "raked").

The relatively soft bottom at the CAD site would tend to adsorb impact energy during placement of the clumps and the displacement of existing bottom sediments could form some degree of lateral confinement. Although the average slope at Port Gardner is 1V on 50H, the bottom is likely composed of a series of irregular ridges and swales which would increase the tendency of material to maintain steeper mound slopes.

Data for Existing Mounds

Data from mounds in Long Island Sound indicate that silty material which is clamshelled and released at the surface exhibits a clearly defined central mound with steep slopes surrounded by a much lesser volume of more fluid material with much flatter slopes. Estimates of the slope of the central mound vary from approximately 1V on 15H to 1V on 25H. Localized slopes as steep as 1V on 10H are evident from survey data for these mounds (Semonian 1983). This steepness is indicative of a high degree of cohesion and clumping of cohesive blocks of material and little entrainment of water during descent. However, the small portion of the material which entrained water during degent exhibited a more fluid-like behavior than the majority of the deposit. This portion of the material was deposited as an apron with flatter slopes surrounding the central mound. Data from the Long Island Sound monitoring indicates that the portion of the mound which is involved with the apron is approximately 20% by volume (Semonian, R.C. 1983). Since the apron material is less dense than the material comprising the central mound, the percentage of material comprising the apron by weight would be a lesser value. The slopes of the apron are expected to be less than 1V on 20H and may be less than 1V on 60H (Bokuniewicz et al 1986).

Data from other sites in which the material was deposited from a slurry, as from a hopper dredge, indicate a much flatter slope for the mounds (Bokuniewicz, et al 1986). For example, in the New York Mud Dump Site, the average slope is approximately 1V on 100H (Suskowski 1983). This slope is also the result of dumping at multiple disposal points. The material comprising the mound had differing characteristics ranging from soft clay-like materials to silts and fine sands. Local slopes at the site were as steep as 1V on 10H. Data from a site in Tampa Bay show a slope of approximately 1V on 100H (Williams 1983). This material was a fine sandy material which would exhibit little or no clumping or cohesion.

All available data on mound slopes indicate that a slope of 1V on 25H or steeper can be attained by fine-grained cohesive material which is dredged by clamshell and disposed from a barge. This data served as the basis for estimates of mound slopes for the Everett contaminated sediments, which would also be dredged by clamshell and dispersed from a barge.

Assumed Mounding Behavior

Placement. Placement of material for the contaminated mound would be by bottom dumping from a stationary position at a designated point, likely marked by a taut-line buoy or some other fixed point. However, it was assumed that the tendency for the contaminated material to form a discrete mound will require that the disposal point be moved periodically. It may be necessary to spread the material in a mound with a relatively flat top amenable to later placement of the cap. Actual placement will depend on the results of construction monitoring. A flatter mound will also aid in maintaining overall mound stability. The placement of the cap by hydraulic discharge at or near the surface will involve a continually moving discharge point using a predetermined, monitored pattern.

Contaminated Material Characteristics. The in-channel water content of the contaminated material is approximately 130% equivalent to a void ratio of 3.5 (Hart-Crowser 1986). It was assumed that some water would be entrained during placement and the average void ratio after placement would be 4.5. This is considered a conservative assumption.

Cap Material Characteristics. The in-situ water content of the uncontaminated material to be used for capping is approximately 50%, equivalent to a void ratio of 1.3. This material would be hydraulically dredged and placed by pipeline discharge at the surface. The resulting void ratio upon deposition in the cap was assumed to be 4.5. Cap placement using hydraulic placement from the surface should result in a sedimentation behavior similar to natural sedimentation, i.e., because of the water depths, no jet or momentum effects will be evident in the lower water column and the material will ultimately settle as discrete or flocculating particles.

Disposal Sequencing. Since the proposed dredging plan extends over a period of two dredging seasons, the sequence of disposal operations was taken into consideration. All dredged material quantities discussed are approximate based on the above assumptions for material characteristics. This sequence was assumed to include initial placement of 100,000 cubic yards of contaminated material, and immediate capping with uncontaminated material. After 9 months, an additional 800,000 cubic yards of contaminated material would be placed and then capped with 1,500,000 cubic yards of uncontaminated material. The area of deposition for individual bargeloads for contaminated material and passes of the pipeline for capping material was assumed to be equal to that determined by the modeling described in Part III.

Mound Slopes. In developing a conceptual mound configuration, it was assumed that both the contaminated and capping material would be deposited on the bottom in a circular pattern with radius corresponding to that indicated by the modeling runs. It was further assumed that as the mound develops, it would roughly assume the form of a truncated cone with the top of the cone equal in radius to the area of deposition of the material. As the material accumulates it would cause spreading to occur with side slopes of 1 to 100 relative to the bottom slope. This results in an angle of repose on the downslope side of approximately 1V on 30H. This slope is within the experience of the Long Island mounds which were formed with similar materials and dredging methods. It was assumed that spreading in the upslope and cross-slope directions would be governed by similar slopes, however, movement of the disposal point as described above may be necessary to maintain a mound with a relatively flat surface and uniform spread in all directions.

The behavior of clamshelled silt material when disposed in open water exhibits a well-defined central mound with side slopes of 1V to 30H or steeper. However, a small portion of the material in each discrete barge dump will entrain water during decent and will behave in a more fluid-like manner than the majority of the deposit. It was assumed that this apron material would tend to deposit with flatter slopes approximating the 1V on 50H slope of the existing bottom surrounding the mound proper. Local variations in the mound surface due to discrete dumps will tend to reduce any tendency of the apron material to flow. The large surface area of the mound and the overall mound slope will also provide the opportunity for deposition of the apron material on the contaminated mound proper. However, without lateral confinement, a portion of the apron material may move off the contaminated mound proper in the downslope direction due to gravity flow or impact from subsequent dumps. The final diameter of the capped mound must exceed the diameter of the contaminated mound. This is necessary to provide the required cap thickness over the entire contaminated mound. The overall diameter of the cap defines the required size of the disposal site which will be capped. In effect the capped site diameter provides a zone in which the majority of apron material flowing off the contaminated mound proper would be capped.

It was assumed that the slopes of the capping material would conform to the slopes taken by the underlying contaminated material since the cap is gradually built up by settling of discrete particles in a manner similar to natural sedimentation. Natural slopes in the general area of the site vary in steepness but appear to be stable at the slopes assumed for the contaminated material. Similar slopes would therefore appear reasonable for the capping material as it accumulates on the mound.

Mound Configuration. Illustrative sections showing the mound configuration and a plan view of the mound for the assumed conditions is shown in Figure 1. The point of disposal for the second dredging phase is shown offset to the upslope direction with respect to the initial mound formed from the first dredging phase. In this way, the first mound could provide a toe for the larger mound and could result in some degree of lateral confinement. A plan view of the mound for the assumed conditions is shown in Figure 1.

Since the deposition area for each barge load of material is smaller than that required for the final configuration of the disposal mound, the overall site dimensions appear to be governed by the total quantity of dredged materials disposed and its mounding characteristics. Assuming that the uncontaminated capping material is adequately "slurried" and that disposal locations are carefully controlled, the total dredging quantity of approximately 3,000,000 cubic yards will result in a disposal mound that is approximately 2400 feet in radius and is approximately 12 feet high. If the dredging plan allows for the final placement of 1,500,000 cubic yards of uncontaminated material, the entire site will be covered by a cap that exceeds 4 feet, as previously estimated, based on 50% consolidation.

Criteria for Successful Capping

Capping will be completely successful if all contaminated material reaching the bottom is capped with a thickness of uncontaminated material in excess of 80 cm. However, a small percentage of the contaminated material apron as described above may not remain on the mound during the mound formation process. The overall diameter of the capped site as described above will provide a means for this material to be capped within the designated boundaries of the disposal site. If any movement of the apron material outside the designated site is found by the monitoring, the capping operations could be modified to insure the material is capped. The placement of a confining berm could be considered as an added measure to minimize any downslope movement of the apron material.

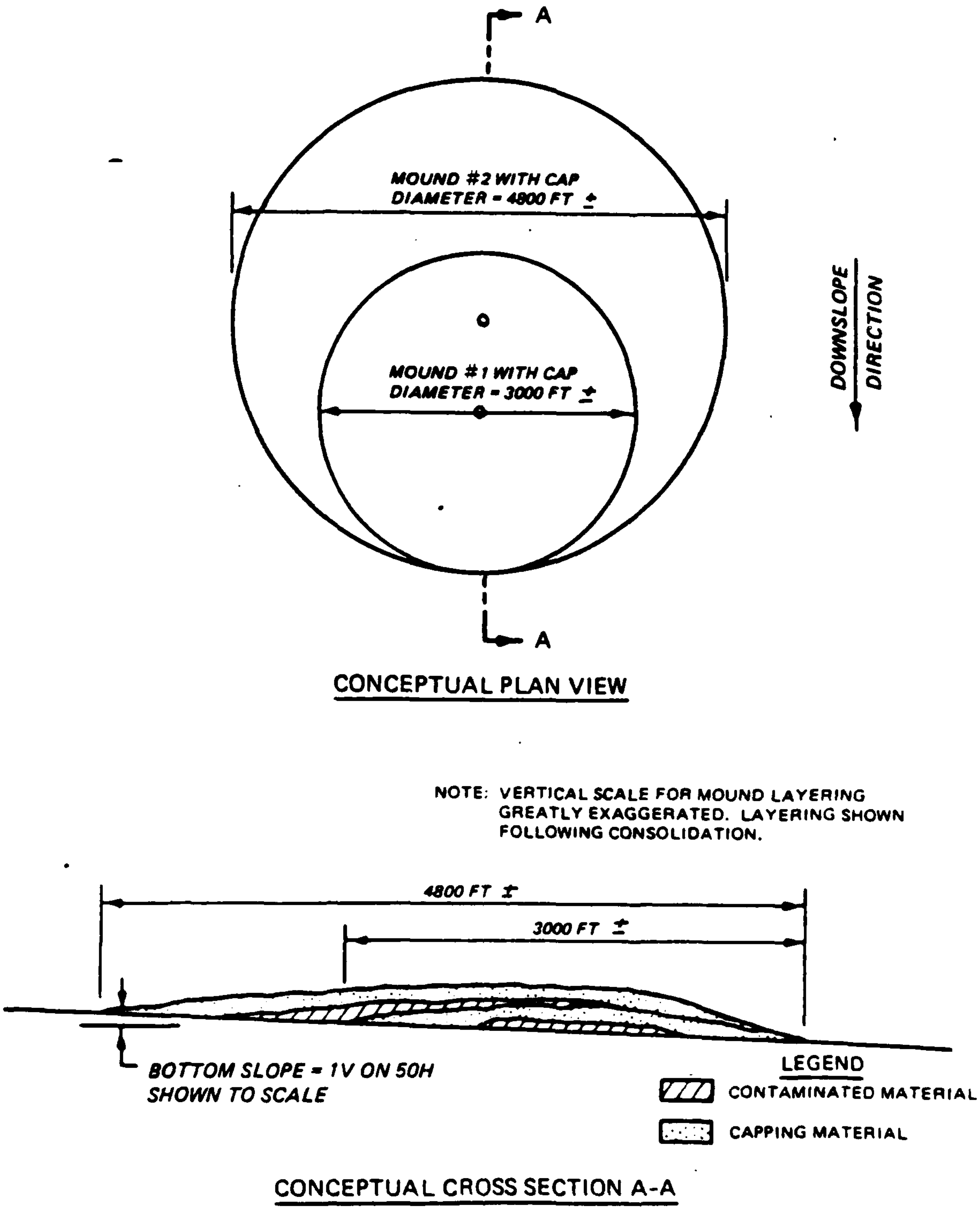

Figure 1. Plan and cross section of CAD site.

The mounding configuration described above indicates that sufficient capping material is available to place a one meter cap over the contaminated mound, and the procedures for cap placement as proposed are designed for a uniform capping thickness. However, local variations in bottom topography, contaminated mound surface, and in actual application of capping material will all result in local variation in the final cap thickness. Monitoring data should define the final configuration of the contaminated mound and the applied cap thickness after initial placement and consolidation.

Monitoring Requirements

The following monitoring requirements are recommended for the CAD alternative:

a) sediment resuspension and contaminant release during the dredging and transport operation,

b) sediment remaining in suspension and contaminant release during placement,

c) configuration and density of confining dike (if built), contaminated sediment in place, and cap,

d) migration of contaminants through the cap, and

e) mound densification and cap erosion.

Monitoring plans are given in Appendix I.

Feasibility Determination

Use of the proposed CAD site without lateral confinement is feasible if the dredged material mound will form and spread with slopes of 1 to 100 relative to the bottom slope or steeper (approximate angle of repose of 1V on 30H) and the site dimensions can be expanded to a diameter of approximately 4800feet. However, it should be stressed that CAD has not been attempted at these depths and there are some uncertainties associated with the placement of the CAD mound on a sloping bottom. Therefore, monitoring during placement of the contaminated material and cap should be conducted for both disposal phases to insure that material behavior and mound configuration are constructed in accordance with the final design. If monitoring of the initial phase indicates that placement of material or cap is not satisfactory, construction of a berm at the site, placement of additional capping material, or shifting disposal operations to an alternate site could be considered as a contingencies. Incorporation of a confining berm as a part of the design is considered an additional measure of conservatism.

Precise placement of the material during the entire CAD operation will be important. The disposal barges used for placement of the contaminated material should be stationary during the release of each dump. This will assist in keeping the dredged material mass in a clumped condition during descent and the resulting mound spread within the estimated limits. Control for the point of discharge should be incorporated in the plans and specifications. Taut-line buoy or real-time electronic positioning with on-board computer printout are possible methods which could be used. For the capping operation, electronic positioning would be appropriate for determining the rate of movement of the pipeline discharge.

The shifting of the CAD site to a deeper site has been proposed to avoid sensitive biological resources. If an alternate site is selected, consideration should be given to locating the site so that existing bottom topography is as flat as possible. This would serve to reduce or eliminate the uncertainties associated with CAD on a sloping bottom.

PART IV: EVALUATION OF INTERTIDAL AND UPLAND SITES

Background

The factors controlling contaminant mobility and the descriptions of potential contaminant migration pathways for placement of dredged material in upland, intermediate and flooded conditions are found in Part VI of the Disposal Alternatives report. The supplemental information in this part stresses the applicability of test results in evaluating upland disposal/alternatives. As for intertidal disposal, an upland disposal site may involve placement of material in one or more disposal environments. The testing results described in the Disposal Alternatives report and the supplemental results contained in this report are directly applicable in evaluating upland disposal alternatives.

An area for potential development of an upland site has been identified at Smith Island, north of the homeport area. Limited information regarding site conditions is available at this time. Further, a number of possible sizes and configurations for the upland site have been identified. Until a site configuration(s) is identified and additional data on site conditions is obtained, a site-specific evaluation for upland disposal similar to those performed for intertidal sites and described in the Disposal Alternatives report cannot be conducted. However, a description of the applicability of test results for representative upland disposal conditions is given in the following paragraphs. An effort has been made to apply data to the Smith Island site to the maximum extent possible.

Solids Retention and Initial Storage

The configurations under consideration for the Smith Island area vary from 35 to 89 acres in surface area. Data on required surface area for various dredge inflow rates, required volumetric storage capacities, and relationship of effluent suspended solids as a function of flowrate were presented in the Design Requirements report and Disposal Alternatives report. This information is directly applicable to evaluation of sites at Smith Island. The allowable inflow rate to maintain effective solids retention and the required volumetric storage will be in direct proportion to the final surface area available for the site.

Effluent Quality

Comparisons of dissolved concentrations of contaminants in effluent as predicted by modified elutriate tests and water quality criteria are presented in the Disposal Alternatives report. These comparisons are valid for any of the upland site configurations now under consideration for Smith Island.

Mass release of contaminants in effluent is dependent on effluent suspended solids concentrations. Determination of mass release is therefore possible only for a specific set of site conditions. However, mass release in effluent would be similar to that determined for the intertidal sites under consideration. Based on the previous evaluations for the intertidal sites, controls for mass release in effluent would likely be required to limit the total mass release for the upland alternative to less that the 5% performance goal. As for the intertidal alternative, chemical clarification is the most effective control measure.

Surface Runoff

The final surface of the contaminated sediments placed in an upland site could be at elevations either above or below the water table. Comparisons of dissolved and particle-associated concentrations of contaminants in surface runoff under both anaerobic and aerobic conditions with water quality criteria are presented in the Disposal Alternatives report. These comparisons are also valid for an upland evaluation including Smith Island.

Mass release of contaminants in surface runoff is directly proportional to surface area of the disposal site, since it can be assumed that rainfall occurrences would be the same for Smith Island as for the intertidal sites. Mass release was found to be negligible for the intertidal condition, and would similarly be negligible for the upland condition. As recommended for the intertidal site, placement of the contaminated material at elevations below the water table would minimize release both surface runoff and leachate and eventual placement of a surface cap would prevent long-term release.

Leachate

The leachate contaminant flux concentrations discussed in Part II and Appendix C are predictions of the concentrations of contaminants in leachate generated under anaerobic and aerobic conditions. However, the prediction of leachate impacts is a function of groundwater movement at the site under consideration. In nearshore or upland sites, various mechanisms such as precipitation, differences in elevation, tidal pumping, etc. tend to drive groundwater movement. Movement of water from the dredged material mass into surrounding groundwater can be inhibited by the presence of relatively impervious natural foundation soils, placement of surface covers to retard infiltration of precipitation, placement of liners to retard movement of leachate, etc. Even if leachate moves into surrounding groundwater, the degree of impact will be determined by the degree of mixing which might occur in the groundwater, adsorbtion of contaminants within the foundation soils, and the sensitivity and quality of surrounding groundwater which may be impacted. All of the above considerations are highly site-specific.

Depending on the site selected and site conditions, contaminated dredged material may be placed above or below the water table. If contaminated material is placed below the water table, the leachate characteristics may be estimated using anaerobic leaching test results. Leachate from material placed above the water table may be estimated using aerobic results.

The predicted leachate values for intertidal alternatives presented in the Disposal Alternatives Report were based on preliminary anaerobic batch leach tests. Subsequent laboratory testing and evaluation yielded the revised anaerobic leachate concentrations shown in Table 1. With the new values both Cr and Pb now exceed the drinking water standards, Cd meets the drinking water standard of .010 mg/ℓ, and PCB has increased from .0002 to .00036 mg/ℓ. Although these values would proportionately increase their percent mass releases, the portion of mass release contributed by leachate to the total mass release was and is still negligible.

Since anaerobic leaching data for Pb and Cr exceeded the drinking water standards, a regional authority decision (RAD) may require some type of control to prevent any contaminant migration from material placed below the water table because of the possibility of deterioration to potential receptors. If the RAD determines that a control would be warranted, several control options are available. The site may be lined with a synthetic or natural liner. A capping system to prevent infiltration could also be installed in concert with the liner. Leachate collection and treatment in place of lining and capping could also be considered; however, Cu and Pb concentrations from the leaching tests are increasing over time which would necessitate long term operation of a leachate collection and treatment system and the associated long term expense of operation and maintenance. In-situ stabilization of the sediments after disposal could also be considered as a remedial measure should contaminant release increase in the future. Stabilization during disposal operations to fix the entire slurry mass or chemical admixing to contain specific contaminants are possible control options, however, any solidification/stabilization process would be expensive.

Aerobic leaching data indicate that Cd, Cr, and Pb exceed the drinking water standard by a much greater margin than the anaerobic test results. This may require a more extensive control measure for contaminated material placed above the water table than would be required for material placed below the water table. Again, site specific conditions would dictate which type of control measure would be necessary. The possibility of a groundwater mixing zone to provide the necessary dilution may be possible. Also a shallow configuration for the containment area would make the installation of a liner a more viable control option.

Depending on the size of the containment area, the amount of material to be dredged, and the site conditions, a practical disposal scenario would be to place the contaminated material below the water table, where the material would remain anaerobic thereby releasing less contaminants. Cleaner material used as a surface cap could be placed above the water table.

Data Needs for Site Specific Evaluation

Data requirements for site-specific evaluation of a specific confined upland disposal site are tabulated as follows:

a) site location, area, and configuration,

b) vegetative cover, precipitation, evaporation, and temperature data,

c) drainage, topography, and tidal or hydrologic information,

d) engineering and geological characteristics of foundation strata, including stratigraphy, depth to bedrock, depth to aquicludes, depths to groundwater,

e) direction and rate of groundwater flow,

f) foundation soil contamination,

g) existing groundwater and/or surface water quality,

h) typical cross-sections of retaining dikes, and

i) potential receptors, sensitive ecological areas, and drinking water wells in the area.

Monitoring Requirements

The following monitoring requirements are recommended for upland disposal:

a) sediment resuspension and contaminant release during the dredging and transport operations,

b) effluent quality during filling operations,

c) surface runoff during a storm event,

d) groundwater quality and quality of seepage through dikes.

Monitoring plans to meet these requirements are given in Appendix I.

PART V: CONCLUSIONS

The data contained in this technical supplement does not result in any changes to the conclusions reached in the Disposal Alternatives report. CAD is feasible at the deeper water sites now under consideration. Confined disposal at the Snohomish and East Waterways sites also remains feasible. Feasibility of upland disposal cannot be determined without a site-specific evaluation.

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APPENDIX C: LEACHATE TESTING

INTRODUCTION

When contaminated dredged material is placed in an upland or nearshore confined disposal facility, the potential exists to generate leachates that may adversely impact ground waters. At present, there is no routinely applied laboratory testing protocol capable of predicting, or even approximating, leachate quality from confined dredged material disposal sites. Experimental testing procedures to predict leachate quality are, therefore, being used to evaluate the confined disposal alternative for Everett Harbor dredged material. These leaching procedures are in an early state of development, and must be interpreted with caution. If the CE can assess leachate quality and quantity, the potential impacts of using a CDF for disposal of contaminated dredged material can be determined, therefore, allowing the most cost effective site design to be developed.

The objective of this study is to evaluate and apply appropriate testing procedures for estimating leachate contaminant levels from Everett Harbor sediment under the CDF disposal alternative. Since the testing procedures are still developmental in nature, detailed descriptions of the procedures used are presented in this appendix.

MATERIALS AND METHODS

Objectives and Approach

The objectives of this study were two-fold. The primary objective was to estimate leachate quality in Everett Harbor sediment. Since standard procedures applicable to dredged material for assessing leaching potential were not available, a supporting objective was to develop, evaluate, and apply appropriate testing procedures for estimating leachate contaminant levels in Everett Harbor sediment.

The technical approach used in this study is an integrated procedure that involves coupling results from batch and continuous flow column tests with a mass transport equation (Myers, Brannon, and Griffin 1986). Comparison of predicted and observed column effluent quality is the basis for evaluating the geochemical processes that govern contaminant leaching from Indiana Harbor sediment. Description of the processes that govern the movement of pore water, site-specific hydraulics, are beyond the scope of the leachate testing.

Sediment Preparation

Sediment acquisition, mixing, and transport procedures have been previously described. Upon arrival at the WES, sediment for use in the anaerobic leaching tests was refrigerated at 4 degrees C in sealed containers until used. Sediment for use in aerobic testing was placed into 38 liter glass aquariums to a depth of approximately 8 cm. The aquaria were then placed in a covered enclosure open to the air and allowed to oxidize at ambient temperatures. Each week, the sediment was thoroughly stirred to expose fresh sediment to the air. When necessary, distilled, deionized water was added to the sediment to prevent drying. At the end of six months of aeration, the sediment was removed from the aquaria, placed into a 115 liter barrel, and thoroughly mixed for two hours. The sediment was then refrigerated at 4 degrees C until used for all aerobic leachate testing.

Batch Testing

Salinity Tests

Prior to testing, the effects of salinity changes in the leachate on metal releases were assessed. Triplicate 250 ml polycarbonate centrifuge tubes, fitted with a leakproof, airtight top were loaded with sufficient sediment and deoxygenated water to obtain a 4:1 water to sediment dry weight ratio for a volume of 200 ml. The 4:1 water to sediment ratio was selected for salinity and kinetic testing because this ratio had proven to be optimum during previous leaching tests. All operations were conducted in a glove box under a nitrogen atmosphere. Sufficient triplicate centrifuge tubes were loaded to allow testing at salinity levels of 0, 5, 15, and 25 parts per thousand. Sea water of known salinity was prepared by diluting Copenhagen Standard Sea Water of known salinity with distilled, deionized water. Samples were placed upright on a mechanical shaker and shaken at 160 cycles per minute for 24 hours. The tubes were then removed from the shaker, centrifuged at 9000 x g for twenty minutes, and the supernatant filtered under a nitrogen atmosphere through 0.45 um pore size membrane filters. The filtrate was then acidified to pH 1 with concentrated Ultrex (TM) nitric acid and stored in plastic bottles until analyzed.

Kinetic Tests

Batch testing was performed to determine shaking time necessary to achieve equilibrium or steady state conditions for metal and organic contaminant leachate concentrations. The general experimental sequence is presented in Figure C1.

For testing metal releases, triplicate 250 ml polycarbonate centrifuge tubes fitted with a leakproof, airtight top were loaded with sufficient sediment and deoxygenated, distilled, deionized water to obtain a 4:1 water to sediment dry weight ratio. All operations were conducted in a glove box under a nitrogen atmosphere. Sufficient triplicate centrifuge tubes were loaded to allow sampling at 24 hours, 48 hours, 72 hours, and 168 hours. Samples were placed horizontally on a mechanical shaker and shaken at 160 cycles per minute for the allotted time. Three tubes were then removed from the shaker, centrifuged at 9000 x g for twenty minutes, and the supernate filtered under a nitrogen atmosphere through 0.45 um pore size membrane filters. The filtrate was then acidified to pH 1 with concentrated Ultrex nitric acid and stored in plastic bottles until analyzed.

Kinetic testing for organic contaminants was conducted in specially fabricated 450 ml stainless steel centrifuge tubes. Twenty-four acetone rinsed centrifuge tubes were loaded with sufficient sediment and deoxygenated, distilled, deionized water to obtain a 4:1 water to sediment dry weight ratio. The total mass of sediment and water added was regulated to allow the tube to be safely centrifuged at 6200 rpm (6500 x g). All operations were conducted under a nitrogen atmosphere. The tubes were then laid on their sides and shaken at 160 cycles per minute for periods of 24 hours, 48 hours, 96 hours, and 168 hours. At each sampling time, the samples were removed from the shaker and centrifuged for 30 minutes. The leachate was then recentrifuged in clean centrifuge tubes to remove remaining particulate material. The recentrifuged supernate was then filtered through a Whatman GF/D glass fiber prefilter and a Gelman AE glass fiber filter with a nominal pore size of 1.0 um.

Neither filter contained binders or detectable quantities of the organic contaminants analyzed during this study. Filtration was conducted under a nitrogen atmosphere followed by acidification with 1 ml of concentrated HCl to prevent iron precipitation and scavenging of organic contaminants from solution by iron precipitates. Samples were then stored in the dark in acetone-rinsed 2 liter glass bottles until analyzed.

Sediment-Water Ratio Testing

Following determination of the shaking time necessary to obtain steady state contaminant concentrations in the leachate, testing to determine the proper sediment to water ratio was conducted. The general test sequence is presented in Figure C2.

For metals, anaerobic Everett Harbor sediment was placed in acid washed 250 ml polycarbonate centrifuge tubes in water to sediment ratios of 4:1, 8:1, 12:1, 50:1, and 100:1 using double-distilled, deionized water. The tubes were then sealed, mechanically shaken horizontally for 24 hours, then centrifuged and filtered through 0.45 um membrane filters; the resulting supernatant was acidified and stored in plastic bottles prior to analysis as previously described. The anaerobic integrity of the samples were maintained throughout the preparation, shaking, and filtration of the sample.

Similar procedures were followed for organic contaminants, except that 24-hour shaking was conducted in 450 ml stainless steel centrifuge tubes. Filtration and other sample preparation procedures are as described for organic contaminants in the kinetic testing section.

Sequential Batch Testing

A 4:1 water to sediment ratio and a shaking time of 24 hours were found to be optimum for application of sequential batch leaching tests to anaerobic sediment. General test procedures for assessing steady-state leachate and sediment metal and organic contaminant concentrations are detailed in Figure C3.

Batch tests were designed to determine metal releases from anaerobic Everett Harbor sediment and provide sufficient leachate to challenge fresh sediment. To obtain this leachate, three 500 ml polycarbonate centrifuge bottles with leakproof caps were loaded under a nitrogen atmosphere with anaerobic Everett Harbor sediment and deoxygenated distilled deionized water to a 4:1 water to sediment ratio; these were mechanically shaken for 24 hours. The bottles were then centrifuged at 9000 x g for 30 minutes. Half of the leachate from each 500 ml centrifuge bottle was filtered through a 0.45 um membrane filter. A portion of the unfiltered leachate was then analyzed for pH using a combination electrode and a millivolt meter and conductivity using a Yellow Springs Instrument Company (TM) conductivity meter and cell. Enough of the remaining unfiltered leachate was weighed into a 250 ml polycarbonate centrifuge tube containing fresh Everett Harbor sediment to obtain a 4:1 water to sediment ratio. This procedure, whereby part of the initial leachate was set aside for analysis, and the remainder used to challenge fresh anaerobic Everett Harbor sediment, was continued for nine days. Fresh deoxygenated, distilled, deionized water was added to each 500 ml centrifuge tube to replace the leachate removed for analysis and challenge of fresh sediment. All operations were conducted under a nitrogen atmosphere. This same procedure was repeated for aerobic sediments, except that aerobic sediment leachate is used to challenge aerobic sediment.

Testing of Everett Harbor sediment for organic contaminants was conducted in a manner similar to that described for metals; however, 450 ml stainless steel centrifuge tubes were used for both the sequential and challenge testing and centrifugation. The filtration procedures used for organic contaminants were as previously described for the kinetic and sediment to water ratio testing, and these are presented in Figure C3. A subsample of filtered leachate was set aside from both the anaerobic and aerobic tests for analysis of total organic carbon. In each case, the leachate was replaced with distilled deionized water, remixed, shaken for 24 hours, and then processed as previously described for the desired number of cycles.

Interstitial Water Extraction

Interstitial water samples for metal and organic contaminant analysis were obtained by centrifugation of the Everett Harbor sediment. To obtain samples for metals from anaerobic Everett Harbor sediment, triplicate 250 ml polycarbonate centrifuge tubes fitted with a leakproof, airtight top were loaded with sediment in a glove box under a nitrogen atmosphere. The centrifuge tubes were then centrifuged at 9000 x g for 30 minutes, and the supernate was filtered under a nitrogen atmosphere through 0.45 um pore size membrane filters. The filtrate was then acidified to pH 1 with concentrated Ultrex grade nitric acid and stored in plastic bottles until analyzed.

Procedures for obtaining interstitial water for metals analysis from aerobic Everett Harbor sediment were similar to those described for anaerobic sediment, except that all steps in the aerobic operation were conducted without the use of nitrogen.

Interstitial water for analysis of organic contaminants was obtained by centrifugation of anaerobic Everett Harbor sediment in 450 ml stainless steel centrifuge tubes. For interstitial water separation from anaerobic Everett Harbor sediment, six tubes were loaded with sediment, then centrifuged for 30 minutes at 6500 x g. The supernate was then recentrifuged in clean centrifuge tubes to remove residual particulate matter, then filtered through a Whatman GF/D glass fiber prefilter and a Gelman AE glass fiber filter with a nominal pore size of 1.0 um. All steps in the operation were conducted under a nitrogen atmosphere. Following filtration, the interstitial water was acidified with 1 ml of concentrated hydrochloric acid then stored in the dark in acetone rinsed 2 liter glass bottles until analyzed. Aerobic interstitial water was obtained in a similar manner except that anaerobic conditions were not maintained during the operation.

Permeameter Testing

Loading and Operation

Column leaching tests were conducted in divided-flow permeameters designed to minimize wall effects and provide for pressurized operation (Figure C4). The inner permeameter ring divides flow, separating the leachate flowing through the center of the column from that flowing down the walls, thereby minimizing wall effects on leachate quality. The applied pressure forces water through the sediment at rates sufficient to allow sample collection in a reasonable period of time.

Permeameter tests were run to simulate leaching of anaerobic and oxidized sediment, prepared as previously described. Permeameter effluent was analyzed for concentrations of arsenic, cadmium, chromium, lead, and zinc, and the organic contaminants listed in Table C2. Separate permeameter tests were run to obtain leachate for metal and organic analysis because of the large leachate volume needed to conduct organic contaminant analyses (1 liter). Column tests were run in triplicate for analysis of metal and organic leachate concentrations in anaerobic and aerobic Everett Harbor sediment, a total of twelve permeameter tests.

Everett Harbor sediment was loaded into the permeameters in several lifts having an average thickness of 5 cm, the number of lifts added depending on the total sediment thickness desired. As each lift of water saturated sediment was added, the permeameter was vigorously agitated on a vibrating table to remove trapped air. The weight and height of each lift was measured and recorded following vibration. Sediment height averaged 18 cm in permeameters used to obtain leachate for metal analysis and 36 cm in permeameters used to obtain leachate for organic contaminant analysis. A greater depth of sediment was needed in the permeameters run for organic analyses because of greater sample volume needs for chemical analyses. Sediment pore volume in the permeameters was determined by measuring the weight and volume of sediment added to the permeameter, then measuring the weight and volume of sediment samples before and following oven drying at 105 degrees C; weight loss upon drying was then equated to the volume of water in the permeable voids. Next, pore volumes were calculated for the sediment column above the inner ring of each permeameter. Therefore, pore volumes refer to the column of sediment above and including the permeameter inner ring.

Following sediment addition, distilled, deionized water was added to the permeameters; the apparatus was then sealed and pressurized with either nitrogen or air depending on whether the test was conducted on anaerobic or aerobic sediment, respectively. It was necessary to periodically add water to the permeameters during the course of a test. Effluent from the inner and outer permeameter rings were drained through teflon tubing into 1000ml graduated cylinders. The cylinder, receiving flow from the inner outlet of each permeameter, was isolated from the atmosphere by a water trap which allowed gas used to pressurize the permeameters to escape without exposing the leachate to the atmosphere. The collection cylinder head-space was purged with nitrogen prior to testing anaerobic sediment.

Effluent flow from the permeameters was regulated by adjusting the operating pressure. The permeability of the sediment decreased for the first two weeks of operation. As permeability decreased, operating pressure was increased to maintain a constant flow. Permeameter flow generally stabilized after two weeks of operation. A daily record was maintained of operating pressure and flow from both the inner and outer ring of the permeameter.

Sampling

Permeameter effluent sampling for metals was conducted as frequently as possible as the first pore volume moved through the column (3 to 4 samples/pore volume), then at less frequent intervals (1 to 2 samples/pore volume) for the duration of the testing. Effluent used for metals analysis was also analyzed for dissolved organic carbon, conductivity, and pH.

Effluent used for organic contaminant analysis was sampled at approximately 0.5 pore volume intervals. The volume collected was analyzed for organic contaminants, except for a small amount used to analyze dissolved organic carbon concentrations.

Leachate samples for metals and organic contaminants from anaerobic sediment were filtered under nitrogen using procedures previously described for batch testing.

Dispersion Coefficient Measurement

The dispersion coefficient, Dp, was determined by operating a separate permeameter specifically for this purpose using anaerobic sediment and distilled-deionized water containing bromide as a tracer (constant concentration = 1000 mg/l). Effluent samples were collected periodically, filtered (0.45 um pore size membrane filter), digested using procedures developed by Chain and DeWalle (1975) for chlorides in sanitary landfill leachate, and analyzed for bromide by silver nitrate titration using a recording titrator with a silver specific ion probe. From these data, the dispersion coefficient was computed using the F-curve procedure described by Levenspiel (1972). This method assumes dispersion within the column to be small, i.e., $D_p/VL < 0.01$. D_p/VL is a dimensionless ratio, termed the dispersion number, and is used to characterize dispersion in flow through system. D_p is the dispersion coefficient; V is the average pore water velocity; and L is the column length.

Chemical Analysis

Sediment samples and leachate from batch testing were analyzed for selected polychlorinated biphenyls (PCB congeners), polyaromatic hydrocarbons (PAHs), As, Cd, Cr, Cu, Hg, Ni, and Zn. Column leachates were analyzed for the same list of parameters with the exception of Ni and Cu. Concentrations of PCB congeners and PAH compounds in sediment samples were determined following soxhlet extraction, Florosil cleanup, and quantification in either a Hewlett Packard 5985A gas chromatograph/mass spectrophotometer equipped with a flame ionization detector (PAHs) or a Hewlett Packard 5880A gas chromatograph equipped with an electron capture detector (PCBs). Concentrations of PAH and PCB compounds in leachate samples following methylene chloride extraction were determined on the same equipment as for sediment samples. Sediment and leachate samples were analyzed for all metals studied except arsenic and mercury using directly-coupled plasma emission spectroscopy on a Beckman Spectraspan IIIB plasma emission spectrometer or by atomic absorption spectroscopy using a Perkin-Elmer Model 5000 atomic absorption spectrometer coupled with a Perkin-Elmer Model 500 hot graphite atomizer following appropriate sample digestion procedures (Ballinger 1979). Arsenic in leachate and sediment samples was determined by hydride generation (Ballinger 1979) using a Perkin-Elmer 305 atomic absorption spectrophotometer coupled with a Perkin-Elmer Model MHC-10 hydride generator. Mercury was analyzed by the cold vapor technique (Ballinger 1979). Total organic carbon was analyzed in leachate and sediment samples using an Oceanographic International 543B organic carbon analyzer and standard procedures (Ballinger 1979).

Statistical Analysis

All statistical analyses were conducted using Statistical Analysis System (SAS) Institute (Barr et al. 1976) procedures. Analysis of variance procedures were used to test for differences between means. Regression analysis was used to determine the equation of the line of best fit between steady state sediment and leachate contaminant concentrations obtained during batch testing, and to evaluate its statistical significance.

THEORETICAL BASIS FOR LEACHATE QUALITY PREDICTION

The purpose of this section is to present a brief overview of the equations used to predict leachate quality and their relationship to the experimental procedures described earlier. The application of these equations, for predictive purposes, to contaminated dredged material is a new approach and should be considered in the research stage of development. Development of the equations and additional discussion concerning their theoretical basis has been presented by Myers, Hill, and Brannon (1986) and Myers, Brannon, and Griffin (1986).

For this discussion it is assumed that water transports contaminants from the dredged material to the boundaries of a CDF. Leaching is defined as interphase transfer of contaminants from the dredged material solids to the aqueous phase as water moves past the dredged material solids. Upon contact with percolating water, contaminants associated with sediment particles can go into solution, thereby increasing contaminant levels in the leachate.

For contaminant leaching occurring as water percolates through porous media, the governing one-dimensional partial differential equation for steady-state flow is given below (Lapidus and Admunson 1952; Lowenbach 1978; Rao et al 1979; Grove and Stollenwerk 1984):

$$\partial C/\partial t + p/\Theta\,(\partial q/\partial t) = D_p\,(\partial C/\partial z) - V(\partial C/\partial z) \qquad \text{(C-1)}$$

Where:

C = aqueous phase contaminant concentration, mg/l

D_p = bulk dispersion coefficient, cm^2/sec

q = solid phase contaminant concentration, mg/kg

p = bulk density, kg/l

Θ = porosity, dimensionless

V = average pore water velocity, cm/sec

z = direction, cm

t = time, sec

Equation C-1 is sometimes referred to as the permeant-porous media equation. The derivation of this equation is based on balancing the mass flux into and out of any arbitrary volume within a column of dredged material. The first term on the right-hand side represents dispersive transport of contaminant; the second represents convective transport (bulk flow). The first term on the left side, sometimes referred to as the accumulation term, represents the resulting change in aqueous phase contaminant concentration with time; the second term on the left side, sometimes referred to as the source or reactive term, represents interphase transfer of contaminant from the sediment solids to the aqueous phase.

The first step in applying equation C-1 is the development of a mathematical formulation for the source term. In this study a linear equilibrium source term was used resulting in Equation C-2.

$$(\partial C/\partial t) + (p\ K_d/\theta)\ (\partial C/\partial t) = D_p\ (\partial C/\partial z) - V\ (\partial C/\partial z) \qquad \text{(C-2)}$$

In this equation K_d is referred to as the distribution coefficient and has units of l/kg. The leach tests described in this report were conducted to test the hypothesis that contaminant leaching from Everett Harbor sediment is described by equation C-2, i.e., the source term can be described as equilibrium-controlled, linear desorption.

An equilibrium relationship between sediment and aqueous phase contaminant concentrations in a batch system can be written as follows (Myers, Brannon, and Griffin 1986):

$$q = K_d\ C \qquad \text{(C-3)}$$

In this equation, q refers to the reversibly sorbed component of the sediment contaminant. However, if q is defined as the bulk sediment contaminant concentration, then the non-reversible component must be added to equation C-3 as follows:

$$q = K_d\ C + q_r \qquad \text{(C-4)}$$

where q_r is the non-reversible component resistant to leaching. Equation (C-4) is a general relationship which applies to a batch system at steady state. In a continuous flow system, q and C at any point do not remain constant over time but change as percolating water leaches contaminants. Application of equation C-4 to a continuous flow system requires

$$\partial q/\partial t = K_d \, (\partial C/\partial t) \qquad \text{(C-5)}$$

Equation C-5 describes a local, linear equilibrium condition at the sediment solids-water interface in a continuous flow system. Substitution of equation C-5 into equation C-1 yields equation C-2.

Equation C-2 is the basis of design for the sequential batch leaching tests, described earlier. By sequentially leaching a portion of sediment with successive aliquots of clean water, a table of C and corresponding q values can be generated and plotted. Such a plot is called a desorption isotherm with slope K_d and intercept q_r. If the desorption isotherm goes through the origin, then q_r is equal to zero. Thus, the intercept value can be interpreted as the contaminant fraction resistant to leaching. Ideal desorption isotherms illustrating the important theoretical features of isotherm analysis are shown in Figure C5.

The previous discussion presents the basic theory behind the development and use of the sequential batch leach tests for Everett Bay sediment. It is clear that sequential batch leach tests, designed to evaluate K_d and q_r, do not provide a complete picture of how the contaminant concentration varies with time and position in a continuous flow system. According to the permeant-porous media equation, as water percolates through a column of dredged material the temporal variation in leachate contaminant concentration at any point is determined not only by the source term but also by the effects of advection and dispersion.

As previously stated, the integrated approach consists of using results from batch leach tests, column leach tests, and equation C-1 to test the hypothesis that contaminant leaching from Everett Harbor sediment can be described as equilibrium-controlled, linear desorption. Application of the integrated approach is illustrated in Figure C6.

Once the information needed to solve Equation C-6 is obtained, column and batch leaching data can be combined using the permeant-porous media equation to provide an integrated picture of leachate quality as a function of time or pore volumes passing through the dredged material. An analytical solution to this equation for equilibrium controlled, linear desorption is presented below (Ogata and Banks 1961).

$$C(z,t) = C_I + (C_o - C_I) \ 0.5 \ \mathrm{erfc} \ \frac{Rz - Vt}{2(DRt)^{.5}}$$

$$+ 0.5 \ \exp \frac{Vz}{D} \ \mathrm{erfc} \ \frac{Rz + Vt}{2(DRT)^{.5}} \qquad \text{(C-6)}$$

where: C_I = initial contaminant concentration in the interstitial water, mg/l

C_o = contaminant concentration in the water entering the sediment, mg/l, equal to zero for the test procedures used in this study.

$R = \frac{1 + K_d}{0}$ = retardation coefficient, dimensionless

p = bulk density, kg/l

Θ = porosity, dimensionless

V = average pore water velocity, cm/sec

D = longitudinal dispersivity = D_p/V, cm

z = distance from top of sediment column, cm

t = time, sec

The initial and boundary conditions used to obtain equation C-6 are as follows:

$$C(z,0) = C_I$$

$$C(0,t) = C_o$$

$$\partial C/\partial z\ (\infty,t) = 0$$

If test procedures are free from error, the solution obtained from equation C-6 should agree with observed effluent concentrations from the permeameters. Thus, the integrated approach can be used to verify the mathematical form of an assumed source term.

RESULTS AND DISCUSSION

Sediment Chemical Concentrations

Contaminant concentrations in Everett Harbor anaerobic sediment and interstitial water are presented in Table C1. Sediment solids contained low concentrations of PCB congeners, PAH compounds, and mercury, but relatively high concentrations of copper, lead, and zinc. Interstitial water concentrations of PAH compounds and PCB congeners were below detection limits as were concentrations of arsenic and mercury. Concentrations of other metals in the interstitial water were low.

Contaminant concentrations in aerobic Everett Harbor sediment and metal concentrations in the interstitial water are presented in Table C2. Organic contaminants were not determined in the aerobic interstitial water because of the low total concentrations of organic contaminants in the aerobic sediment, the lack of detectable organic contaminants in the anaerobic interstitial water, and the small amounts of interstitial water extractable from aerobic sediment. Of particular notice were the high concentrations of Cd, Cu, Ni, and Zn in the aerobic interstitial water, a result of the lower pH in the aerobic sediment (3.9) compared to the anaerobic sediment (7.0).

In this report, organic contaminants are referred to by number because of the complexity of compound names and the number of organic contaminants analyzed. The key to organic compound identification is contained in Table C3. Specific PCB congeners were analyzed and reported instead of PCB Aroclors™ in order to achieve the enhanced limits of detection in water for congeners (0.01 ug/l) compared to Aroclors (0.10 ug/l). Only PCB Arochlor™ 1254 was detectable (0.25 mg/kg) in Everett Harbor sediment. Sediment detection limits for PCB congeners were 0.002 ug/g.

Salinity Testing

Leaching with water of varying salinity was conducted to determine if salinity would significantly impact metal concentrations in Everett Harbor leachate. Test data are presented in Table C4. These data show that increasing salinity had no apparent impact on release of heavy metals from Everett Harbor sediment solids into the leachate. The salinity of the water used in the testing should, therefore, exert little influence on leachate results.

Kinetic Testing

Kinetic testing was performed to determine shaking time necessary to reach steady state leachate contaminant concentrations. Test results for metals are presented in Table C5. Results show that leachate metal concentrations following one day of shaking did not significantly differ ($p<0.05$) from leachate metal concentrations following 2, 3 or 7 days of shaking. It was therefore determined that a 24 hour shaking time was sufficient for metal concentrations to reach steady state conditions. No release of Hg was observed, but testing for this parameter was continued.

Organic contaminant leachate results as a function of shaking time are presented in Table C6. Data showed that shake time did not alter leachate concentrations of the three PAH compounds detected. However, concentrations of these compounds were near the detection limit and were only detected because the GC/MS signal is particularly strong for these compounds. In this test, PCB congeners were not run since, during early testing of this sediment, all PCB Arochlor™ concentrations were below detection limits and testing for PCB congeners had not yet begun. Previous work on Indiana Harbor sediment has shown, however, that PCB congeners and PAH compounds behave similarly during kinetic testing. Therefore a 24 hour shaking time was considered appropriate for batch testing of organic contaminants as well as metals.

Selection of Water to Sediment Ratio

Batch leaching tests were also conducted to determine the water to sediment ratio that would approximate contaminant distributions found in settled dredge material placed in a confined disposal facility. When dredged material is first added to a site, this would approximate a 1:1 ratio. However, the water to sediment ratio must also be large enough to allow generation of sufficient leachate for organic contaminant analyses (approximately 1 liter/sample). The effect of varying the water to sediment ratio on leachate metal concentrations from anaerobic Everett Harbor sediment is presented in Table C7. Concentrations at water to sediment ratios of 4:1 were either higher than (As) or statistically the same as ($p<0.05$) leachate metal concentrations measured at higher water to sediment ratios. Comparison of anaerobic interstitial water metal concentrations (Table C1) with anaerobic leachate results in Table C7 showed general agreement with the exception of As which was lower in the interstitial water, and Pb, which was slightly higher. Therefore, use of a 4:1 water to sediment ratio should yield contaminant distributions that reasonably estimate the distribution at a liquid-solids ratio of 1:1.

Aerobic Everett Harbor sediment leachate possessed a low pH which can strongly impact metal mobility. As a result, an additional water to sediment ratio test was conducted with the aerobic sediment to determine if results observed for metals with anaerobic sediment held for the aerobic sediment. Results are presented in Table C8, and show that leachate metal concentrations at water to sediment ratios of 4:1 were either higher or statistically the same ($p<0.05$) as leachate metal concentrations at higher water to sediment ratios. Therefore, a 4:1 water to sediment ratio was also considered appropriate for aerobic Everett Harbor sediment despite its low pH. Leachate pH during this test averaged 4.3 with a standard error of 0.03.

The effect of the water to sediment ratio on leachate concentrations of organic contaminants in anaerobic Everett Harbor sediment is presented in Table C9. Leachate concentrations in the 4:1 water to sediment ratio test were either higher than or equal to leachate concentrations at higher water to sediment ratios. Organic contaminants were not detected in the Everett Harbor interstitial water (Table C1); thus, leachate concentrations in the 4:1 water to sediment ratio provided a possible worst case estimate.

Sequential Batch Leaching

General Leachate Quality.

Leachate conductivity, pH, and total organic carbon concentrations (TOC) for the batch leaching tests are summarized in Tables C10, C11 and C12, respectively. For all tests conducted, leachate conductivity gradually decreased. Leachate pH from anaerobic sediment was 7.3 during the first two leaching sequences, then increased steadily to a peak of 8.8 as leaching continued, a pH rise of 1.5 units. Similar trends were observed in the anaerobic challenge tests although the rise in pH was not as high and occurred two leach sequences later. Anaerobic leachate TOC concentrations peaked in the fourth step of sequential batch testing, coincident with the rise in leachate pH. Similar trends were observed in the anaerobic challenge testing. TOC in the aerobic batch tests did not show the trends observed during anaerobic testing, but exhibited a generally steady decrease from initial values. There was no difference in initial TOC concentrations between anaerobic and aerobic tests despite the large difference between anaerobic (7.15%) and aerobic (3.11%) sediment TOC concentrations. A marked difference in leaching conditions was, therefore experienced during the course of the anaerobic leaching procedure. The change in anaerobic conductivity should not cause changes in metal release characteristics based on results of the salinity tests. The same cannot be said for the change in leachate pH over the course of the anaerobic leaching procedure. Such a pronounced change would be expected to have a marked impact on anaerobic metal release.

Aerobic Everett Harbor sediment leachate pH was much lower than the values observed for anaerobic sediment (Table C11). Challenging aerobic sediment with aerobic leachate resulted in even lower pH's. Leachate pH during the initial aerobic testing exceeded the value of 4.3 observed in the water to sediment ratio testing; this occurred even though only one week passed between the two tests and the aerobic sediment was refrigerated at 4 degrees centigrade between tests. These pH differences were apparently due to reduction processes in the stored sediment. The redox potential of stored aerobic sediment that gave a leachate pH of 4.8 was +200mv. When this sediment was placed into glass aquaria and allowed to oxidize for two weeks using the same procedure employed during the initial oxidation, redox potential of the sediment rose to +550 mv and pH dropped to 4.3. Because of the pH rise during storage, aerobic challenge testing results most closely match leaching conditions for fully oxidized Everett Harbor sediment. In the future only freshly oxidized, unstored sediment should be used for aerobic testing.

Metal Releases

Steady-state metal concentrations in sediment (q) and leachate (C) obtained from the sequential batch leaching tests for anaerobic Everett Harbor sediment are presented in Tables C13 and C14, respectively. Steady state q and C concentrations obtained from the challenge testing for anaerobic Everett Harbor sediment are presented in Tables C15 and C16, respectively. Changes in releases of metals in anaerobic leachate can be seen in Figure C7, which presents changes in leachate concentration of As and Ni as a function of sequential leach number. These data show that As and Ni leachate concentrations were low initially, peaked at either the the third or fourth leach step, then declined. That is, initially the isotherms for these elements exhibited an inverse relationship (C increases as q decreases). However, after the third or fourth leaching step the relationship between q and C changed to a direct one (C decreases as q decreases).

Desorption isotherms for the anaerobic metal data are provided in Figures C8 through C14. As shown in these figures, release of metals from anaerobic sediment did not follow the ideal desorption isotherms presented in Figure C5. Two of the desorption isotherms are double-valued (Figures C8 and C13), and two, although linear, had reverse slopes (Figures C11 and C12). The turning point for the As and Ni desorption isotherms, Figures C8 and C13, is coincident with establishment of steady leachate pH (Table C11). Reverse and double-valued desorption isotherms are indicative of non-constant sediment chemistry, probably variable pH, that affect metal mobility.

If all the steps in the sequential leach procedure are considered, there is no significant ($p<0.05$) linear relationship between steady state sediment and leachate As or Ni concentrations. However, if only data following the peak are considered, there is a strong linear relationship between steady state sediment and leachate concentrations for As and Ni. Thus, after pH became constant, distribution of As and Ni between sediment solids and leachate behaved like an ideal desorption isotherm. Distribution coefficients for As and Ni and associated standard error for the ideal portion of the desorption isotherm were 5.36(0.56) and 8.56(1.49), respectively. The data in Tables C13 and C14 and Figures C8 through C14 show that the remainder of the metals analyzed did not exhibit the leaching trends of As and Ni. Copper and Pb showed significant inverse linear relationships ($p < 0.05$) between steady state sediment and leachate concentrations yielding distribution coefficients (standard error) of -13.9(0.58) and -15.7(0.84), respectively. The non-ideal desorption isotherms for Cu and Pb (reverse isotherms) are also probably a pH effect, although a turning point was not observed. Theoretically and practically, a turning point must exist, otherwise the desorption isotherm will intersect the absisica, a physical impossibility. Mercury was not detected in any of these leachates. The remainder of the metals, Cd, Cr, and Zn, displayed no well-defined relationship between steady state sediment and leachate concentrations.

Many of the same trends observed in the anaerobic sequential testing were also observed in the anaerobic sequential challenge testing (Tables C15 and C16). Leachate concentrations of Ni and As showed similar trends to that presented in Figure C7 although peak leachate concentrations for both parameters occurred during the fourth leach cycle. Distribution coefficients (standard error) in the challenge tests derived for As and Ni in the same manner as for the sequential batch tests following peak concentrations were 3.75(0.44) and 4.11(1.65), respectively. The remainder of the metals displayed no well-defined relationship between q and C.

Steady state q and C metal concentrations obtained from the sequential batch leaching tests under aerobic conditions are presented in Table C17 and C18, respectively. Steady state q and C metal concentrations obtained from the challenge sequential batch leaching tests under aerobic conditions are presented in Tables C19 and C20 respectively. Mercury data are not presented because all values were below the detection limit of 0.002 mg/l. Arsenic and Cr displayed no linear relationship between concentrations for either sequential or challenge batch testing, as did Cd, Cu and Pb in the sequential batch testing. Distribution coefficients for aerobic Everett Harbor sequential and challenge batch leaching for which a statistically significant ($p<0.05$) linear relationship exists are summarized in Table C21.

Development of aerobic conditions in Everett Harbor sediment resulted in substantial releases of heavy metals into batch test leachate. Metal losses observed during this study under anaerobic and aerobic leaching conditions are summarized in Table C22. As can be seen, release of over 85% of sediment bound Zn occurred during the course of aerobic challenge testing.

Organic Contaminant Releases.

Steady state organic contaminant concentrations in leachate and sediment of anaerobic Everett Harbor sediment are listed in Tables C23 and C24, respectively. Of particular note is that only 8 of 33 compounds monitored were detected in the leachate. Compounds that were detected were present in very low concentrations, generally below the stated detection limits of 5 ug/l for PAH compounds analyzed using GC/MS. They were detected only because they have a strong, stable molecular ion that does not readily fragment, resulting in a strong signal at the detector. Concentrations of PCB congeners were very low as would be expected based on the low concentrations in the sediment. Similar results were obtained in the sequential challenge testing for organic contaminants in anaerobic sediment (Tables C25 and Tables C26). Changes in steady state sediment concentrations for both sequential and challenge batch testing were small; 0.124 ug/g was the the highest concentration of any organic contaminant and 0.005 ug/g the highest concentration of any PCB congener released during the sequential leaching process (Table C27).

Organic contaminant concentrations present in steady state leachate and sediment of aerobic Everett Harbor sediment are given in Tables C28 and C29, respectively. Only 7 compounds were detected in the leachate, although they differed somewhat from those detected during anaerobic testing. Analysis of first day leachate from sequential challenge batch testing for organic contaminants showed that only 5 of 7 compounds found in the aerobic batch test were detected. Concentrations of these compounds were similar to those measured in the batch testing. For reasons given in the following paragraphs, it was not necessary to analyze further aerobic challenge samples to obtain a valid single point organic challenge distribution coefficient.

Statistical analysis of the organic contaminant data revealed that no significant ($p<0.05$) linear relationship existed between steady state sediment and leachate organic contaminant concentrations from either the anaerobic sequential or challenge batch leaching and the aerobic sequential batch leaching. This type of behavior is expected if the distribution coefficient is very large and the resulting changes in steady state contaminant concentration are small. It is reasonable to assume that, unlike metals, all of the organic contaminants associated with a sediment are potentially leachable. The lack of complete reversibility observed in numerous experiments is probably due to kinetics, i.e., the presence of a slowly desorbing sediment contaminant component (Di Toro, 1985). This is not the case for metals because of the known association of metals with immobile sediment phases (Brannon et al. 1976, 1980). Using this assumption, single point organic contaminant distribution coefficients were calculated for the sequential and challenge batch testing using the average steady state leachate and sediment concentration for each of the three replicate tests conducted. These data are presented in Table C30. Distribution coefficients for both the anaerobic sequential and challenge testing were high; K_d values for PAH compounds did not fall below 1000 l/mg. Distribution coefficients for PCB congeners were somewhat lower than those measured for PAH compounds. Distribution coefficients for aerobic testing were generally comparable to those noted under anaerobic conditions when the same compounds were released under both conditions.

Permeameter Testing

Continuous flow column leaching tests were conducted using divided flow permeameters, as previously described, with both anaerobic and aerobic Everett Harbor sediment. Approximately three pore volumes passed through the anaerobic columns and 3.5 pore volumes through the aerobic columns before testing ended.

Metals and DOC

Effluent metal concentrations and corresponding pore volumes are summarized in Tables C31 and C32 for anaerobic and aerobic columns, respectively. In general, samples from the anaerobic columns had relatively low concentrations, usually within a factor of ten of the detection limit. DOC increased from around 50 mg/l to 225 mg.l. This is consistent to results obtained during batch testing which showed DOC concentrations peaking at the fourth step (181 mg/l). Leachate pH increased from 7.3 to 8.4 during column operation, again consistent with the increase observed in the anaerobic sequential batch tests.

Metal concentrations measured in the effluent from aerobic columns were generally higher by an order of magnitude than corresponding samples from the anaerobic columns. Cr and Zn leachate concentrations were more variable than other metals between columns. Average DOC concentrations ranged from 64 mg/l to 85 mg/l, showing no washout or significant increase. Batch DOC concentrations were generally constant around 40 mg/l, also showing no washout or significant increase. Initially the pH of the aerobic column leachate was low, around 3.5. However, pH increased to 7.0 by the conclusion of column operation. This is contrary to results obtained in the sequential batch leach tests (Table C11). The difference between batch and column leachate pH is probably due to differences in oxidation-reduction potential. In the column tests the sediment is in a flooded condition. Due to sediment oxygen demand, the system rapidly becomes anaerobic, resulting in a decrease in redox potential and a rise in pH. In the aerobic batch tests, oxygen is continually replenished by turbulence, redox potential remains high, and the pH remains low. Consequently, the leaching conditions are not comparable, and contaminant mobility will not be the same.

<u>Organics and DOC</u>

No PAH compounds were detected in the effluent from either aerobic or anaerobically operated columns. Concentrations of each PCB congener and dissolved organic carbon are provided in Tables C33 and C34 for aerobic and anaerobic columns, respectively. Variation in pH, conductivity and DOC during batch and column studies is summarized in Table 35. Total Arochlor 1254™ congener concentration varied from 0.00001 to 0.00036 mg/l in leachate from the anaerobic columns. Five samples from aerobic columns have been analyzed, total congener concentrations range from 0.00001 to 0.00176 mg/l. DOC values from the anaerobic columns increased from around 50 mg/l to 250 mg/l, behavior similar to that observed for anaerobic metals. Aerobic DOC concentrations increased from 60 mg/l to around 200 mg/l.

As described earlier and shown in Table C30, an average, single point distribution coefficient was computed for each congener measured and for total Aroclor™ 1254 congeners using anaerobic batch leaching data. Using equation C1 and the appropriate value of K_d in Table C30 an approximate equilibrium concentration for each congener detected and total Aroclor™ 1254 congeners was computed. These values are provided in Table C36 along with average measured concentration for each sample. Measured and computed equilibrium concentrations were generally similar.

Integrated Approach

Anaerobic Metals

The contaminant transport equation, equation C-6 previously presented in this appendix assumes that sequential batch leach data will provide ideal desorption isotherms (Figure C5) for contaminants of interest. For an ideal desorption isotherm, K_d is a constant greater than zero. As previously discussed, the desorption isotherms for Everett Harbor anaerobic metals were generally non-ideal. The plots for Zn, Cd, Cr did not exhibit statistically valid linear relationships between q and C, thus K_d could not be determined as the isotherm slope for these metals. Isotherm plots for Cu and Pb exhibited an inverse relationship between q and C, that is, C increased as q decreased, as illustrated in Figures C11 and C12. Desorption isotherms for As and Ni initially exhibited an an inverse relationship but changed orientation to a ideal relationship (C decreased as q decreased) at the third and fourth steps, respectively of the sequential leaching procedure, as shown in Figures C7 and C8. Because the contaminant transport equation requires constant values of K_d it is not possible to predict permeameter leachate concentrations using this equation. The effort required to develop a numerical solution to equation C-1 for variable distribution coefficients was not within the scope of this study.

A simplified alternative method that roughly approximates equation C-1 was, therefore, developed. Houle and Long (1980) recognized that a continuously leached column is equivalent to running a series of discrete batch leach tests. If the physical-chemical processes in a series of batch leach tests are the same as those occurring in a continuous flow column then it should be possible to predict the general shape of a column elution curve using desorption isotherm analysis. Further, each step in the sequential leach test can be related to a pore volume of water through a continuous-flow allowing a direct comparison of batch leachate concentration and column leachate concentration to be made.

If dispersion is neglected, column leachate concentrations can be predicted by relating the leachate concentrations in each step of the sequential batch test to an equivalent pore volume through the columns. This is done on the basis of equivalent liquid-solids ratios. A liquid-solids ratio for an operating column is defined as the weight of the accumulated volume passed through the column divided by the weight of the sediment in the column. For Everett Bay sediment the initial water content (W_w/W_s) in the columns was 1.81, while that in each step of the sequential leaching process is 4:1. Because the weight of water contacting the solids in the column increases with increasing throughput, the column liquid-solid ratio will reach 4:1 when 2.2 (4/1.8) pore volumes have passed through the column. Thus each step in the batch leaching procedure is equivalent to the passage of 2.2 pore volumes thru the column. The leachate concentration obtained during each step in the batch procedure represents the average concentration over the corresponding pore volume increment. Thus, the concentration measured during the first step in the sequential batch leach test is an estimate of the column leachate concentration at 1.1 (0 to 2.2 P.V. interval) pore volumes. Cumulative pore volumes, equivalent liquid-solid ratios and the corresponding batch test step number are listed in Table C37.

As noted above, the desorption isotherm data for Cu and Pb produced desorption isotherms with inverse slopes. An "inverse isotherm" predicts that column contaminant concentrations should continuously increase with time (pore volumes). The desorption isotherms for As and Ni were double-valued, changing slopes from inverse to direct (ideal). An isotherm which changes direction (inverse to direct) implies that column concentrations should increase to a peak then decrease. Thus, the sequential batch leach data can be used to indicate the general shape of the column elution curves for Cu, Pb, As, and Ni. However, as with anything that is simple and direct, there are limitations. Since the direct comparison procedure does not include advection and dispersion, the procedure cannot predict shifting and spreading of peaks caused by advection and dispersion.

Using the direct comparison procedure described above, predicted column concentrations and corresponding pore volumes are plotted for As, Cd, Cr, Pb, and Zn in Figures C15 through C19, respectively. On the same figures are plotted the observed column concentrations. The predicted concentrations of Ni, and Cu are plotted in Figure C20. Several metals showed concentration peaks at between 6 and 10 pore volumes. With the exception of a single observed Cr value both predicted and observed values were relatively low for all metals.

Overlap of batch and column data for the direct comparison method began at 1.1 pore volumes. Operation of the columns was terminated at approximately 3.5 pore volumes. In the region where observed and predicted results can be compared (1.1 < pore volume < 3.0) agreement is reasonably good for As, Cd, and Pb. Substantial disagreement occurred for As, and Cr. Because predicted and observed data agree reasonably well for As, Cd, and Pb it seems reasonable that extrapolation of the direct comparison method to the field is valid, at least for indicating the overall pattern of contaminant release.

Anaerobic Organics

Previous work (Myers, Brannon, Griffin 1986) has demonstrated that when the desorption coefficient, K_d, is large, as is the case for PCB or PAH compounds, the source term in the one dimensional contaminant transport equation is dominant. Predicted contaminant concentrations will therefore remain at or near initial equilibrium pore water levels (Figure C21.) As a result, application of the integrated approach to PCB and PAH compounds in sediment involves comparing the equilibrium concentration predicted using batch test data to those in the column effluent in order to verify the value of K_d used. Initial equilibrium concentrations are computed using equation C- 7 below

$$C = q_o \;/\; (K_d + L/S) \qquad \text{(C-7)}$$

where K_d is determined from batch testing, q_o is the initial bulk contaminant concentration, and L/S is the liquid-solids ratio. Since the liquid-solids ratio in the column tests is 1.8 and the distribution coefficients are greater than 100 l/kg, L/S can be neglected.

The data in Table C36 were used to compare predicted equilibrium congener concentrations to observed values for all PCB compounds for which a value of K_d is available (compound numbers 28, 29, 30, and 32) as well as total PCB congener concentration. The average congener and total congener concentration of each of the four column samples collected varies around their respective predicted equilibrium values. Given the complexity of the sequential procedure and column operation such variation is not unexpected. Conservative estimates of contaminant flux are assured if the maximum observed average column concentration is used in each case.

To illustrate application of equation C-6, computed and predicted concentrations of total Arochlor™ 1254 congeners are compared in Figure C22. Predicted concentrations were computed using equation C-6. This figure clearly shows the effect of a large distribution coefficient (K_d=483) on resulting contaminant concentrations. Varying K_d between 367 and 599 (K_d plus or minus 1 S.E.) had no effect on computed concentrations, which remained at the initial value of .0002 mg/l. Since individual PCB congeners detected are characterized by distribution coefficients ranging from 266 to 1835 l/kg, similar behavior would be expected.

The batch data suggest that two PAH compounds, compound Numbers 7 and 9, should have been detected in the column leachates. At present, the absence of detectable concentrations of these two contaminants in column leachates cannot be explained.

Aerobic Metals and Organics

Previous work (Environmental Laboratory 1986) has shown that the use of batch desorption coefficients determined under aerobic conditions, to predict contaminant concentrations from columns initially filled with aerobic sediment is inappropriate. Even sediment placed in an oxidizing environment for six months retains enough oxygen demand to become anaerobic once it is placed in a column and flooded. This change in the oxidation-reduction potential of the sediment affects its desorptive properties. The differences between aerobic column and aerobic batch leachate data are illustrated in Figures C23 through C26 for Cr, Cd, Zn, and Pb. Unlike anaerobic column results where agreement between observed and predicted concentrations was usually reasonable, the initial concentrations from the "aerobic" columns were much higher than obtained during batch testing. The physical chemical basis for these differences has not yet been fully explained. However, the pH variation during the anaerobic column test matched that in the anaerobic batch test quite closely. In the aerobic batch test the pH dropped while in the aerobic column study the pH rose substantially. Because of the pH differences between aerobic batch and column tests, application of the integrated approach to partially oxidized sediment is of limited value because the assumption of equivalent leaching environments is not fully satisfied.

Summary

Releases of metals during anaerobic testing were relatively low. Two elements (Cu, Pb) were characterized by inverse desorption isotherms and two others (As, Ni) by double-valued desorption isotherms. The remainder (As, Cd, and Cr) produced clustered desorption isotherms for which well-defined relationships were not evident. This is believed to be the first time inverse and double-valued desorption isotherms have been reported in sediment leaching studies. As previously discussed, the inverse and double-valued isotherms are indicative of non-constant geochemistry during the sequential leaching. Figure C27 shows how changing sediment chemistry can produce inverse desorption isotherms and the upper limb of double-valued desorption isotherms. Changes in sediment chemistry between steps in the sequential leach procedure increases contaminant mobility (decrease in K_d). The concept presented in Figure C27 is tentative, and further testing and verification is required before this explanation of inverse and double-valued desorption isotherms can be accepted.

Using a simplified integrated approach, direct comparison of anaerobic batch and column data was possible. For those metals analyzed during both anaerobic batch and column studies (As, Cd, Cr, Pb, and Zn), column behavior was well predicted for As, Cd, and Zn. Less agreement was observed for Pb and Cr.

Aerobic test results were characterized by large metal losses during batch testing. Thus, the potential for contaminant release is higher in a CDF that allows the dredged material to become oxidized than in a CDF that maintains anaerobic leaching condition. In most CDFs, partially oxidized sediment will constitute a relatively thin surface crust making up a small part of the total sediment mass. Even though the contaminant release from the crust may be significantly higher than from underlying material, contaminant flux through foundation soils or through dikes probably will not be affected unless a significant portion of the CDF reaches a partially oxidized state. The disposal alternative for which oxidization of the dredged material is most likely to be important is the upland alternative.

Average concentrations of specific PCB congeners (compound numbers 28, 29, 30, and 32) as well as total PCB congeners were about the same in anaerobic batch and column tests. Average anaerobic column concentrations agreed well with equilibrium concentrations computed using single point estimates of K_d.

Worst-case contaminant flux calculations can be made using the maximum concentration observed in either the batch or column testing. For example, the maximum anaerobic concentration for Cr was observed in column tests while that for Zn was observed in batch tests. In the case of Ni and Cu, column data are not available and maximum batch values must be used. Contaminant concentrations recommended for contaminant flux calculations are listed in Table 1 in the main body of this report. Because the peak concentration values used in this table do not occur until several pore volumes have passed, the peak contaminant flux may not occur until a CDF has been in operation for some time. Further, maximum flux for all metals is not expected to occur simultaneously.

CONCLUSIONS

An integrated laboratory approach was used to investigate contaminant leaching from Everett Harbor sediment. The integrated approach appears to provide a useful theoretical framework within which to describe leaching phenomena. The results presented in this appendix, in part, provide the basis for performing contaminant flux analysis for proposed confined disposal facilities. Specific conclusions are provided below.

a. A contaminant transfer equation based on the assumption of equilibrium-controlled linear desorption reasonably predicted anaerobic column leachate concentrations for PCBs.

b. Overall, Everett Harbor results indicate that anaerobic column behavior could be predicted using batch data, although the basis for direct comparison using an approximate method was limited. Results for the anaerobic column data and application of the direct comparing method are presented in Figures C15 through C20 and C22.

c. Approximate methods for applying the integrated approach can be used. However, methods that do not use a contaminant transport equation will require significantly longer column operation.

d. A contaminant transport equation with variable coefficients is needed in order to couple interphase transfer of contaminants from sediment solids to leachate with the advective and dispersive flux in continuous flow systems. In order to apply a more sophisticated equation, functional relationships between distribution coefficients and pore-volume throughput will be required. The effort required to develop reliable input needed for a complicated model was not within the scope to this study.

e. Higher contaminant release to the environment from Everett Harbor sediment will occur in instances where the sediment is allowed to oxidize. The potential significance of this result is dependent on the operating scenario of the CDF and is therefore highly site specific.

f. The anaerobic sequential batch leach tests for Everett Harbor sediment exhibited non-constant geochemistry (variable pH) that resulted in two types of non-ideal desorption isotherms for metals, inverse and double-valued. This is believed to be the first time inverse and double-valued desorption isotherms have been reported for sediment.

g. An understanding of the diversity of chemical interactions and sediment geochemistry is required in order to interpret data from batch leach tests. Data reduction and analysis by statistical procedures alone can be seriously misleading. The integrated approach used in this study provides a technical basis for interpretating batch leach data.

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Figure C1. Experimental Sequence for Determining Appropriate Shaking Times Everett Harbor Kinetic Testing

STEP 1	PLACE SEDIMENT IN APPROPRIATE CENTRIFUGE TUBE (STAINLESS STEEL OR POLYCARBONATE), ADD SUFFICIENT DEOXYGENATED DISTILLED WATER TO MAINTAIN WATER TO SEDIMENT RATIO OF 4:1.
STEP 2	PLACE CENTRIFUGE TUBES HORIZONTALLY ON SHAKER AND SHAKE AT 160 CYCLES PER MINUTE.
STEP 3	REMOVE TUBES (ENOUGH FOR TRIPLICATE SAMPLES FOR ORGANICS AND FOR METALS) FROM SHAKER AT APPROPRIATE INTERVALS: 1, 2, 4, and 7 DAYS FOR ORGANIC CONTAMINANTS AND AT 1, 2, 3, and 7 DAYS FOR METALS.
STEP 4	CENTRIFUGE FOR 30 MINUTES AT 6500 X G FOR ORGANICS AND 9000 X G FOR METALS. REPETITION OF STEP 4 USING CLEAN CENTRIFUGE TUBES WAS NECESSARY FOR LEACHATE FOR ORGANIC ANALYSES.
STEP 5	FILTER CENTRIFUGED LEACHATE THROUGH 0.45 um PORE SIZE MEMBRANE FILTERS FOR METALS AND THROUGH A WHATMAN GF/D GLASS FIBER PREFILTER AND A GELMAN AE GLASS FIBER FILTER OF 1 um NOMINAL PORE SIZE FOR ORGANICS.
STEP 6	ACIDIFY LEACHATE FOR ORGANIC ANALYSIS WITH HCL AND LEACHATE FOR METALS WITH ULTREX NITRIC ACID. STORE LEACHATE FOR ORGANIC ANALYSIS IN ACETONE RINSED GLASS BOTTLES AND LEACHATE FOR METALS ANALYSIS IN PLASTIC BOTTLES.

Figure C2. Test Sequence for Determining Appropriate Water to Sediment Ratio for Use During Batch Testing Procedures

STEP 1	PLACE SEDIMENT IN APPROPRIATE CENTRIFUGE TUBES; 250 ml POLYCARBONATE FOR METALS AND 450 ml STAINLESS STEEL FOR ORGANIC CONTAMINANTS. ADD WATER TO EACH TUBE TO BRING FINAL WATER TO SEDIMENT RATIO TO 4:1, 8:1, 12:1, 50:1, and 100:1.
STEP 2	MIXTURES WERE THEN SHAKEN HORIZONTALLY AT 160 CYCLES PER MINUTE FOR 24 HOURS.
STEP 3	CENTRIFUGE FOR 30 MINUTES AT 6500 X G FOR ORGANICS AND 9000 X G FOR METALS. SAMPLES FOR ORGANIC ANALYSIS REQUIRED REPETITION OF STEP 3 USING CLEAN STAINLESS STEEL CENTRIFUGE TUBES TO REMOVE ADDITIONAL PARTICULATE MATTER.
STEP 4	FILTER LEACHATE THROUGH 0.45 um MEMBRANE FILTERS FOR METALS OR THROUGH A WHATMAN GD/F GLASS FIBER PREFILTER FOLLOWED BY PASSAGE THROUGH A GELMAN AE GLASS FIBER FILTER OF 1.0 um NOMINAL PORE SIZE FOR ORGANICS.
STEP 5	ACIDIFY LEACHATE FOR ORGANIC ANALYSIS WITH HCL AND LEACHATE FOR METALS ANALYSIS WITH ULTREX NITRIC ACID. STORE LEACHATE FOR ORGANIC ANALYSIS IN ACETONE RINSED GLASS BOTTLES AND LEACHATE FOR METALS ANALYSIS IN PLASTIC BOTTLES.

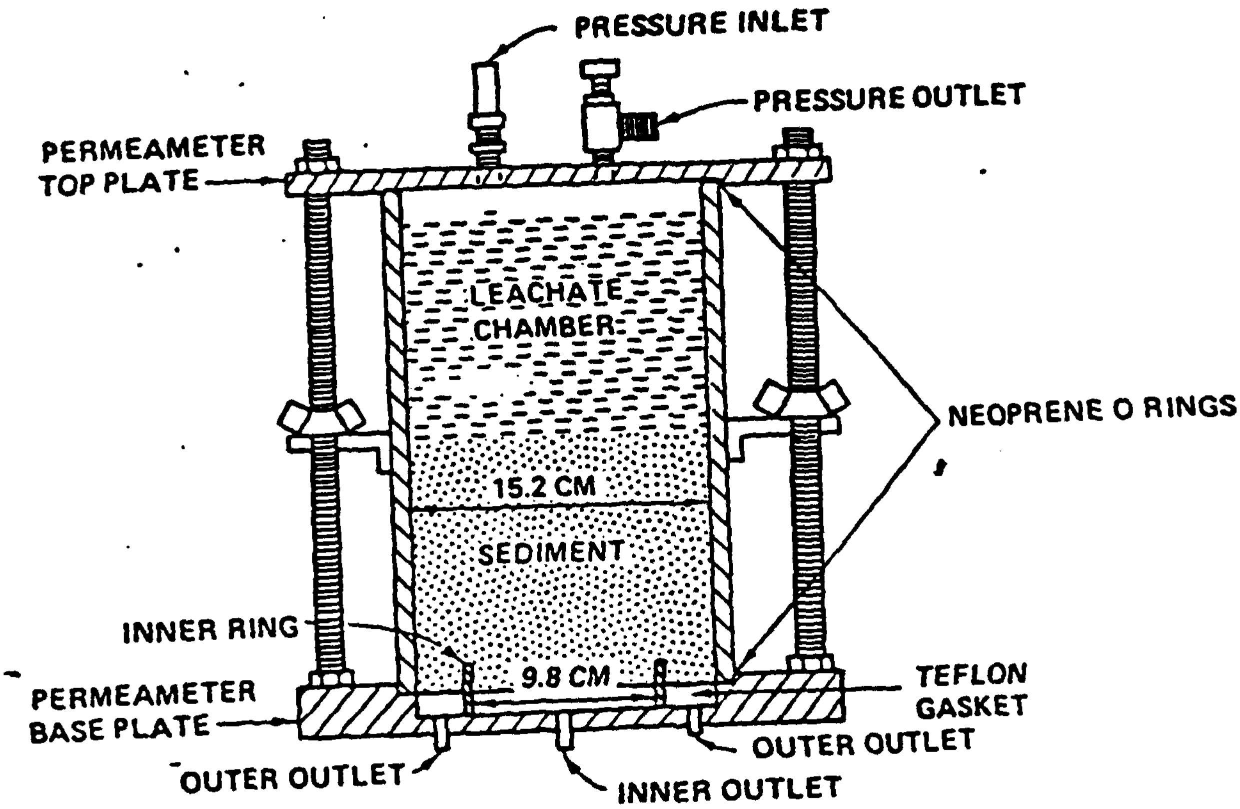
NOTE: THE ANAEROBIC INTEGRITY OF THE SAMPLE WAS MAINTAINED DURING SAMPLE ADDITION TO CENTRIFUGE TUBES, SHAKING, CENTRIFUGATION, AND FILTRATION.

Figure C3. Test Sequence for Sequential Batch Leaching and Challenge Testing of Anaerobic Everett Harbor Sediment for Metals and Organic Contaminant Analysis.

STEP 1	LOAD SEDIMENT INTO APPROPRIATE CENTRIFUGE TUBES; 500 ml POLYCARBONATE FOR METALS AND 450 ml STAINLESS STEEL FOR ORGANIC CONTAMINANTS. ADD SUFFICIENT WATER TO EACH TUBE TO BRING FINAL WATER TO SEDIMENT RATIO TO 4:1. SUFFICIENT STAINLESS STEEL TUBES MUST BE LOADED TO OBTAIN ENOUGH LEACHATE FOR ANALYSIS AND FOR USE IN LEACHING FRESH SEDIMENT.
STEP 2	GO THROUGH STEPS 2 AND 3 IN FIGURE 2.
STEP 3	FOR HALF OF THE LEACHATE FOR METALS, CARRY THROUGH STEPS 4 AND 5 IN FIGURE 2, SETTING ASIDE A SMALL AMOUNT OF LEACHATE PRIOR TO ACIDIFICATION FOR ANALYSIS OF pH AND CONDUCTIVITY. INTRODUCE THE REMAINING CENTRIFUGED LEACHATE INTO 250 ml POLYCARBONATE CENTRIFUGE TUBES FOR METALS AND 450 ml STAINLESS CENTRIFUGE TUBES FOR ORGANIC CONTAMINANTS. CARRY THESE CENTRIFUGE TUBES THROUGH STEPS 2 THROUGH 5 IN FIGURE 2.
STEP 4	RETURN TO STEP 2 AFTER REPLACING LEACHATE REMOVED IN THE INITIAL SET OF CENTRIFUGE TUBES WITH DEOXYGENATED DISTILLED WATER. REPEAT THE ENTIRE PROCEDURE THE DESIRED NUMBER OF TIMES.

NOTE: TESTING SEQUENCE IS THE SAME FOR AEROBIC SEDIMENTS EXCEPT THAT AEROBIC SEDIMENT LEACHATE IS USED TO CHALLENGE AEROBIC SEDIMENT AND ANAEROBIC INTEGRITY IS NOT MAINTAINED.

Figure C4. Divided-Flow Permeameter



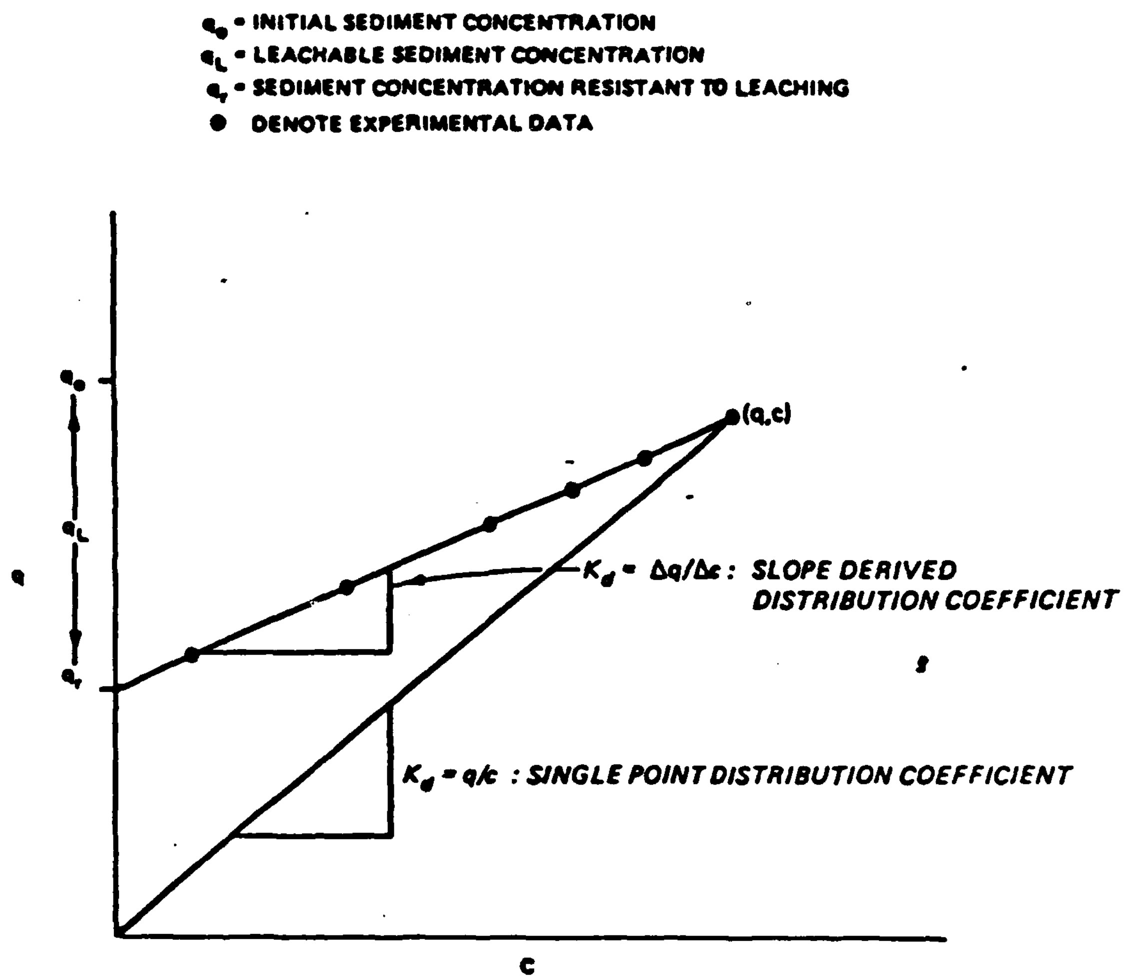


Figure C5. Ideal desorption isotherms: slope and single-point distribution coefficients

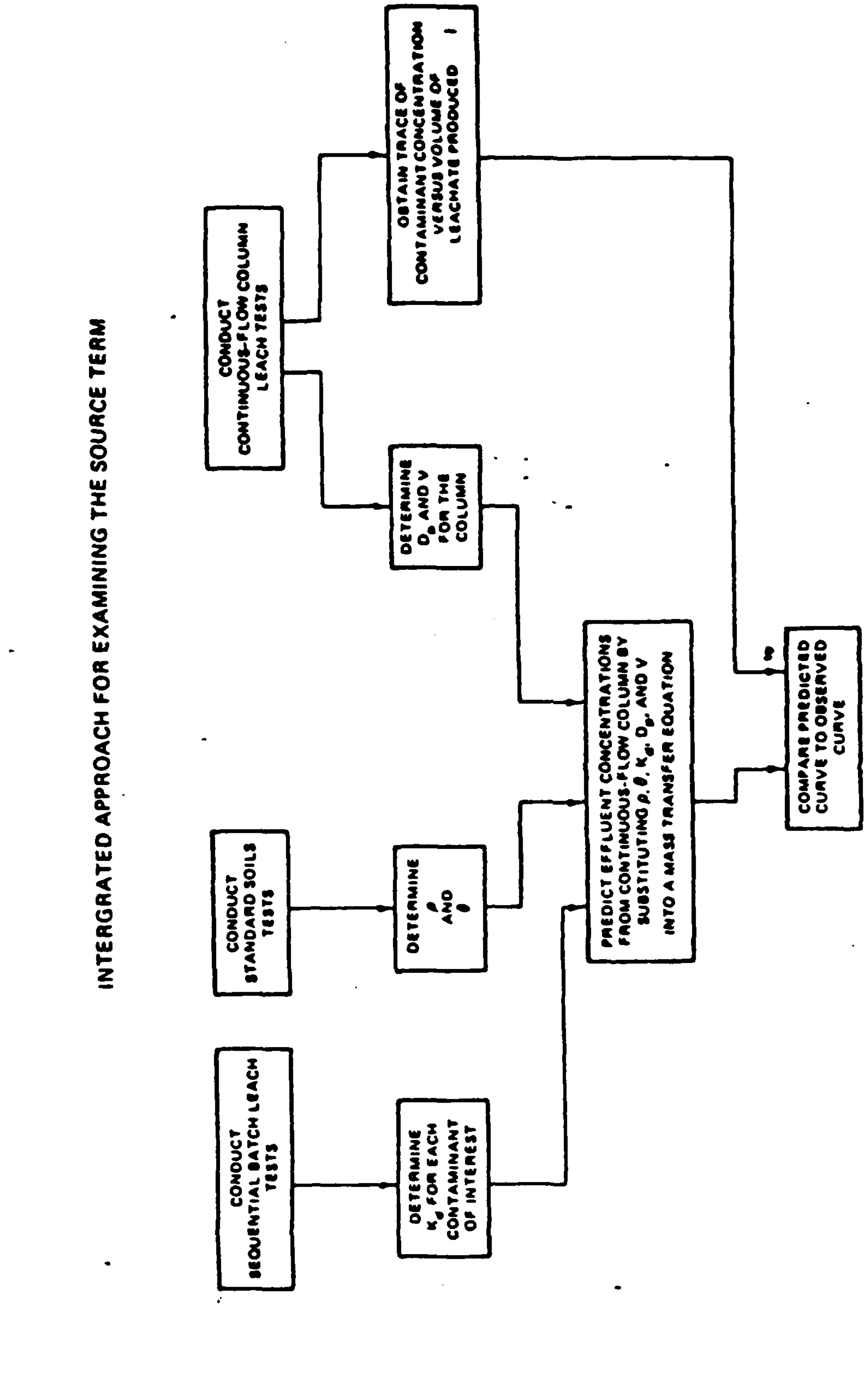


Figure C6. Schematic of integrated approach.

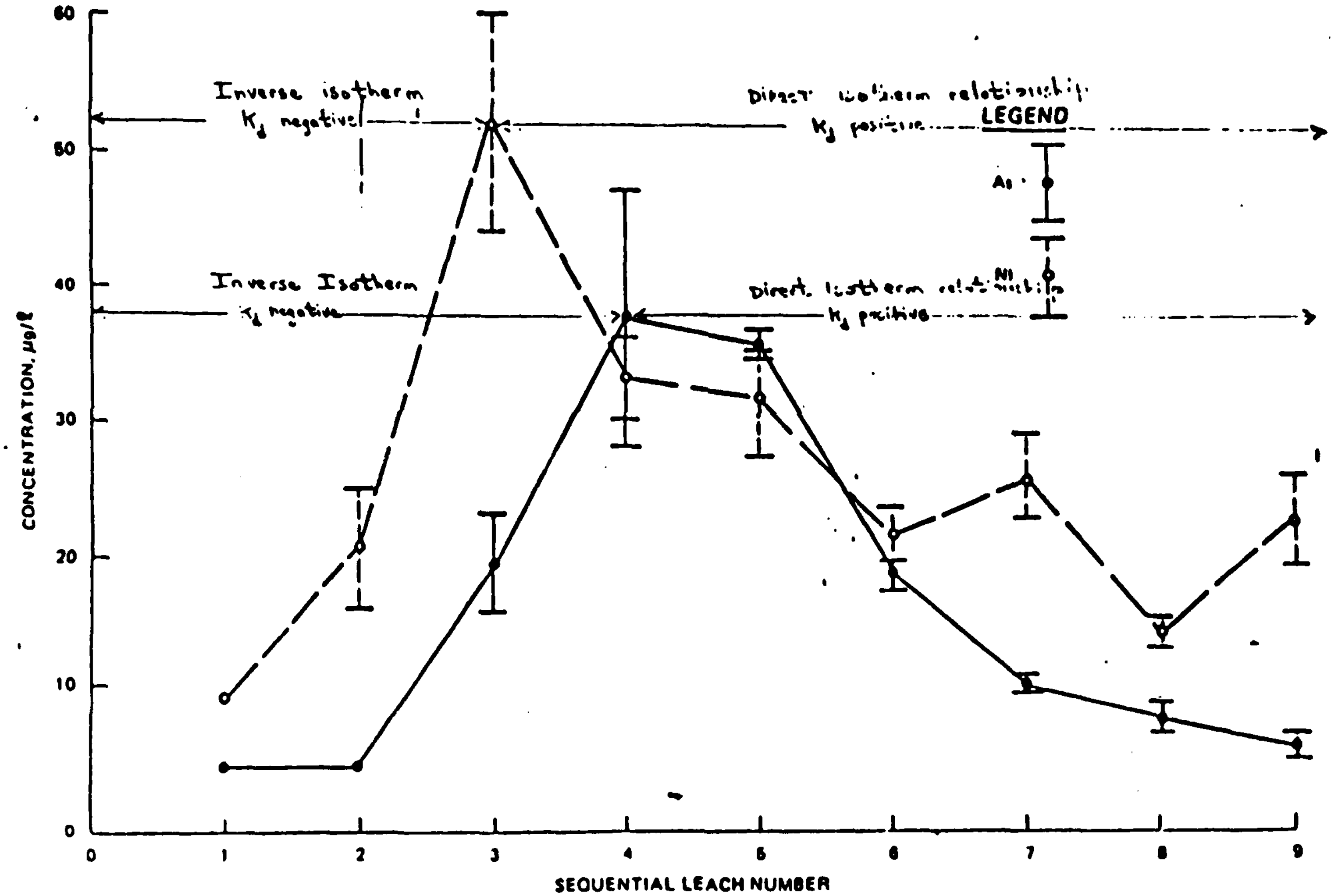


Figure C7. Arsenic and Ni concentrations in Everett Harbor leachate.

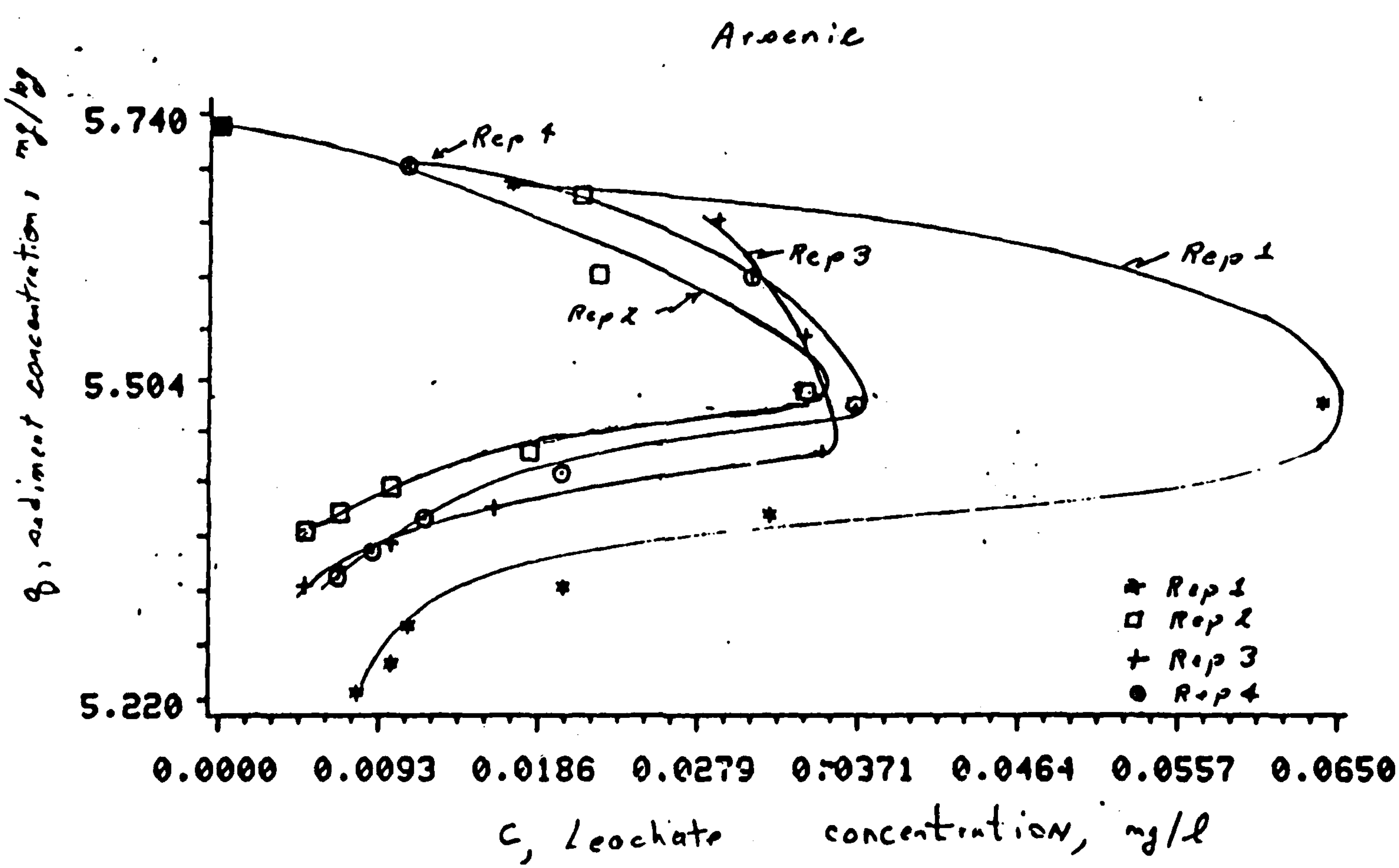


Figure C8. Arsenic desorption isotherm, anaerobic sediment

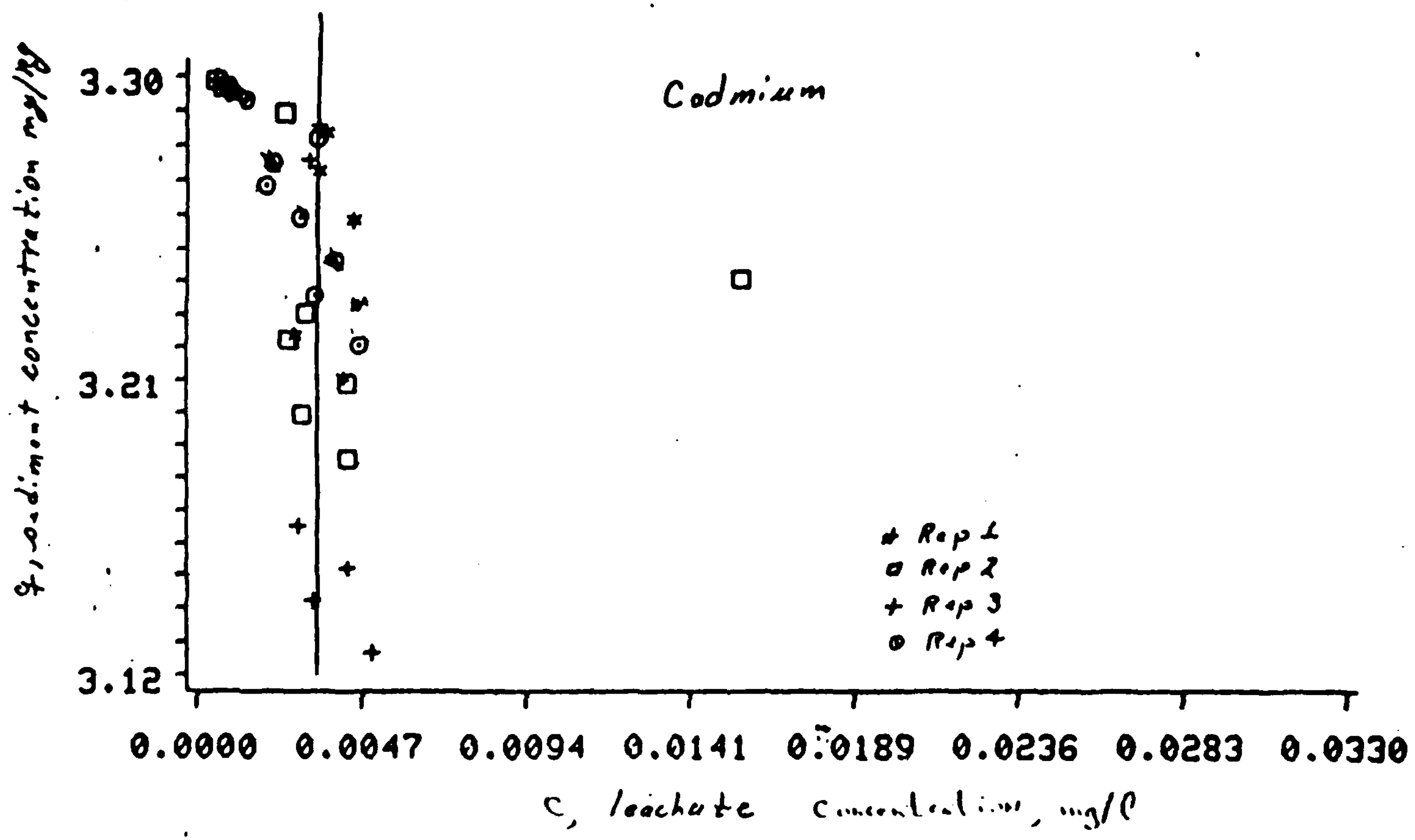


Figure C9. Cadmium desorption isotherm, anaerobic sediment

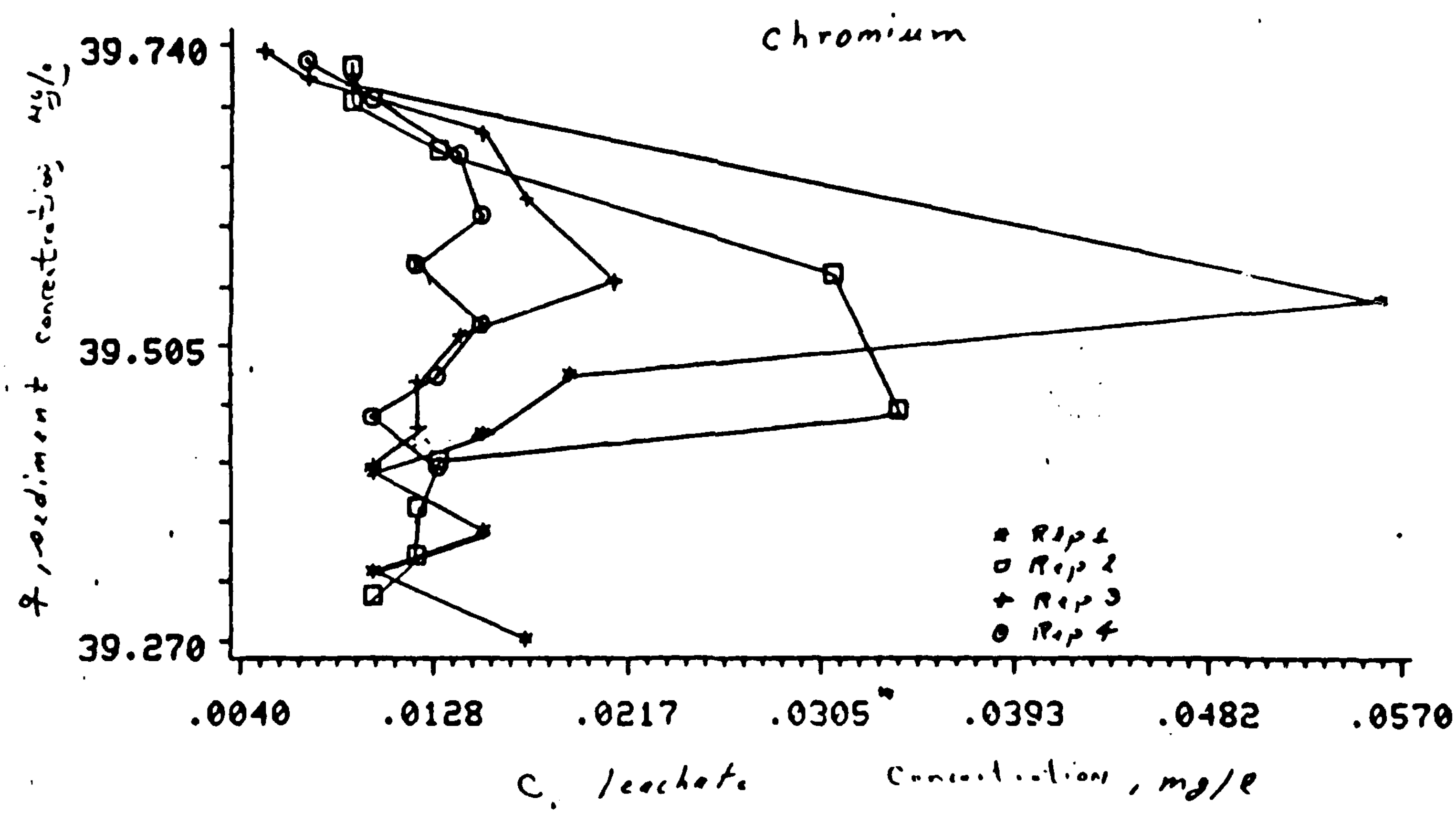


Figure 10. Chromium desorption isotherm, anaerobic sediment

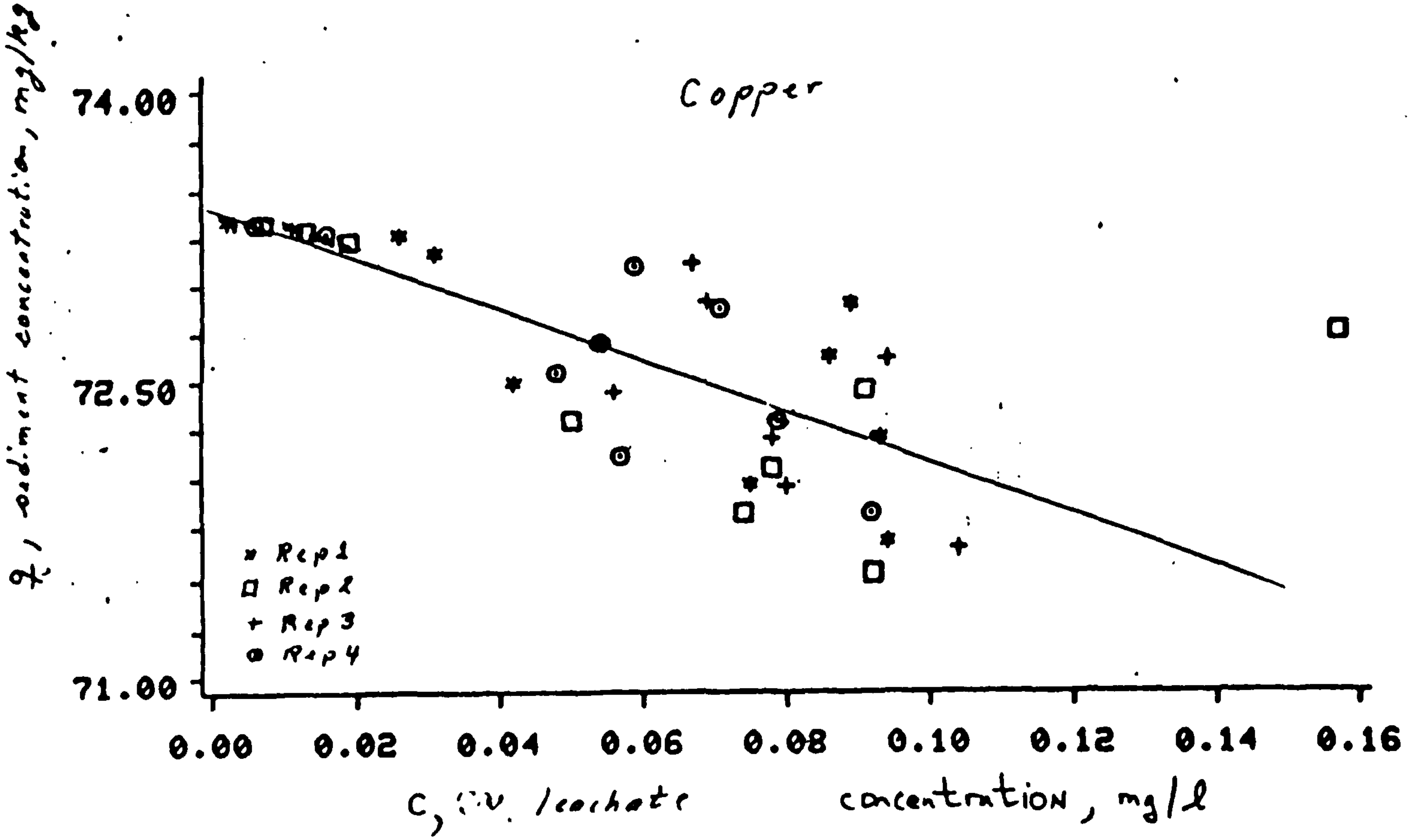


Figure C11. Copper desorption isotherm, anaerobic sediment

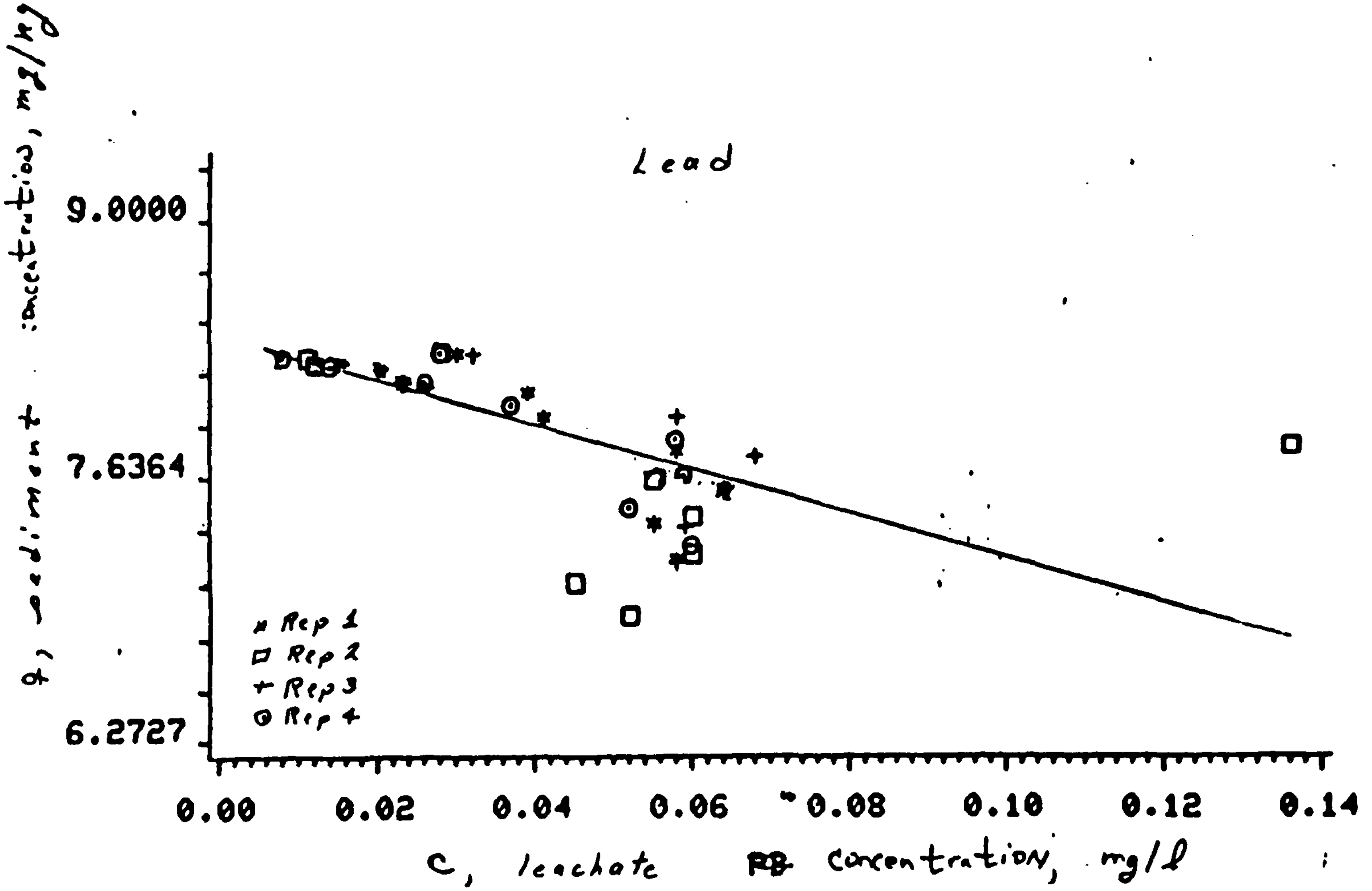


Figure C12. Lead desorption isotherm, anaerobic sediment

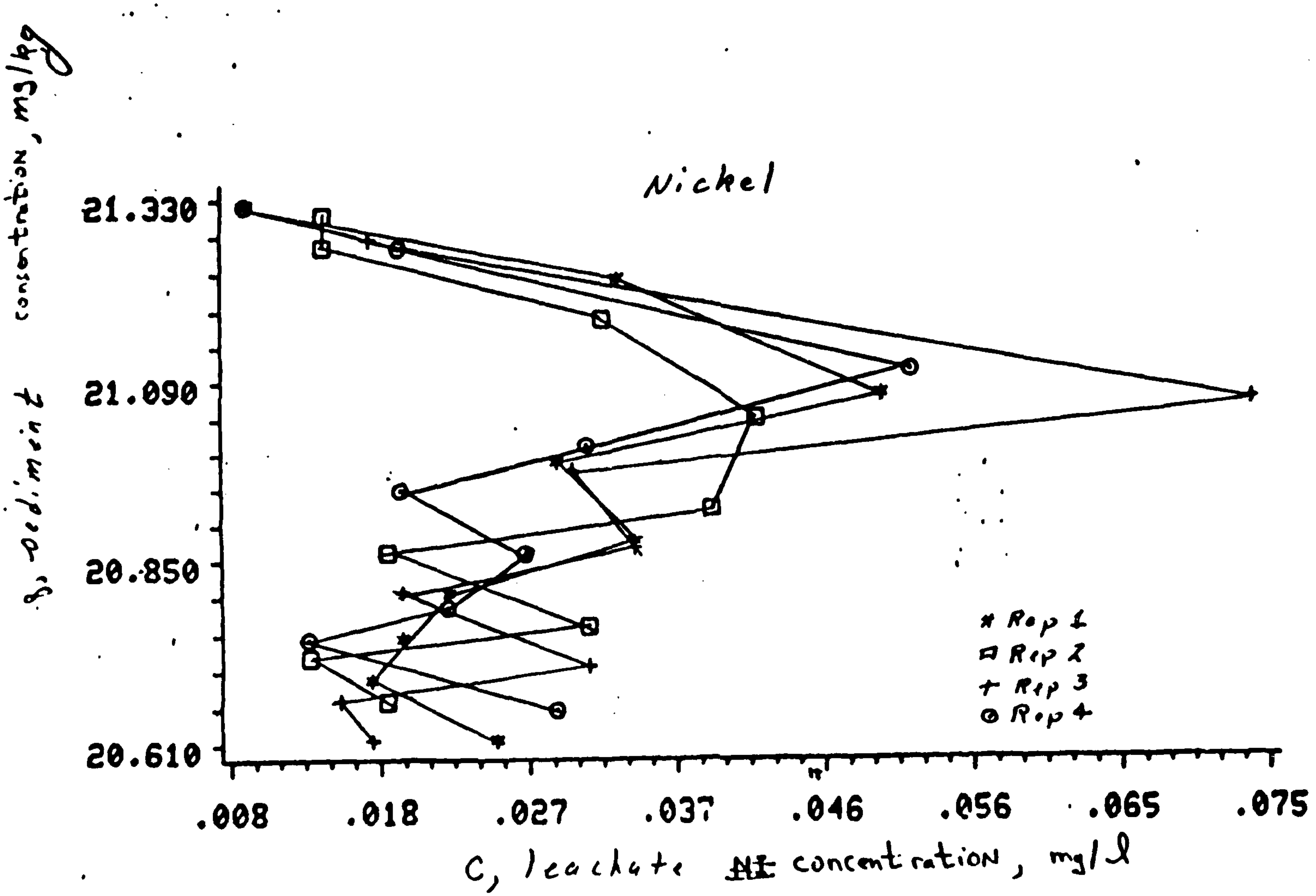


Figure C13. Nickel desorption isotherm, anaerobic sediment

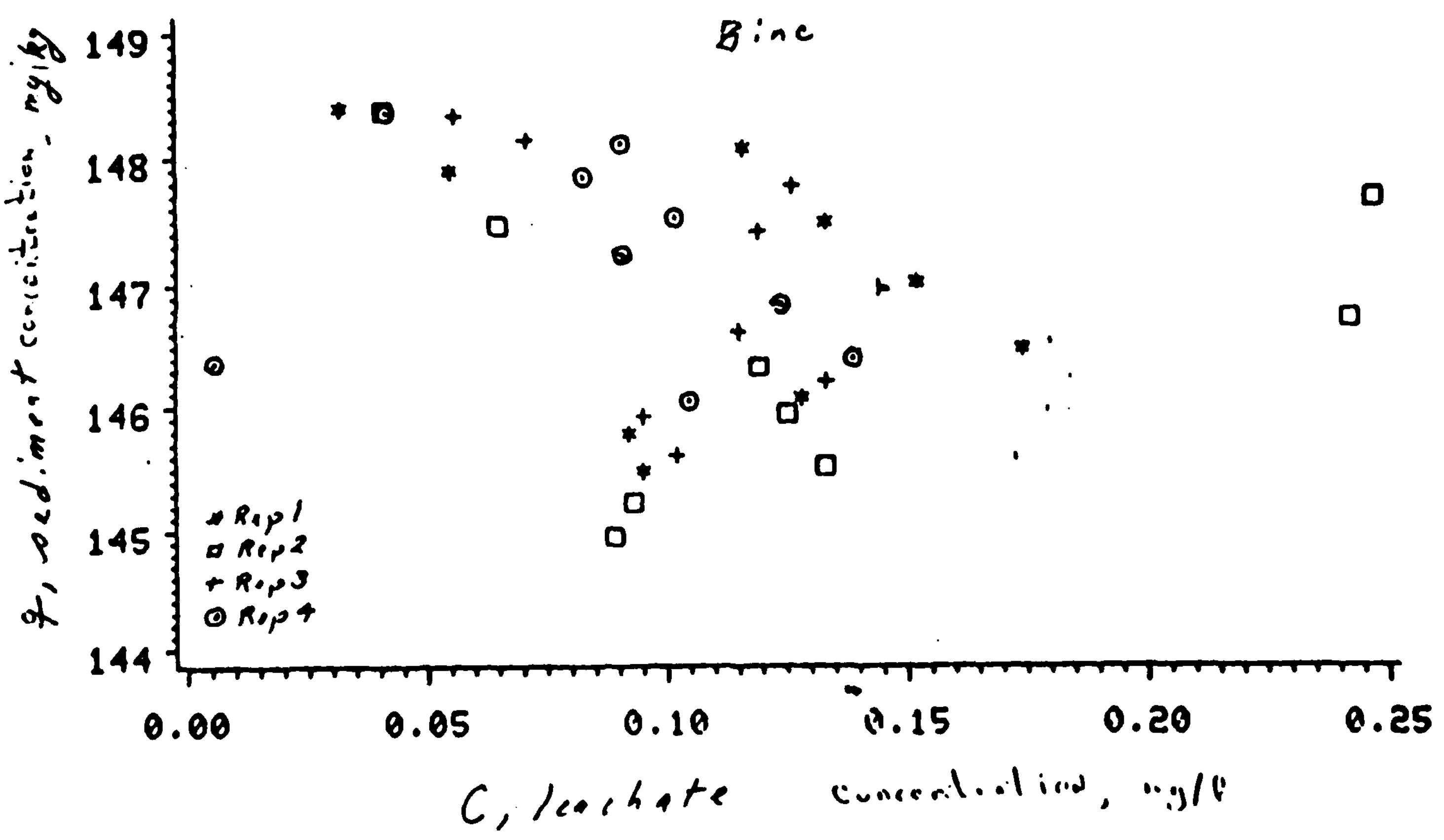


Figure C14. Zinc desorption isotherm, anaerobic sediment

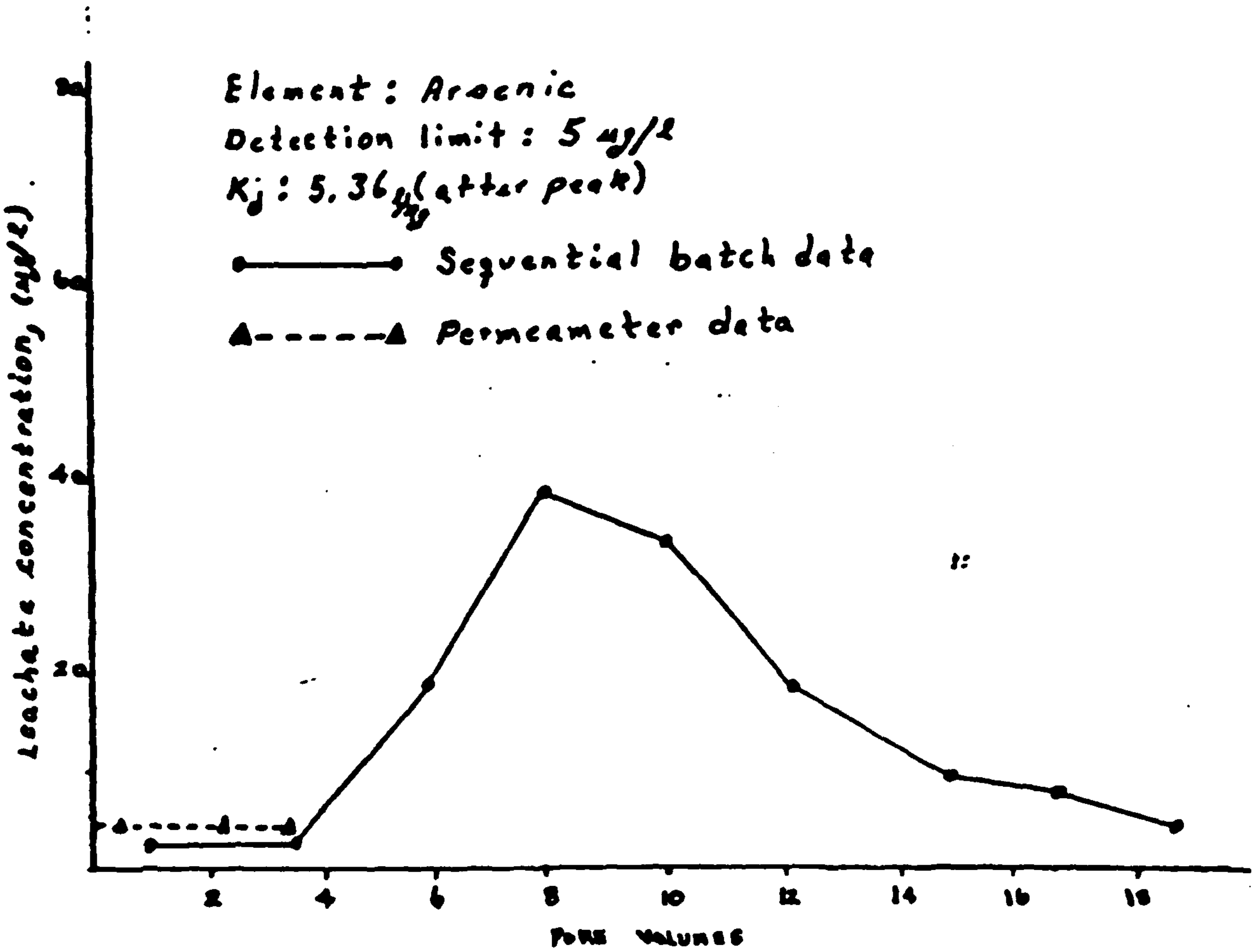


Figure C15. Comparison of observed and predicted arsenic concentrations in leachate from anaerobic permeameters

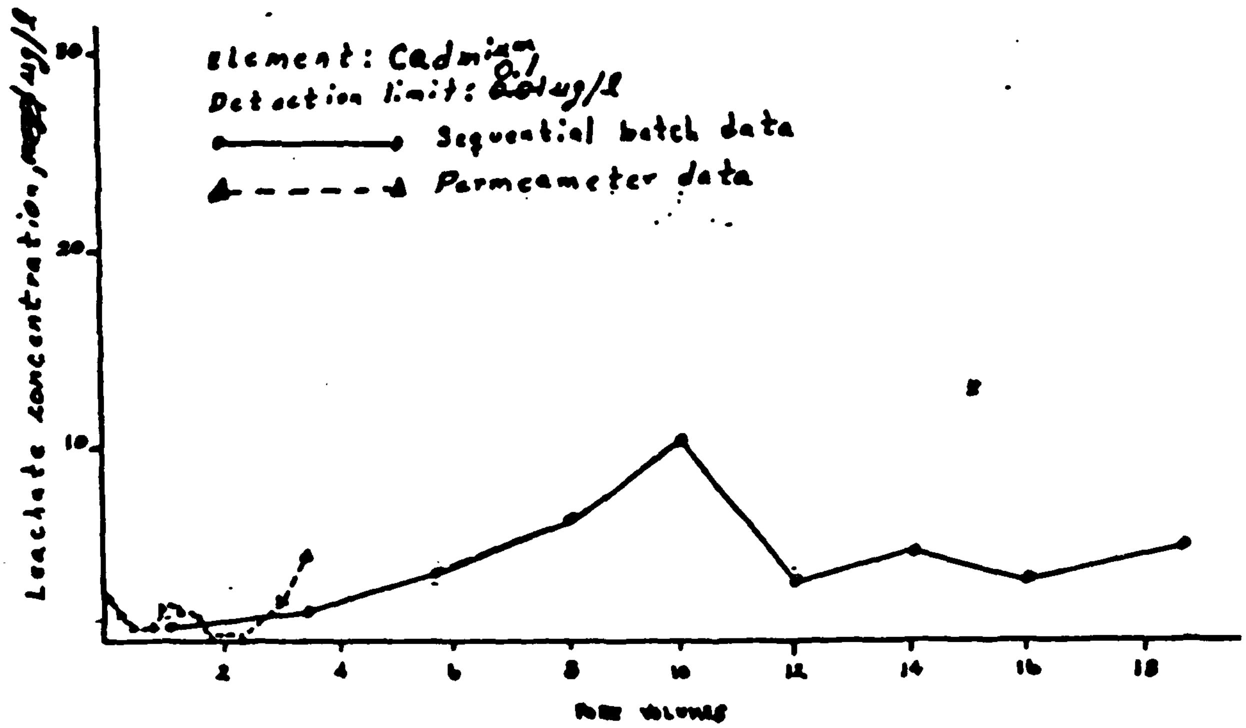


Figure C16. Comparison of observed and predicted cadmium concentrations in leachate from anaerobic permeameters.

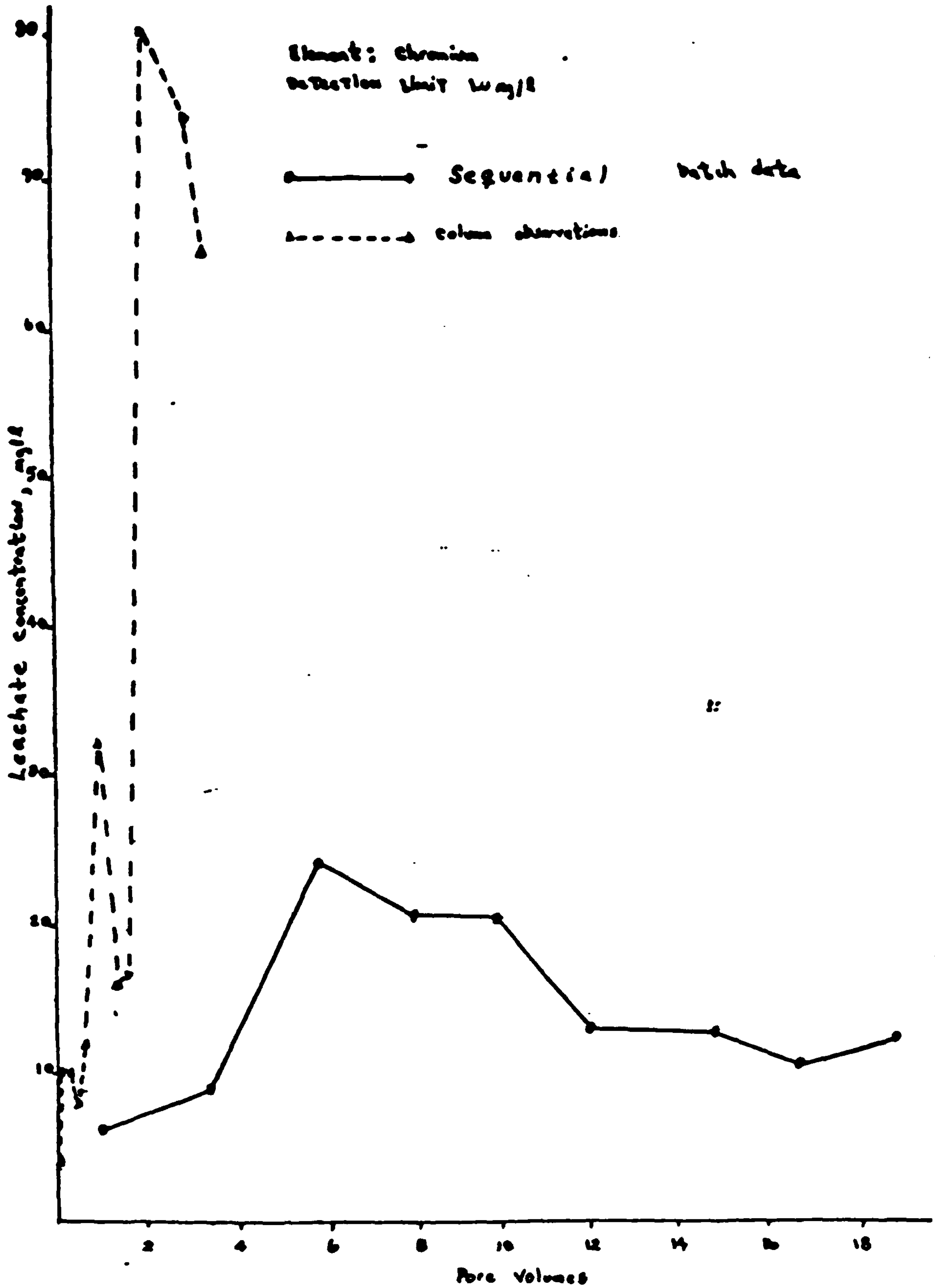


Figure C17. Comparison of observed and predicted chromium concentrations in leachate from anaerobic permeameters

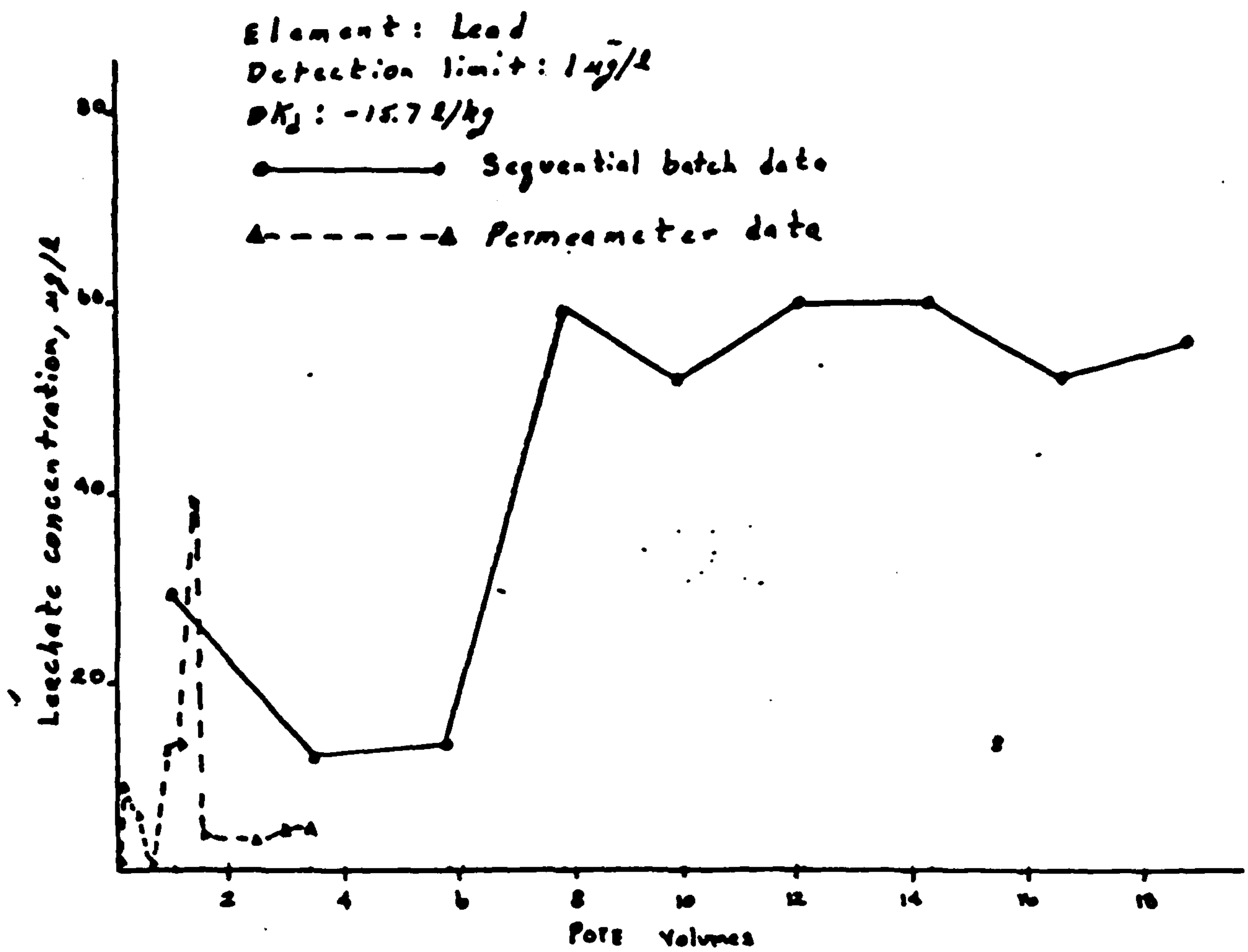


Figure C18. Comparison of observed and predicted chromium concentrations in leachate from anaerobic permeameters

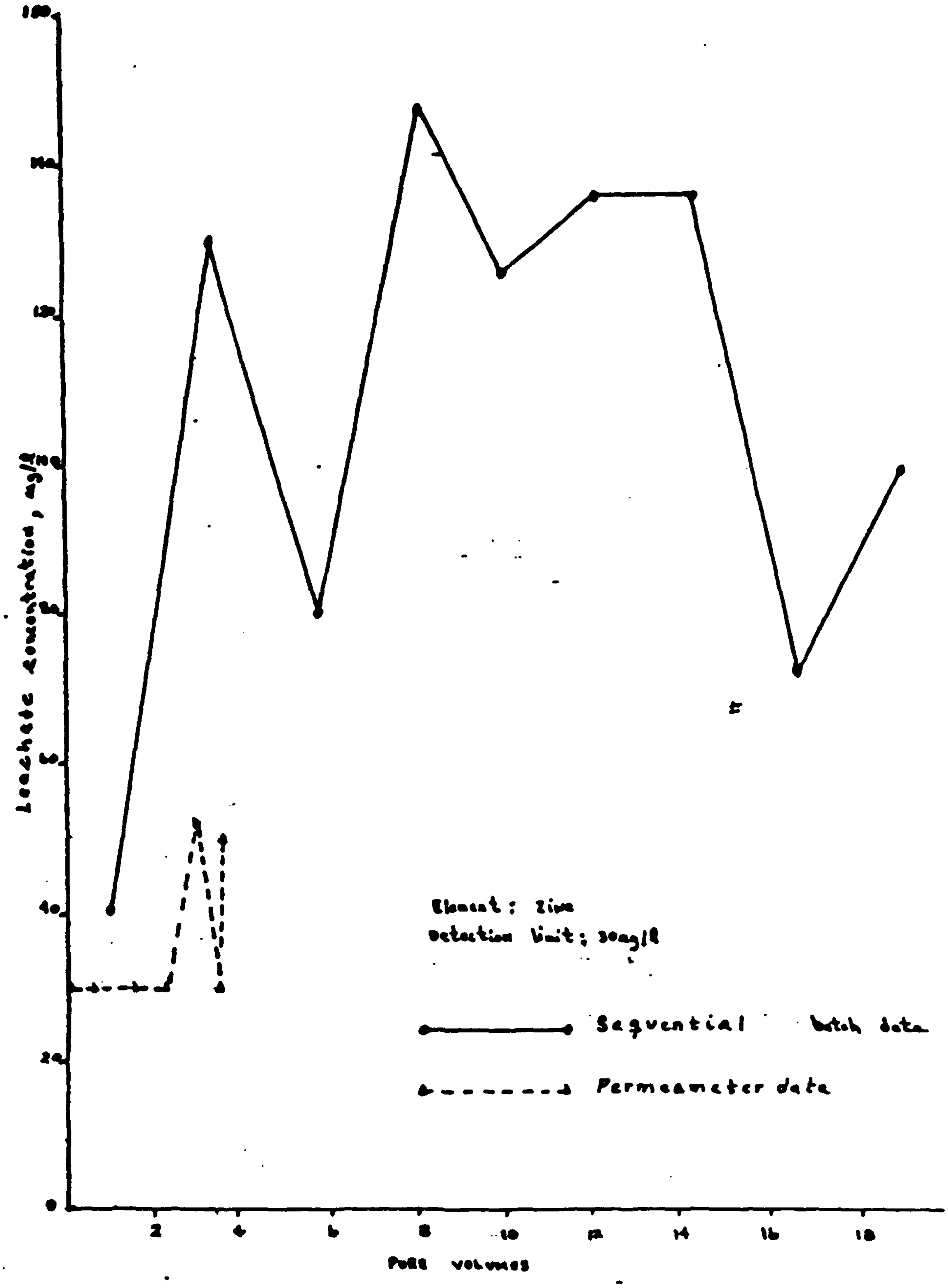


Figure C19. Comparison of observed and predicted zinc concentrations in leachate from anaerobic permeameters

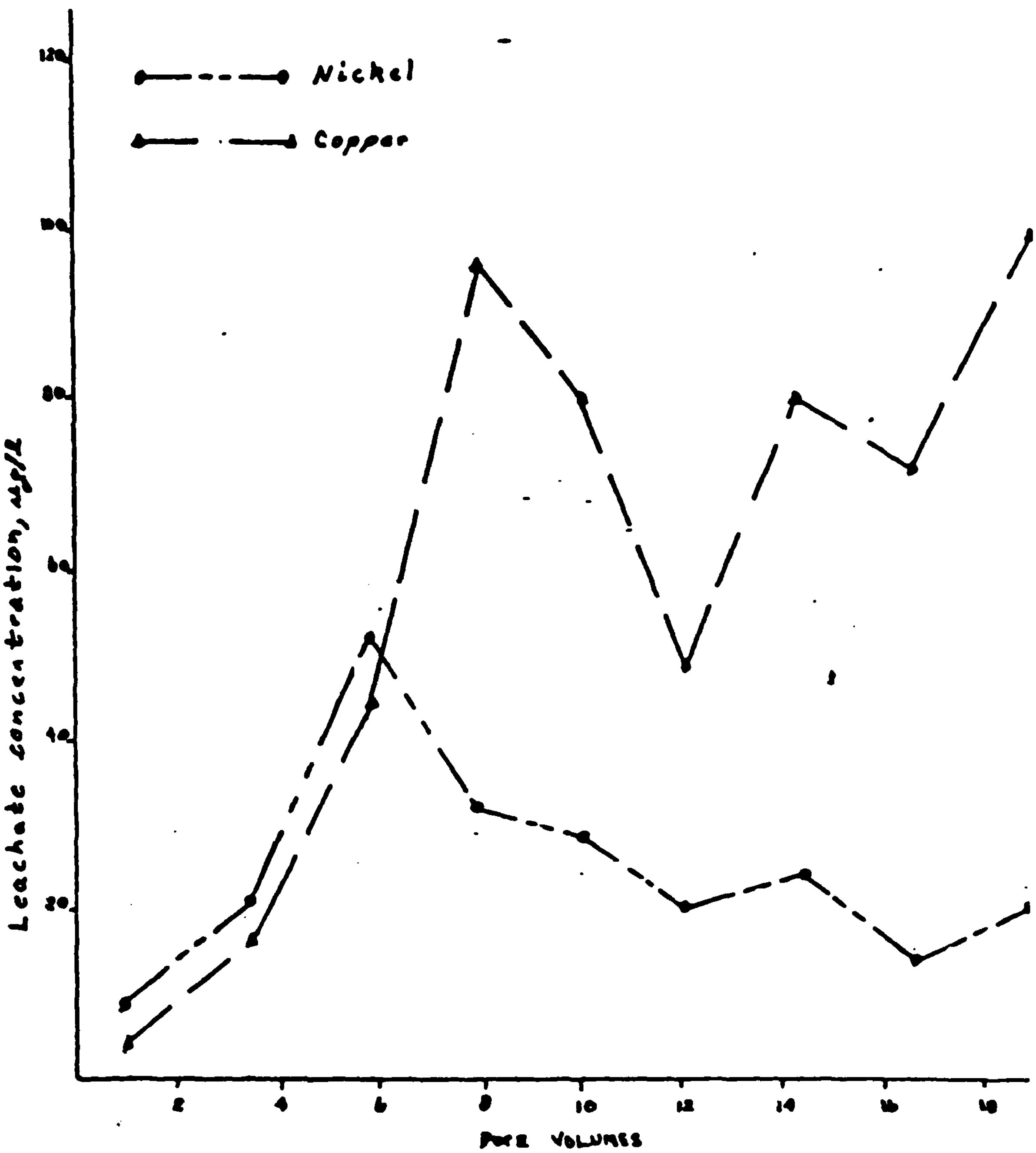


Figure C20. Predicted permeameter leachate concentrations for copper and nickel

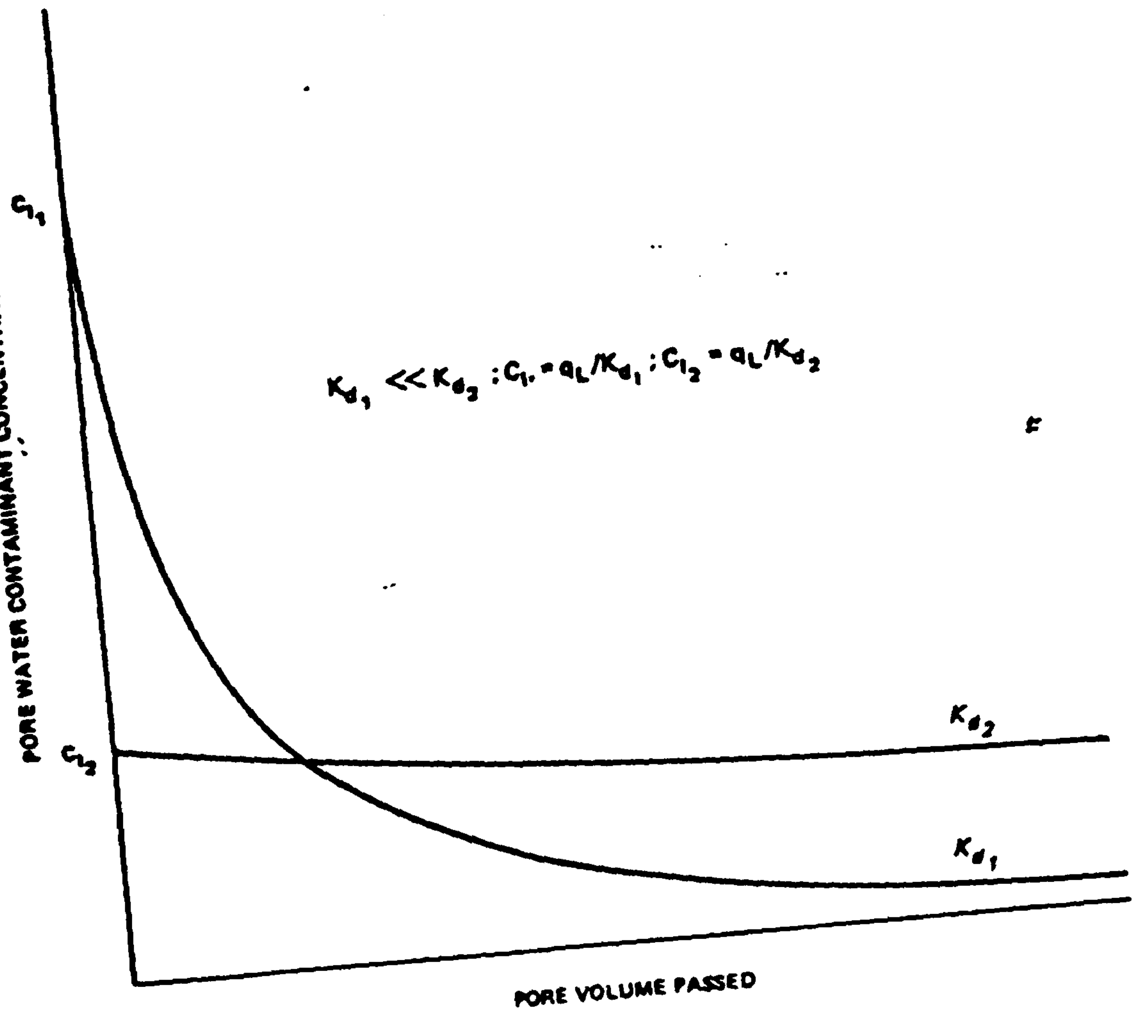


Figure C21. Schematic showing the effect of a large K_d on pore water concentration

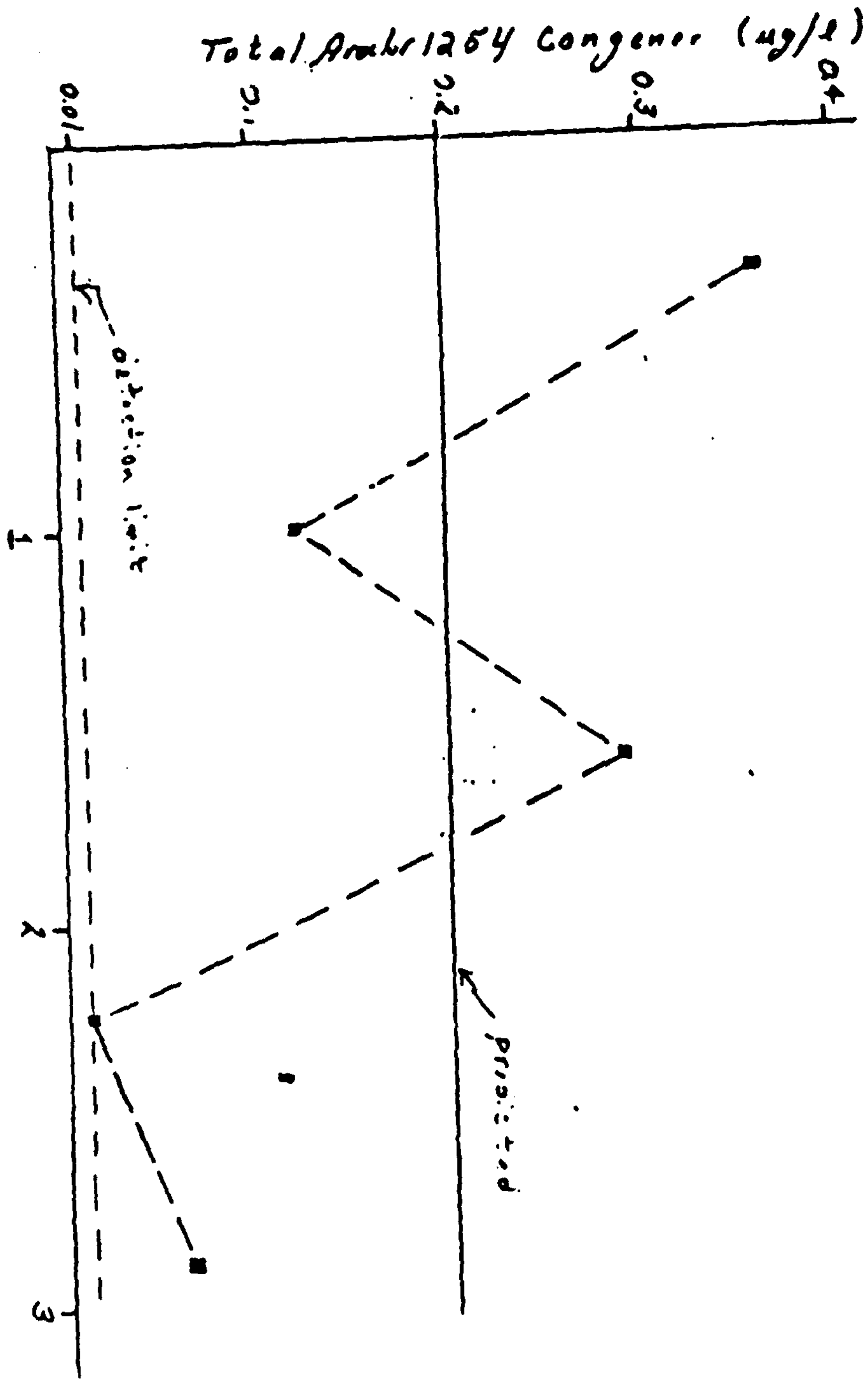


Figure C22. Comparison of observed as a predicted total Aroclor™ 1254 congener concentrations in anaerobic permeameter leachate

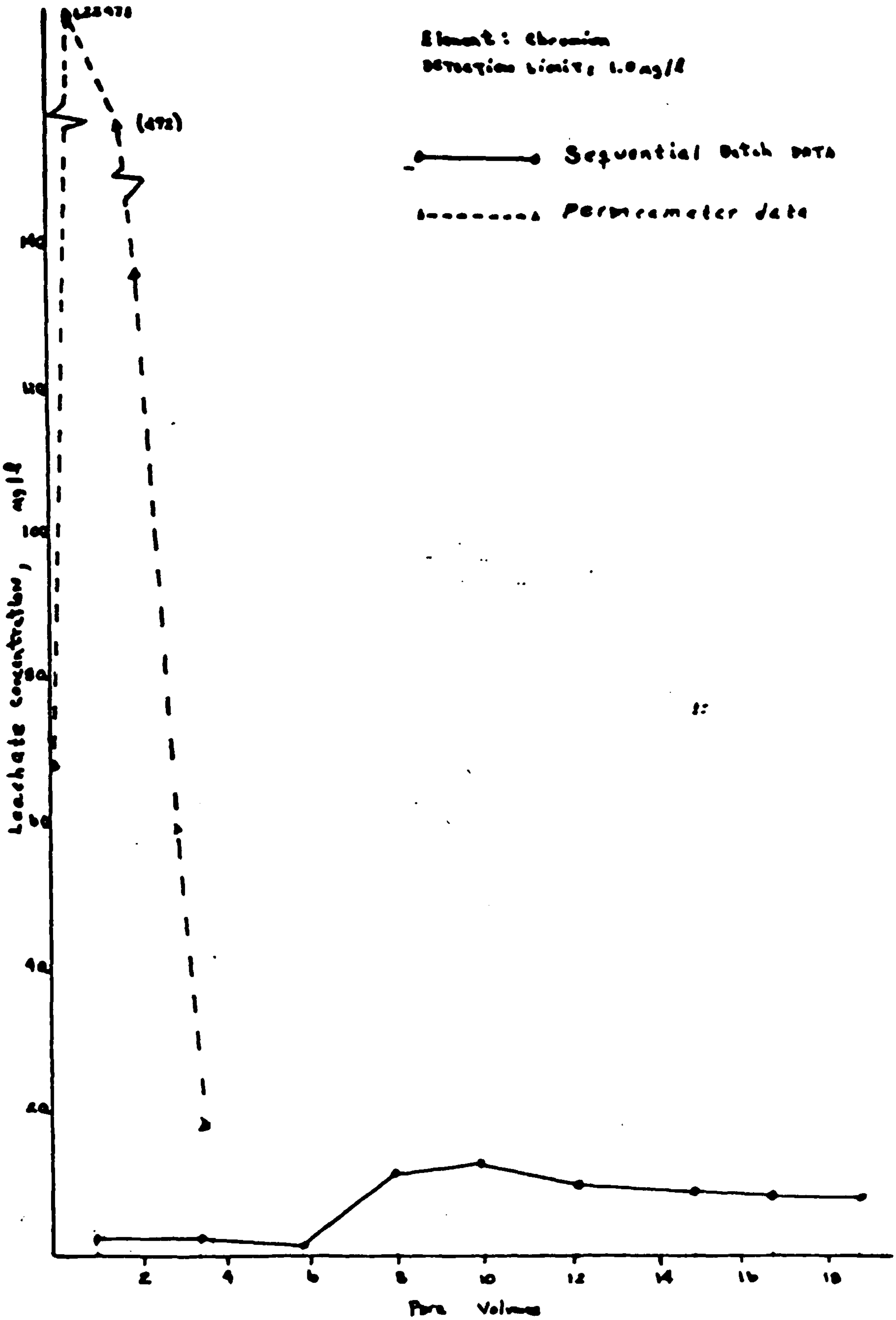


Figure C23. Comparison of permeameter and sequential batch leachate chromium concentrations during aerobic leaching

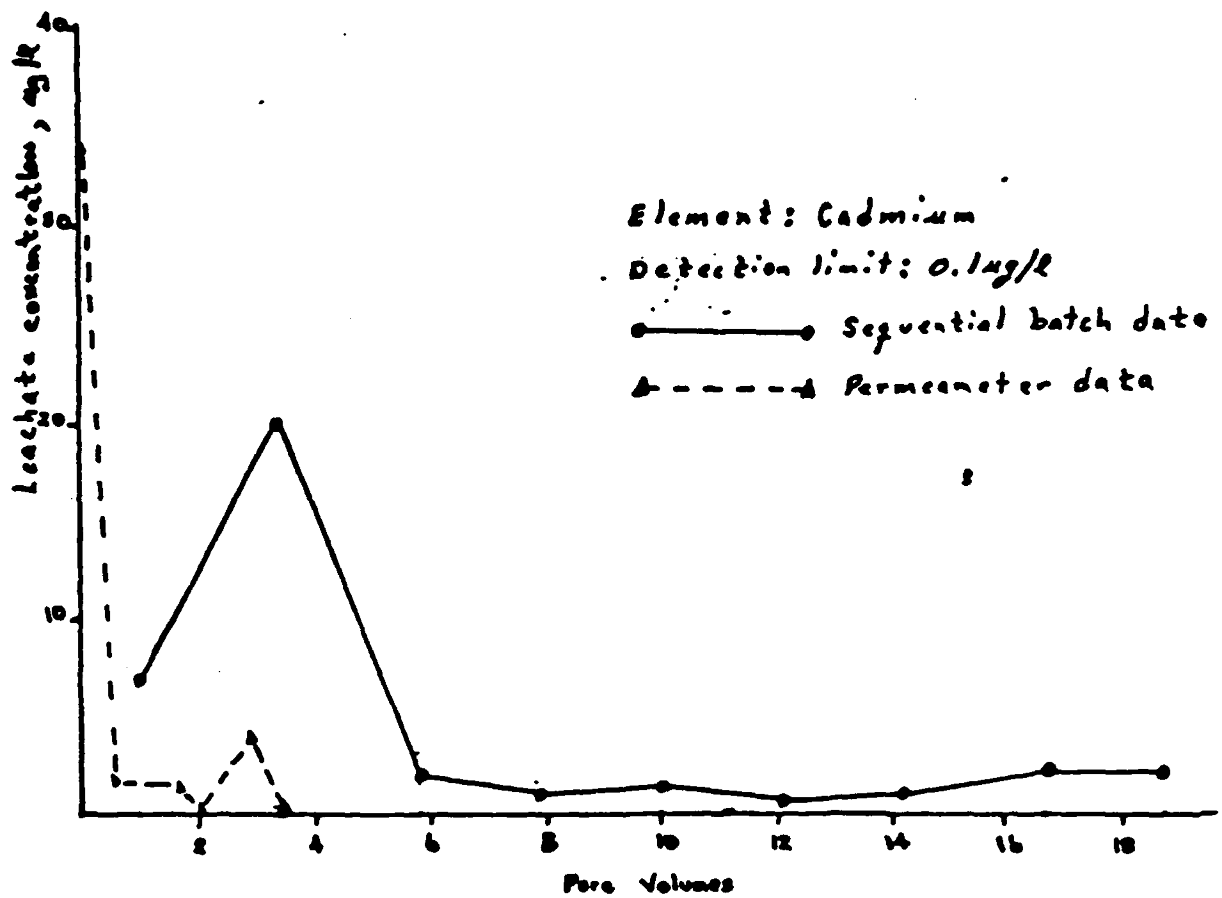


Figure C24. Comparison of permeameter and sequential batch leachate cadmium concentrations during aerobic leaching

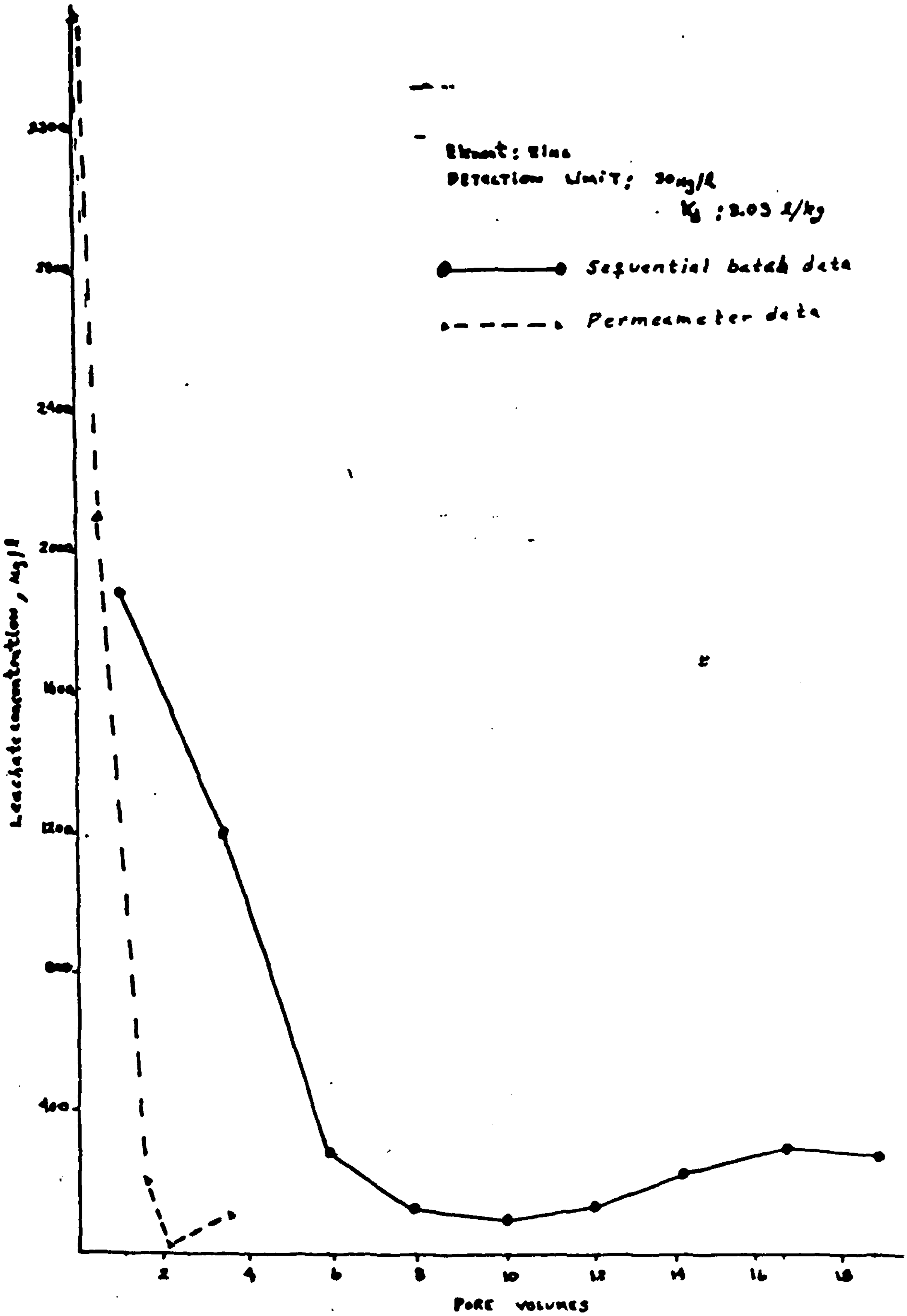


Figure C25. Comparison of permeameter and sequential batch leachate zinc concentrations during aerobic leaching

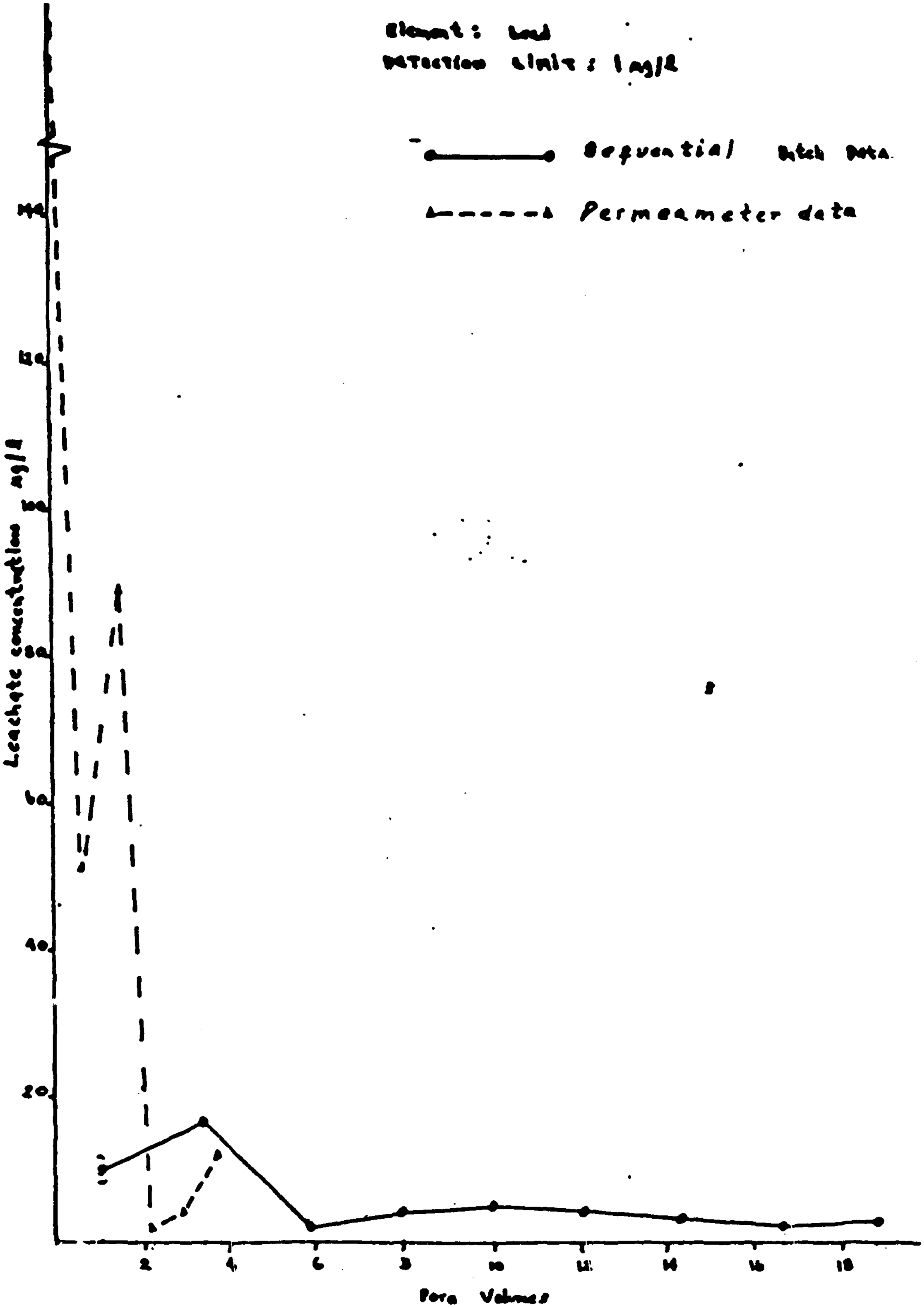


Figure C26. Comparison of permeameter and sequential batch leachate lead concentrations during aerobic leaching

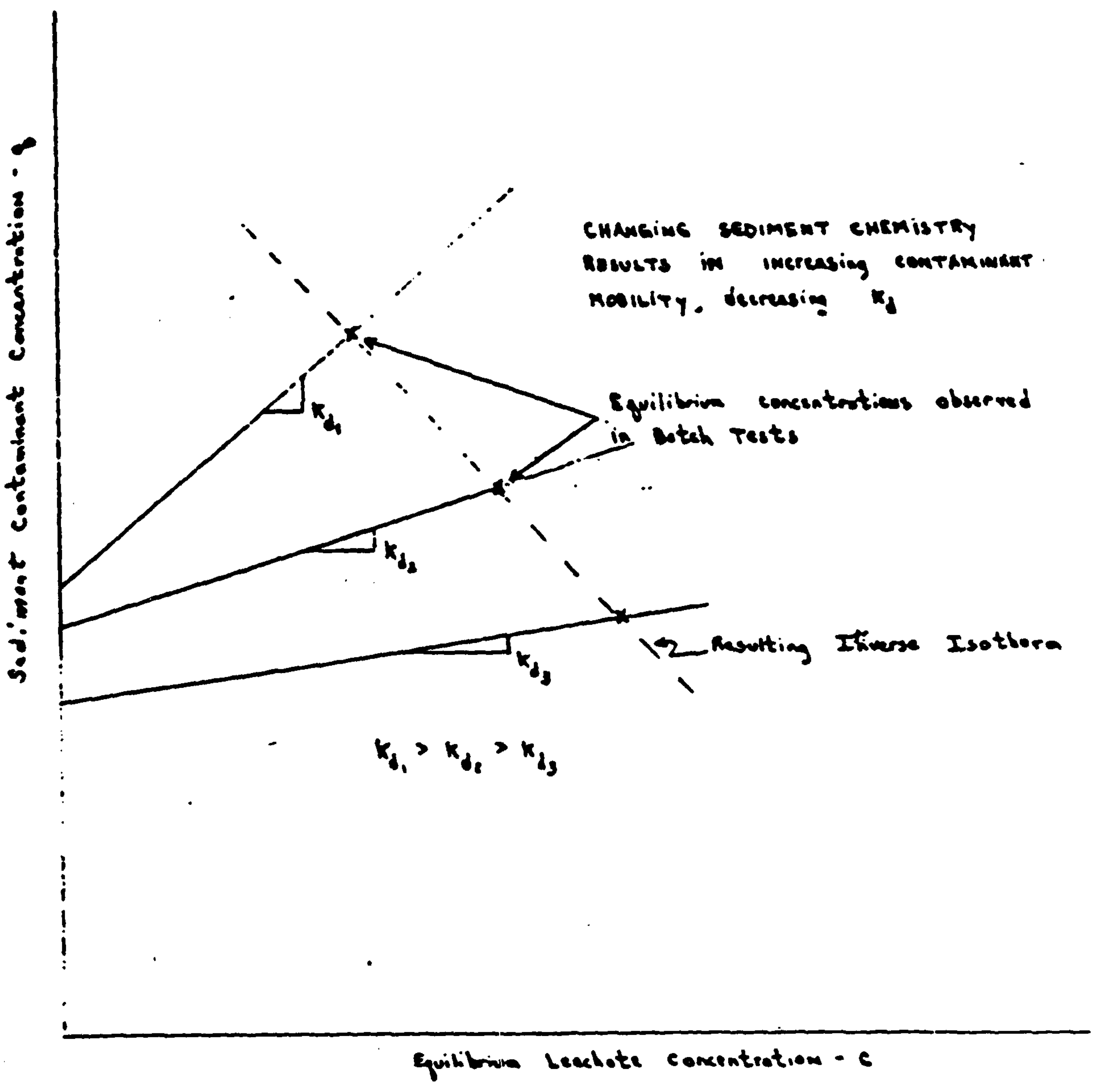


Figure C27. Effect of changing sediment chemistry on contaminant distribution between sediment solids and leachate

Table C1. Contaminant concentration in anaerobic Everett Harbor sediment and interstitial water.

Parameter	Sediment Concentration, ug/g	Interstitial Water Concentration, mg/l
As	5.7	<0.005
Cd	3.3	0.0014(0.0001)
Cr	39.7	0.014(0.003)
Cu	73.4	0.004(0.001)
Pb	48.1	0.056(0.006)
Hg	0.2	<0.002
Ni	21.4	0.01(0.0003)
Zn	148.5	0.049(0.006)
Organics*		
1	8.2	<0.005
2		<0.005
3		<0.005
4	<1	<0.005
5	2.0	<0.005
6	2.2	<0.005
7	5.7	<0.005
8	1.5	<0.005
9	4.5	<0.005
10	4.0	<0.005
11	1.8	<0.005
12	2.1	<0.005
13	2.5	<0.005
14	2.5	<0.005
15	1.4	<0.005
16	<1	<0.005
17	<1	<0.005
18	<1	<0.005
19	<0.0002	<0.00001
20	0.0087	<0.00001
21	<0.0002	<0.00001
22	<0.0002	<0.00001
23	<0.0002	<0.00001
24	<0.0002	<0.00001
25	<0.0002	<0.00001
26	0.0079	<0.00001
27	<0.0002	<0.00001
28	0.0087	<0.00001
29	0.0036	<0.00001
30	0.042	<0.00001
31	<0.0002	<0.00001
32	0.01	<0.00001
33	<0.0002	<0.00001
34	0.0809	

* Organics = Key to organic contaminants listed in Table C3.

Table C2. Contaminant concentration in aerobic Everett Harbor sediment and interstitial water.

Parameter	Sediment Concentration, ug/g	Interstitial Water Concentration, mg/l
As	5.7	0.005
Cd	3.3	0.52(0.01)
Cr	39.7	0.02(0.0007)
Cu	73.4	0.48(0.01)
Pb	48.1	0.09(0.003)
Hg	0.2	0.0008
Ni	21.4	2.94(0.03)
Zn	148.5	37.5(0.015)
Organics*		
1	4.2	NS**
2		NS
3		NS
4	0.17	NS
5	1.3	NS
6	1.4	NS
7	5.0	NS
8	0.65	NS
9	4.3	NS
10	3.6	NS
11	1.4	NS
12	2.5	NS
13	2.5	NS
14	2.5	NS
15	1.1	NS
16	0.53	NS
17	0.63	NS
18	0.38	NS
19	0.002	NS
20	0.0093	NS
21	0.0061	NS
22	0.002	NS
23	0.002	NS
24	0.002	NS
25	0.0061	NS
26	0.0079	NS
27	0.002	NS
28	0.012	NS
29	0.047	NS
30	0.002	NS
31	0.002	NS
32	0.021	NS
33	0.042	NS
34	0.151	NS

* Organics = Key to organic contaminants listed in Table C3.

** NS = Not sampled.

Table C3. Organic compound identification key used in this report.

1.	Naphthalene	17.	Dibenzo (a h) anthracene
2.	1-Methylnaphthalene	18.	Benzo (g h i) perylene
3.	2-Methylnaphthalene	19.	2,4-dichlorobiphenyl
4.	Acenaphthalene	20.	2,4'-dichlorobiphenyl
5.	Acenapthene	21.	2,4,4'-trichlorobiphenyl
6.	Fluorene	22.	2,3',4',5-tetrachlorobiphenyl
7.	Phenathrene	23.	2,2',4,5'-tetrachlorobiphenyl
8.	Anthracene	24.	2,2',5,5'-tetrachlorobiphenyl
9.	Fluoranthene	25.	2,2',4,6-tetrachlorobiphenyl
10.	Pyrene	26.	2,2',3',4,5-pentachlorobiphenyl
11.	Chrysene	27.	2,2',4,5,5'-pentachlorobiphenyl
12.	Benzo (a) anthracene	28.	2,2',3,4,5'-pentachlorobiphenyl
13.	Benzo (b) fluoranthene	29.	2,2',3,4,4',5'-hexachlorobiphenyl
14.	Benzo (k) fluoranthene	30.	2,2',4,4',5,5'-hexachlorobiphenyl
15.	Benzo (a) pyrene	31.	2,2',3,3',6,6'-hexachlorobiphenyl
16.	Indeno (1 2 3-c d) pyrene	32.	2,2',3,4,5,6'-hexachlorobiphenyl
		33.	2,2',3,4,4',5,5'-heptachlorobiphenyl

Table C4. Heavy metal leachate concentration [mg/l (standard error)] as a function of leachate salinity.

Parameter	Salinity, parts per thousand			
	0	5	15	25
As	0.009 (0.0006)	0.009 (0.002)	0.008 (0.0025)	0.008 (0.0005)
Cd	0.002 (0.001)	0.0006 (0.0001)	0.0003 (0.0001)	0.0004 (0.0001)
Cr	0.003 (0.0006)	0.002 (0.0003)	0.002 (0.0000)	0.006 (0.002)
Cu	0.003 (0.0006)	0.003 (0.0003)	0.003 (0.0007)	0.009 (0.006)
Pb	0.020 (0.007)	0.004 (0.0000)	0.004 (0.0005)	0.003 (0.0006)
Hg	<0.002	<0.002	<0.002	<0.002
Ni	0.007 (0.0015)	0.006 (0.0006)	0.0095 (0.002)	0.01 (0.002)
Zn	0.048 (0.011)	0.050 (0.003)	0.044 (0.002)	0.053 (0.006)

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Table C7. Release of metals into leachate from anaerobic Everett Harbor sediment as a function of liquid to solid ratio. Concentrations are given in mg/l (standard error).

Parameter	Water to sediment ratio 4:1	8:1	12:1	50:1	100:1
As	0.024 (0.001)	<0.005	<0.005	<0.005	<0.005
Cd	0.0014 (0.0003)	0.001 (0.0001)	0.0008 (0.00003)	0.0011 (0.000)	0.0007 (0.00007)
Cr	0.002 (0.0006)	0.003 (0.0009)	0.003 (0.0009)	0.007 (0.002)	0.006 (0.001)
Cu	0.004 (0.0003)	0.004 (0.0003)	0.006 (0.003)	0.003 (0.000)	0.004 (0.0007)
Pb	0.006 (0.001)	0.002 (0.000)	0.002 (0.0003)	0.002 (0.0007)	0.002 (0.0003)
Hg	<0.002	<0.002	<0.002	<0.002	<0.002
Ni	0.016 (0.004)	0.013 (0.002)	0.009 (0.004)	0.007 (0.002)	0.004 (0.0007)
Zn	0.050 (0.010)	0.030 (0.003)	0.045 (0.004)	0.042 (0.0042)	0.035 (0.0035)

Table C8. Release of metals into aerobic leachate as a function of liquid to solid ratio. Concentrations are given in mg/l (standard error).

Parameter	Water to sediment ratio					
	4:1	10:1	20:1	30:1	40:1	50:1
As	0.004(0.001)	0.005(0.002)	0.008(0.001)	0.008(0.003)	<0.005	<0.005
Cd	0.11(0.006)	0.07(0.005)	0.009(0.000)	0.004(0.003)	0.009(0.000)	0.006(0.000)
Cr	0.008(0.001)	0.007(0.002)	0.25(0.25)	0.003(0.0004)	0.003(0.0003)	0.002(0.000)
Cu	0.008(0.002)	0.03(0.006)	0.02(0.003)	0.03(0.008)	0.01(0.001)	0.008(0.0004)
Pb	0.10(0.008)	0.04(0.003)	0.01(0.001)	0.01(0.001)	0.005(0.001)	0.008(0.003)
Hg	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ni	0.93(0.02)	0.47(0.008)	0.20(0.008)	0.14(0.004)	0.12(0.002)	0.08(0.004)
Zn	10.36(0.2)	5.10(0.10)	1.79(0.07)	1.27(0.03)	1.02(0.04)	0.69(0.03)

Table C9. Release of PAH compounds into leachate from anaerobic Everett Harbor sediment as a function of liquid to solid ratio. Concentrations are given in mg/l (standard error).

Water to Sediment Ratio	Parameter 5	7	9	10
4:1	0.0012(0.0002)	0.0036(0.0002)	0.0023(0.0001)	0.0023(0.00007)
8:1	0.0013(0.00003)	0.0003(0.0005)	0.0017(0.0001)	0.0015(0.0001)
12:1	0.0015(0.0003)	0.001(0.0005)	0.001(0.0005)	0.001(0.0004)
50:1	0.0007(0.0003)	0.0015(0.0008)	<0.001	<0.001
100:1	0.0005(0.0002)	<0.001	<0.001	<0.001

Table C10. Conductivity [millisiemens (standard error)] in Everett Harbor serial batch leachate.

Test	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
Anaerobic	8.23(0.6)	3.0(0.02)	1.2(0.04)	2.4(0.01)	0.3(0.02)	0.2(0.01)	0.2(0.01)	0.2(0.01)	0.1(0.01)
Anaerobic Challenge	9.9(0.2)	4.5(0.1)	2.5(0.05)	1.2(0.02)	0.7(0.03)	0.5(0.01)	NC	0.4(0.02)	0.4(0.03)
Aerobic	6.5(0.21)	2.9(0.11)	1.4(0.13)	0.6(0.05)	0.3(0.03)	0.3(0.00)	0.2(0.01)	0.2(0.01)	0.2(0.004)
Aerobic Challenge	14.3(0.13)	5.2(0.2)	2.2(0.04)	1.3(0.05)	0.7(0.02)	0.5(0.01)	0.4(0.01)	0.4(0.01)	NC

NC = not conducted.

Table C11. Everett Harbor serial batch leachate pH (standard error).

Test	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
Anaerobic	7.3(0.005)	7.3(0.25)	8.2(0.01)	8.5(0.02)	8.7(0.02)	8.8(0.02)	8.8(0.01)	8.8(0.01)	8.7(0.14)
Anaerobic Challenge	7.1(0.002)	7.4(0.015)	7.2(0.00)	7.5(0.01)	8.4(0.04)	8.5(0.04)	NC	8.1(0.12)	7.8(0.15)
Aerobic	4.8(0.03)	4.7(0.02)	4.9(0.04)	4.9(0.03)	4.8(0.03)	4.8(0.03)	4.6(0.04)	4.7(0.03)	4.6(0.03)
Aerobic Challenge	3.9(0.05)	3.5(0.07)	3.6(0.08)	3.6(0.07)	3.9(0.07)	3.9(0.06)	3.8(0.07)	3.7(0.07)	NC

NC = not conducted.

Table C12. Total organic carbon concentration [mg/l (standard error)] in Everett Harbor leachate.

Time, Days	Anaerobic Testing		Aerobic Testing	
	Sequential	Challenge	Sequential	Challenge
1	84(10)	75(6)	54(5)	77(9)
2	94(25)	86(4)	28(2)	52(12)
3	130(37)	125(32)	22(6)	26(1)
4	181(28)	152(63)	39(8)	25(1)
5	85(8)	168(86)	37(11)	34(2)
6	67(8)	127(32)	42(7)	21(2)
7	56(10)	NT*	31(3)	NT

NT = Not Tested

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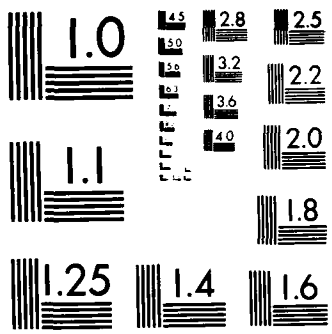

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Table C13. Heavy metal concentrations [ug/1 (Standard Error)] in leachate from anaerobic Everett Harbor sediment

Compound	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
As	<5	<5	19.5(3.7)	37.8(9.1)	34.5(1.0)	18.5(1.0)	10.8(0.5)	8.3(0.8)	6.3(0.8)
Cd	0.7(0.1)	1.0(0.1)	3.3(0.3)	6.1(3.2)	10.7(7.5)	3.1(0.3)	4.3(0.1)	3.1(0.1)	4.6(0.2)
Cr	6.3(1.1)	8.8(0.6)	24.5(10.5)	20.5(3.6)	20.5(4.9)	13.0(1.1)	13.0(0.7)	11.0(0.6)	12.5(1.7)
Cu	4.5(1.2)	16.5(3.3)	44.0(11.4)	96.5(20.7)	81.3(9.2)	49.0(2.9)	82.0(3.7)	71.5(5.0)	95.5(2.9)
Pb	29.5(1.0)	10.3(1.8)	14.5(1.9)	56.0(26.9)	47.8(5.2)	61.0(2.4)	60.8(1.1)	52.8(3.0)	57.0(1.7)
Ni	10.0(1.4)	20.8(4.2)	52.0(8.6)	33.0(3.0)	31.5(4.3)	21.5(2.0)	25.8(3.1)	14.5(1.0)	22.3(2.9)
Zn	42.8(5.0)	131(40)	82.3(15.7)	149(31.7)	127(13.8)	135(13.4)	133(2.3)	71.5(21.8)	97.8(3.6)

Table C14. Steady state sediment metal concentrations [ug/g (standard error)] for Everett Harbor sediment following anaerobic leaching.

Metal	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
As	5.73(0.00)	5.73(0.00)	5.67(0.01)	5.55(0.03)	5.45(0.03)	5.39(0.03)	5.35(0.03)	5.33(0.03)	5.31(0.03)
Cd	3.30(0.00)	3.29(0.00)	3.29(0.00)	3.27(0.01)	3.23(0.02)	3.22(0.02)	3.21(0.02)	3.20(0.02)	3.19(0.02)
Cr	39.7(0.00)	39.7(0.00)	39.6(0.03)	39.6(0.03)	39.5(0.03)	39.5(0.03)	39.4(0.03)	39.4(0.03)	39.3(0.04)
Cu	73.3(0.00)	73.3(0.01)	73.2(0.03)	72.9(0.04)	72.6(0.05)	72.4(0.05)	72.2(0.05)	72.0(0.06)	71.7(0.06)
Pb	48.0(0.00)	48.0(0.01)	47.9(0.01)	47.8(0.08)	47.6(0.09)	47.4(0.09)	47.2(0.09)	47.1(0.08)	46.9(0.08)
Ni	21.3(0.00)	21.3(0.01)	21.1(0.03)	21.0(0.01)	20.9(0.02)	20.8(0.02)	20.8(0.02)	20.7(0.02)	20.6(0.01)
Zn	148.4(0.01)	148.0(0.11)	147.7(0.10)	147.3(0.19)	146.9(0.20)	146.5(0.19)	146.0(0.19)	145.8(0.24)	145.5(0.23)

Table C15. Steady state sediment metal concentrations [ug/g (standard error)] in anaerobic Everett Harbor sediment challenged with leachate from anaerobic Everett Harbor sediment.

Parameter	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
As	5.66(0.06)	5.45(0.11)	5.34(0.11)	5.22(0.10)	5.18(0.09)	5.15(0.09)	5.13(0.08)	5.12(0.08)	5.12(0.08)
Cd	3.30(0.002)	3.25(0.05)	3.24(0.05)	3.21(0.04)	3.20(0.04)	3.12(0.07)	3.11(0.07)	3.09(0.07)	3.08(0.07)
Cr	39.7(0.002)	39.6(0.12)	39.6(0.12)	38.7(0.68)	38.6(0.67)	38.5(0.7)	38.5(0.7)	38.4(0.7)	38.4(0.7)
Cu	73.3(0.004)	72.4(0.79)	72.4(0.79)	72.0(0.75)	71.6(0.73)	71.0(0.7)	70.2(0.7)	69.8(0.7)	69.6(0.6)
Pb	48.0(0.04)	47.6(0.41)	47.5(0.41)	47.4(0.39)	47.2(0.37)	46.8(0.32)	46.5(0.3)	46.4(0.3)	46.3(0.3)
Ni	21.3(0.02)	20.9(0.26)	20.9(0.25)	20.1(0.33)	19.9(0.31)	19.8(0.31)	19.7(0.3)	19.6(0.3)	19.6(0.3)
Zn	148.2(0.19)	147.1(0.88)	146.9(0.87)	145.5(1.23)	144.9(1.15)	144.3(1.11)	143.8(1.09)	143.4(1.06)	143.1(1.04)

Table C16. Steady state leachate metal concentrations [ug/l (standard error)] in anaerobic Everett Harbor sediment challenged with leachate from anaerobic Everett Harbor sediment.

Parameter	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
As	23.7(18.2)	31.0(1.6)	35.3(3.1)	34.0(4.9)	15.0(2.5)	8.5(0.6)	7.8(0.8)	1.3(1.3)	BDL
Cd	1.6(0.6)	1.3(0.2)	1.2(0.1)	8.7(6.4)	3 .9(0.4)	24.3(11.8)	5.4(0.3)	3.9(0.3)	3.0(0.5)
Cr	7.3(0.9)	7.8(0.9)	9.8(0.8)	270(223)	26.3(4.0)	21.0(3.1)	19.3(2.1)	11.3(1.5)	8.5(1.6)
Cu	10.0(1.7)	23.0(9.5)	21.8(3.6)	105(46)	120(6.1)	21.0(10.3)	233(13.3)	115(10.2)	65(15.3)
Pb	25.3(10.8)	18.3(3.7)	12.5(2.3)	44.3(16.6)	57(3.9)	118(18)	81(1.5)	37(8.4)	19(5.7)
Ni	33.0(8.5)	20(7.0)	21(3.3)	239(122)	43(6.1)	37(1.2)	36(1.3)	18(2.7)	11(1.6)
Zn	108(63)	43(18.3)	53(4.2)	444(319)	183(21.4)	179(9.3)	169(8.9)	126(14.3)	76(9.5)

BDL = Below Detection Limit

Table C17. Steady state sediment metal concentration [ug/g (standard error)] for aerobic Everett Harbor sediment.

Metal	Sequential Leach Number								
	1	2	3	4	5	6	7	8	9
As	5.7(0.000)	5.7(0.000)	5.7(0.000)	5.7(0.000)	5.68(0.006)	5.68(0.000)	5.68(0.000)	5.68(0.000)	5.65(0.01)
Cd	3.27(0.009)	3.03(0.08)	2.92(0.002)	2.91(0.003)	2.89(0.002)	2.88(0.001)	2.86(0.003)	2.84(0.005)	2.80(0.006)
Cr	39.7(0.003)	39.7(0.004)	39.7(0.004)	39.5(0.04)	39.3(0.03)	39.2(0.03)	39.0(0.02)	38.9(0.02)	38.7(0.02)
Cu	73.4(0.003)	73.3(0.01)	73.3(0.007)	73.1(0.06)	72.8(0.06)	72.5(0.04)	72.3(0.02)	72.1(0.02)	72.0(0.02)
Pb	48.1(0.009)	47.9(0.06)	47.8(0.003)	47.7(0.01)	47.6(0.01)	47.6(0.01)	47.5(0.007)	47.5(0.004)	47.5(0.008)
Ni	19.6(0.41)	16.6(0.74)	15.0(0.10)	14.6(0.04)	14.4(0.03)	14.2(0.04)	13.9(0.05)	13.5(0.06)	13.1(0.08)
Zn	140.9(1.55)	127.4(3.6)	117.9(0.88)	114.6(0.37)	113.0(0.24)	110.9(0.36)	107.9(0.58)	103.8(0.69)	99.4(0.76)

Table C18. Steady state leachate metal concentrations [mg/l (standard error)] for aerobic Everett Harbor sediment.

Metal	Sequential Leach Number 1	2	3	4	5	6	7	8	9
As	< 0.005	< 0.005	< 0.005	< 0.005	0.002(0.002)	< 0.005	< 0.005	< 0.005	0.003(0.002)
Cd	0.007(0.002)	0.020(0.019)	0.002(0.001)	0.001(0.0001)	0.001(0.000)	0.0007(0.0002)	0.001(0.0001)	0.002(0.0002)	0.002(0.0001)
Cr	0.002(0.0006)	0.002(0.0003)	0.001(0.0005)	0.011(0.003)	0.013(0.001)	0.010(0.0005)	0.009(0.001)	0.008(0.0008)	0.008(0.0005)
Cu	0.005(0.0008)	0.004(0.0006)	0.003(0.0003)	0.019(0.007)	0.023(0.002)	0.015(0.0009)	0.011(0.002)	0.007(0.0005)	0.006(0.0006)
Pb	0.010(0.002)	0.017(0.013)	0.002(0.0006)	0.004(0.001)	0.005(0.0004)	0.004(0.0003)	0.003(0.0005)	0.002(0.0003)	0.003(0.0004)
Ni	0.449(0.102)	0.249(0.102)	0.036(0.002)	0.013(0.0006)	0.012(0.001)	0.015(0.0003)	0.020(0.002)	0.026(0.001)	0.023(0.002)
Zn	1.88(0.387)	1.20(0.424)	0.312(0.051)	0.138(0.014)	0.091(0.026)	0.141(0.003)	0.220(0.01)	0.269(0.008)	0.289(0.015)

Table C19. Steady state sediment metal concentration [ug/g (standard error)] in aerobic Everett Harbor sediment challenged with leachate from aerobic Everett Harbor sediment.

Metal	Sequential Leach Number							
	1	2	3	4	5	6	7	8
As	5.67(0.005)	5.64(0.02)	5.65(0.01)	5.65(0.01)	5.65(0.01)	5.64(0.01)	5.64(0.01)	5.64(0.01)
Cd	2.68(0.04)	2.18(0.05)	1.99(0.05)	1.89(0.05)	1.84(0.05)	1.78(0.05)	1.75(0.05)	1.68(0.05)
Cr	39.7(0.001)	39.6(0.005)	39.6(0.01)	39.6(0.01)	39.6(0.01)	39.6(0.01)	39.6(0.02)	39.5(0.02)
Cu	73.4(0.004)	73.2(0.02)	73.0(0.06)	72.8(0.08)	72.6(0.11)	72.4(0.14)	72.1(0.18)	71.8(0.22)
Pb	47.4(0.09)	46.9(0.14)	46.8(0.20)	46.7(0.15)	46.7(0.15)	46.7(0.15)	46.6(0.16)	46.6(0.16)
Ni	15.9(0.12)	12.6(0.24)	11.3(0.28)	10.7(0.31)	10.4(0.32)	10.1(0.33)	9.7(0.37)	9.3(0.40)
Zn	93.3(1.78)	58.1(3.08)	43.6(3.93)	37.5(4.53)	33.5(5.06)	30.2(5.59)	26.2(6.23)	21.4(6.96)

Table C20. Steady state leachate metal concentration [mg/l (standard error)] in aerobic Everett Harbor sediment challenged with leachate from aerobic Everett Harbor sediment.

Metal	Sequential Leach Number							
	1	2	3	4	5	6	7	8
As	0.009(0.001)	0.004(0.003)	< 0.005	< 0.005	< 0.005	0.002(0.002)	< 0.005	< 0.005
Cd	0.155(0.01)	0.126(0.003)	0.047(0.008)	0.024(0.002)	0.014(0.001)	0.017(0.004)	0.006(0.002)	0.018(0.003)
Cr	0.007(0.00003)	0.006(0.001)	0.006(0.002)	0.004(0.0005)	0.004(0.001)	0.004(0.001)	0.005(0.001)	0.005(0.001)
Cu	0.006(0.001)	0.016(0.004)	0.075(0.01)	0.06(0.006)	0.05(0.007)	0.05(0.015)	0.07(0.009)	0.09(0.01)
Pb	0.187(0.022)	0.107(0.015)	0.039(0.004)	0.014(0.002)	0.009(0.001)	0.009(0.002)	0.008(0.001)	0.009(0.003)
Ni	1.37(0.03)	0.837(0.029)	0.330(0.01)	0.143(0.007)	0.082(0.005)	0.073(0.008)	0.097(0.01)	0.11(0.009)
Zn	13.8(0.45)	8.81(0.36)	3.60(0.25)	1.53(0.16)	1.00(0.14)	0.904(0.14)	1.00(0.16)	1.20(0.19)

Table C21. Distribution coefficients for sequential and challenge batch leaching of metals from aerobic Everett Harbor sediment.

Metal	Sequential testing	Challenge testing
As	NLR	NLR
Cd	NLR	5.38(0.62)
Cr	NLR	NLR
Cu	NLR	-14.3(1.6)
Pb	NLR	3.73(0.21)
Ni	1.6(0.16)	4.4(0.11)
Zn	3.03(0.15)	4.7(0.28)

NLR = No linear relationship

Table C22. Summary of metal losses (ug/g dry weight and % of total sediment concentration) from sediment following sequential and challenge leaching of anaerobic and aerobic Everett Harbor sediment.

	Anaerobic Leaching				Aerobic Leaching			
	Sequential		Challenge		Sequential		Challenge	
Metal	ug/g	%	ug/g	%	ug/g	%	ug/g	%
As	0.042	7.3	0.58	10.2	0.02	0.4	0.06	1.1
Cd	0.11	3.3	0.22	6.7	0.15	4.5	1.62	49.1
Cr	0.40	1.0	1.3	3.3	0.26	0.7	0.16	0.4
Cu	1.67	2.3	3.8	5.2	0.36	0.5	1.62	2.2
Pb	1.12	2.3	1.8	3.7	0.20	0.4	1.52	3.2
Ni	0.68	3.2	1.8	8.4	3.39	15.8	12.13	56.7
Zn	2.85	1.9	5.4	3.6	18.2	12.3	127.1	85.6

Table C23. Steady state organic contaminant leachate concentrations [ug/l (standard error)] for anaerobic Everett Harbor sediment following anaerobic leaching.

Compound	Sequential Leach Number						
	1	2	3	4	5	6	7
5	1.3(0.2)	1.0(0.5)	2.1(0.4)	1.9(0.2)	1.0(0.5)	1.4(0.0)	0.8(0.4)
7	2.9(0.5)	2.0(1.2)	0.9(0.9)	3.6(0.5)	0.7(0.7)	0.6(0.6)	0.5(0.5)
9	2.0(0.2)	1.7(0.4)	4.3(0.9)	2.0(1.0)	0.7(0.7)	1.5(0.1)	0.3(0.3)
10	2.0(0.2)	1.4(0.7)	3.1(2.0)	3.0(0.5)	1.2(0.6)	0.9(0.5)	0.5(0.3)
28	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.03(0.00)
29	0.06(0.03)	0.06(0.03)	0.09(0.05)	0.03(0.03)	0.03(0.03)	0.07(0.03)	0.03(0.03)
30	0.04(0.04)	0.04(0.01)	0.08(0.03)	0.03(0.03)	0.04(0.03)	0.04(0.01)	0.12(0.01)
32	0.03(0.03)	0.08(0.01)	0.06(0.03)	0.09(0.01)	0.07(0.01)	0.06(0.03)	0.07(0.04)

Note: Compounds for which no data is presented were not detected in the leachate.

Table C24. Steady state sediment organic contaminant concentrations [ug/g dry weight (standard error)] for Everett Harbor sediment following anaerobic leaching.

Compound	Sequential Leach Number						
	1	2	3	4	5	6	7
5	1.995(0.001)	1.985(0.002)	1.963(0.004)	1.941(0.005)	1.923(0.002)	1.910(0.003)	1.899(0.003)
7	5.689(0.002)	5.674(0.002)	5.665(0.004)	5.628(0.009)	5.612(0.003)	5.604(0.002)	5.597(0.002)
9	4.492(0.001)	4.479(0.003)	4.437(0.009)	4.401(0.004)	4.388(0.000)	4.377(0.004)	4.368(0.001)
10	3.992(0.001)	3.982(0.002)	3.943(0.003)	3.918(0.008)	3.982(0.002)	3.881(0.002)	3.875(0.002)
28	0.008(0.000)	0.008(0.000)	0.008(0.000)	0.008(0.000)	0.007(0.000)	0.007(0.000)	0.007(0.000)
29	0.0026(0.000)	0.0025(0.000)	0.0024(0.000)	0.0024(0.000)	0.0023(0.000)	0.0022(0.000)	0.0022(0.000)
30	0.041(0.000)	0.040(0.000)	0.040(0.000)	0.039(0.000)	0.038(0.000)	0.038(0.000)	0.037(0.000)
32	0.018(0.000)	0.017(0.000)	0.016(0.000)	0.015(0.000)	0.014(0.000)	0.014(0.000)	0.013(0.000)

Note: Data is not presented for compounds which were not detected in the leachate.

Table C25. Steady state organic contaminant leachate concentrations [ug/l (standard error)] for anaerobic Everett Harbor sediment challenged with leachate from anaerobic Everett Harbor sediment.

Compound	Sequential Leach Number					
	1	2	3	4	5	6
5	0.23(0.23)	0.83(0.28)	2.05(0.65)	1.6(1.6)	0.95(0.35)	1.9(1.9)
7	ND	ND	0.65(0.65)	2.3(2.3)	1.1(1.0)	2.5(2.5)
9	ND	ND	0.75(0.75)	2.9(0.75)	1.1(1.1)	2.6(2.6)
10	ND	0.57(0.57)	ND	2.8(0.8)	1.9(0.00)	2.2(2.2)
28	0.013(0.013)	0.03(0.007)	0.03(0.01)	0.02(0.02)	0.02(0.02)	0.02(0.02)
29	0.013(0.013)	0.09(0.05)	0.11(0.01)	0.14(0.04)	0.05(0.05)	0.05(0.05)
30	0.02(0.02)	0.09(0.05)	0.12(0.01)	0.05(0.05)	0.06(0.06)	0.05(0.05)
32	0.07(0.03)	0.06(0.04)	0.08(0.04)	0.07(0.005)	0.08(0.02)	0.1(0.02)

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Table C27. Summary of organic contaminant losses from Everett Harbor sediment (ug/g dry weight) and percent of total sediment concentration lost during sequential and challenge testing.

Organic Parameter	Sequential		Challenge	
	ug/g	%	ug/g	%
5	0.096	4.8	0.06	3.0
7	0.092	1.8	0.05	0.9
9	0.124	2.9	0.06	1.3
10	0.117	3.1	.06	1.5
28	0.008	10.3	.0011	0.1
29	0.0004	15.4	0.0004	15.4
30	0.004	9.8	0.005	11.9
32	0.005	27.9	0.004	22.2

Table C28. Steady state organic contaminant leachate concentrations [ug/l (standard error)] for aerobic Everett Harbor sediment.

Compound	Sequential Leach Number		
	1	2	3
20	0.003(0.003)	0.003(0.003)	0.007(0.007)
21	0.007(0.003)	ND*	0.013(0.007)
25	0.007(0.003)	ND	0.013(0.007)
26	0.007(0.007)	0.023(0.023)	0.057(0.029)
28	0.030(0.015)	0.013(0.013)	0.037(0.018)
32	0.020(0.020)	0.033(0.033)	0.014(0.02)
33	0.003(0.003)	0.063(0.018)	ND

*ND = Not Detected

Table C29. Steady state sediment contaminant concentrations [ug/g dry weight(standard error)] for Everett Harbor sediment following aerobic leaching.

Compound	Sequential Leach Number		
	1	2	3
20	0.0093(0.00001)	0.0093(0.00003)	0.0092(0.00005)
21	0.0061(0.00001)	0.0061(0.00001)	0.0060(0.00004)
25	0.0061(0.00001)	0.0061(0.00001)	0.0060(0.00004)
26	0.0079(0.00003)	0.0078(0.00008)	0.0076(0.0002)
28	0.0119(0.00006)	0.0118(0.0001)	0.0117(0.0001)
32	0.0209(0.00008)	0.0208(0.0001)	0.0202(0.0002)
33	0.0420(0.00001)	0.0417(0.0006)	0.0417(0.00006)

Table C30. Single point distribution coefficients [1/Kg (standard error)] for organic contaminants in Everett Harbor leachate.

Parameter	Anaerobic Testing		Aerobic Testing	
	Sequential	Challenge	Sequential	Challenge
5	1473(141)	3574(2879)	NMR*	NMR
7	3774(629)	5981(7969)	NMR	NMR
9	3045(2453)	5460(2453)	NMR	NMR
10	2579(653)	4359(1876)	NMR	NMR
20	614(413)	NMR	3220(467)	NMR
21	NMR	NMR	682(229)	454(153)
25	NMR	NMR	682(229)	454(153)
26	NMR	NMR	549(394)	109(0)
28	1835(3)	561(304)	525(182)	167(0)
29	553(133)	378(64)	NMR	NMR
30	929(261)	935(458)	NMR	NMR
32	266(12)	227(23)	605(260)	NMR
33	NMR	NMR	2335(533)	NMR
34	483(116)	480(138)	1173(440)	2855(2369)

*NMR = No Measurable Release

Table C31. Metal and dissolved organic carbon concentration [mg/l (standard error)] in permeameter effluent from anaerobic Everett Harbor sediment.

Pore Volume	Parameter					
	As	Cd	Cr	Pb	Zn	DOC
0.085	<0.005	0.0022 (0.0001)	0.009 (0.005)	0.009 (0.005)	<0.03	48 (0.1)
0.22	<0.005	0.0016 (0.0001)	0.009 (0.004)	0.010 (0.003)	<0.03	49 (1.0)
0.38	<0.005	0.0007 (0.0003)	0.009 (0.001)	0.005 (0.009)	<0.03	44 (3.2)
0.56	<0.005	0.0008 (0.0001)	0.008 (0.003)	0.001 (0.001)	<0.03	37 (1.5)
0.78	<0.005	0.0034 (0.0008)	0.012 (0.002)	0.015 (0.001)	<0.03	42 (0.1)
1.00	<0.005	0.0036 (0.0001)	0.033 (0.002)	0.015 (0.001)	<0.03	46 (0.1)
1.22	<0.005	0.0026 (0.0001)	0.016 (0.002)	0.043 (0.011)	<0.03	59 (2.3)
1.43	<0.005	<0.0001	0.017 (0.003)	0.004 (0.001)	<0.03	88 (2.6)
2.29	<0.005	<0.0001	0.079 (0.003)	0.003 (0.001)	0.03 (0.01)	361 (16)
3.00	0.006 (0.001)	0.0002 (0.0001)	0.074 (0.003)	0.005 (0.007)	0.052 (0.013)	259 (43)
3.45	0.005 (0.001)	0.0008 (0.0006)	0.067 (0.005)	0.005 (0.002)	0.030	224 (17)
3.51	0.005 (0.001)	0.0001 (0.0001)	0.063 (0.001)	0.004 (0.001)	0.051 (0.008)	256 (11)

Table C32. Metal and Dissolved organic carbon concentrations [mg/l (standard error)] in permeameter effluent from aerobic Everett Harbor sediment.

Pore Volume	Parameter					
	As	Cd	Cr	Pb	Zn	DOC
0.14	<0.005	0.0343 (0.0110)	0.068 (0.045)	0.210 (0.063)	3.65 (0.20)	64 (2)
0.51	<0.005	0.0018 (0.0012)	2.25 (2.20)	0.050 (0.002)	2.13 (0.38)	66 (1)
1.56	<0.005	0.0017 (0.0016)	0.472 (0.469)	0.090 (0.089)	0.217 (0.201)	68 (7)
2.07	<0.005	0.0002 (0.0001)	0.136 (0.126)	0.002 (0.001)	0.060 (0.042)	72 (3)
2.76	<0.005	0.0042 (0.0038)	0.058 (0.042)	0.004 (0.007)	0.030 (0.016)	89 (13)
3.42	<0.005	0.0002 (0.0001)	0.018 (0.009)	0.012 (0.009)	0.097 (0.049)	85 (9)

Table C35. Summary of pH, conductivity, and DOC trends during batch and column leach testing.

Test	pH	Conductivity	DOC
Anaerobic batch	Increased (7.3—>8.7)	Decreased	Peaked (84—>181—>56)
Anaerobic column M+	Increased (7.3—>8.5)	Decreased	Increased (47—>250)
Anaerobic column Or	-	-	Increased (50—>250)
Aerobic batch	Static (3.8)	Decreased	Static (40)
Aerobic column M+	Increased (3.5—>7.5)	Decreased	Increase (64—>85)
Aerobic column Or	-	-	Increase (62—215)

M+: metals leaching column
Or: organics leaching column
-: no data

Table C36. Predicted and observed values of PCB compounds from anaerobic Everett Harbor sediment.

Compound*	Pore Volume	Average conc., mg/l	Computed Equilibrium conc., mg/l
28	0.33	0.00002	
	0.99	0.00001	
	1.61	0.00005	
	2.23	<0.00001	
	average	0.00002	<0.00001
29	0.33	0.00007	
	0.99	<0.00001	
	1.61	<0.00001	
	2.23	<0.00001	
	average	0.00002	<0.00001
30	0.33	0.00008	
	0.99	0.00006	
	1.61	<0.00001	
	2.23	<0.00001	
	average	0.00004	0.00005
32	0.33	0.00005	
	0.99	0.00002	
	1.61	0.00005	
	2.23	<0.00001	
	average	0.00003	0.00004
34	0.33	0.00036	
	0.99	0.00012	
	1.61	0.00029	
	2.23	0.00001	
	average	0.0002	0.00002

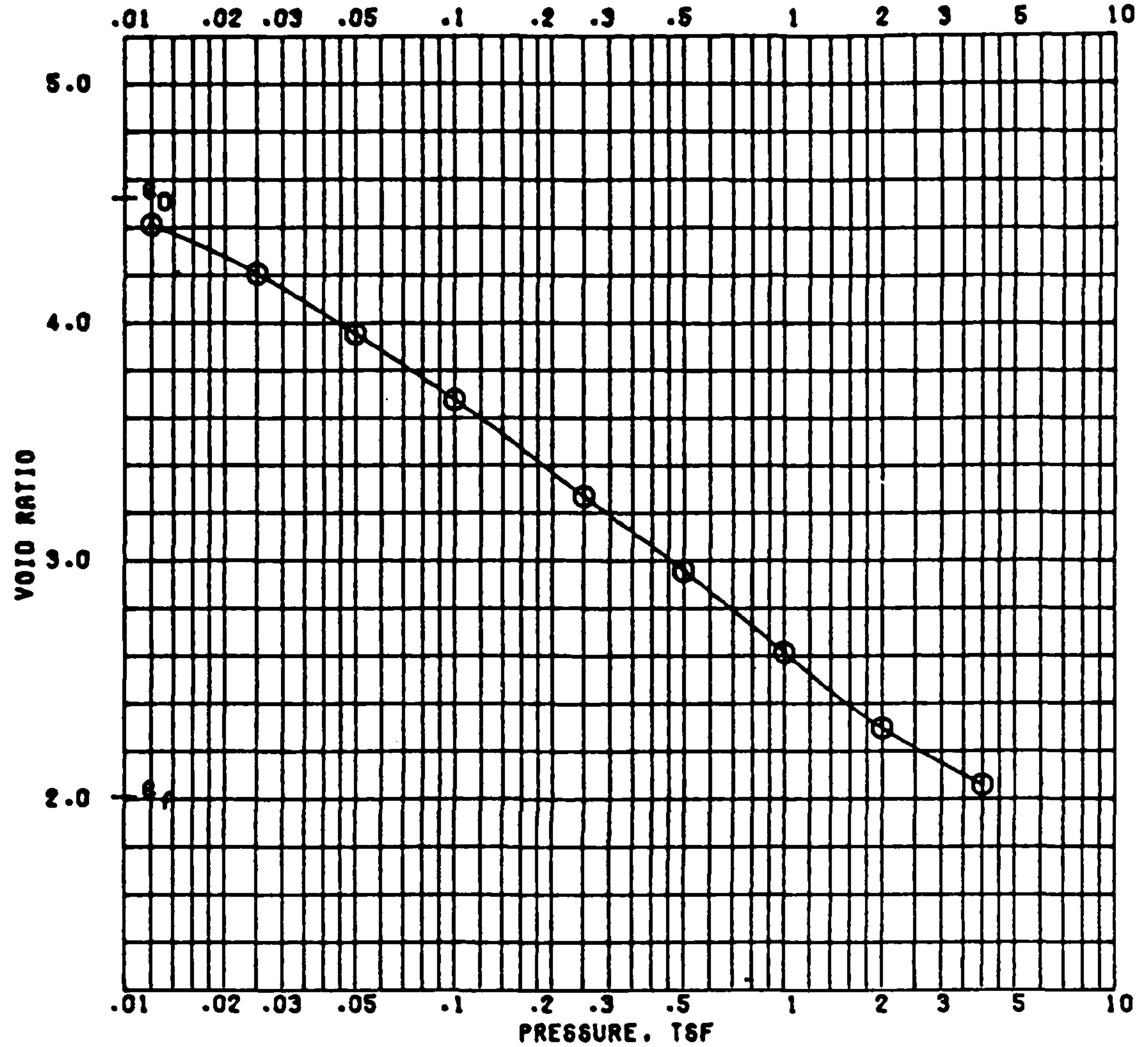
Compound* = compound numbers correspond to Table C3.

Table C37. Batch sequence number and equivalent pore volumes through Everett Harbor permeameters*.

Batch Sequence Number	Cumulative Batch L/S Ratio	Cumulative L/S for Batch Leachate Concentration	Equivalent Pore Volume Through Permeameters
1	0 to 4/1	2/1	1.1
2	4/1 to 8/1	6/1	3.3
3	8/1 to 12/1	10/1	5.6
4	12/1 to 16/1	14/1	7.8
5	16/1 to 20/1	18/1	10.0

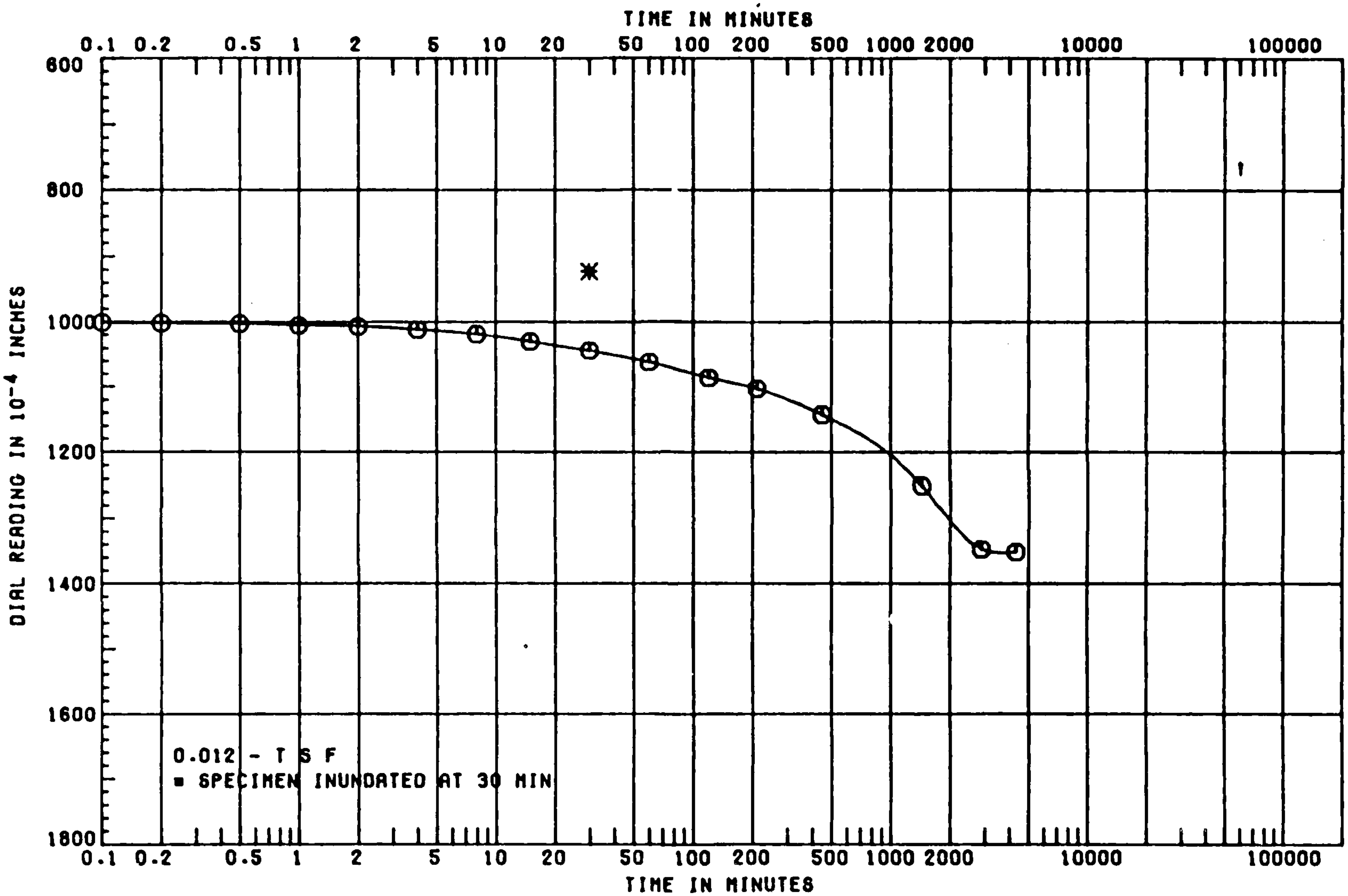
* Batch conducted at L/S = 4/1; L/S in permeameters = 1.8/1

APPENDIX G



				BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE, TSF			WATER CONTENT, %	165.1	86.2
PRECONSOL. PRESSURE, TSF			DRY DENSITY, PCF	30.6	56.1
COMPRESSION INDEX			SATURATION, %	98.7	100 +
TYPE SPECIMEN	UNDISTURBED		VOID RATIO	4.517	2.003
DIA. IN 4.44	HT. IN 1.235		BACK PRESSURE, TSF		
CLASSIFICATION ORGANIC SILT (OH), GRAYISH BLACK					
LL 116	PL 57	PI 59	PROJECT EVERETT BAY, WA		
GS 2.70 (EST)	D_{10}				
REMARKS			BORING NO. -	SAMPLE NO. -	
			DEPTH/ELEV -	DATE 11 FEB 86	
			CONSOLIDATION TEST REPORT		

SHEET 1 OF 10



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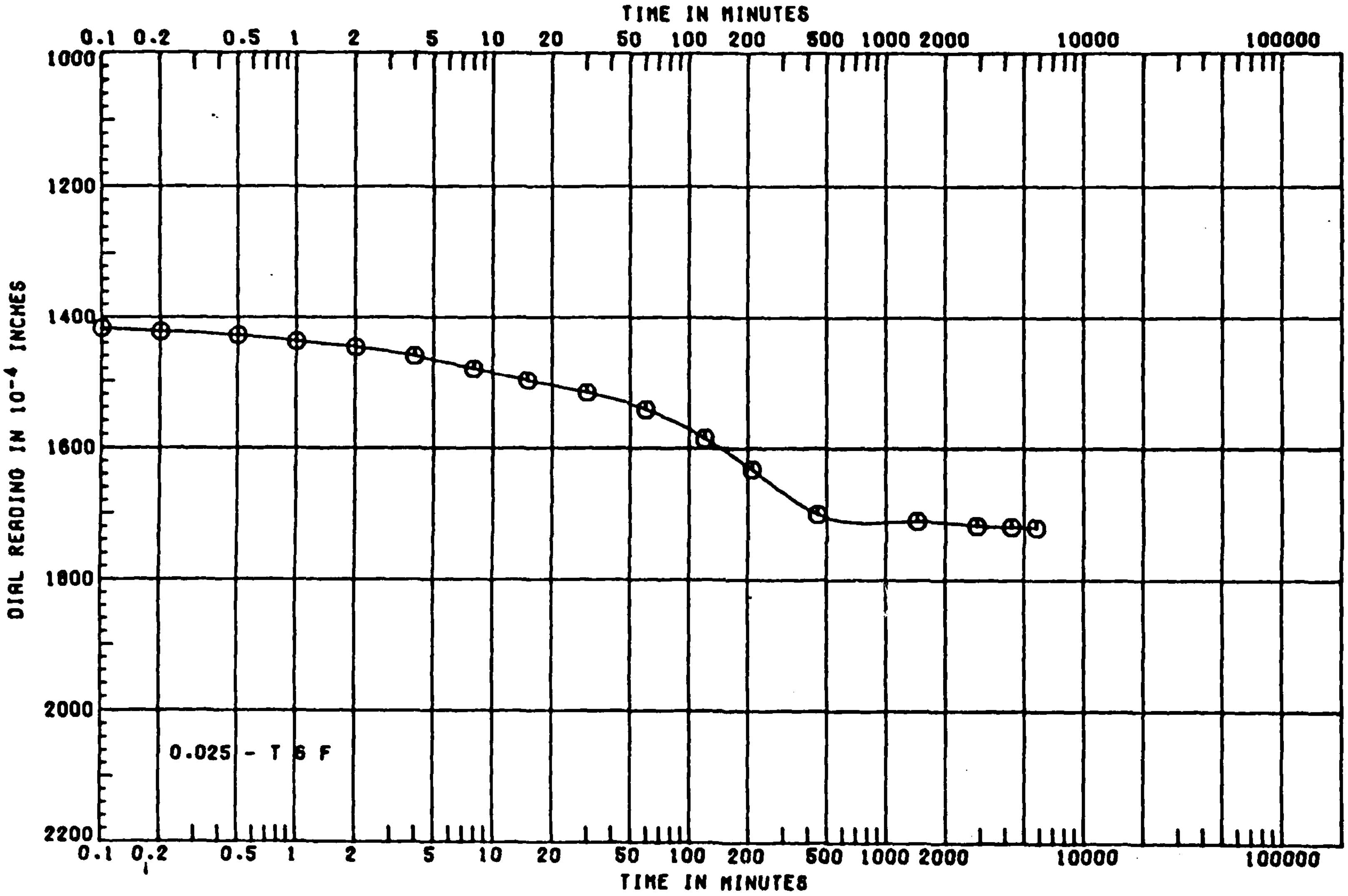
BORING -	SAMPLE NO. -	
DEPTH/ELEV -	DATE 11 FEB 86	

SHEET 2 OF 10



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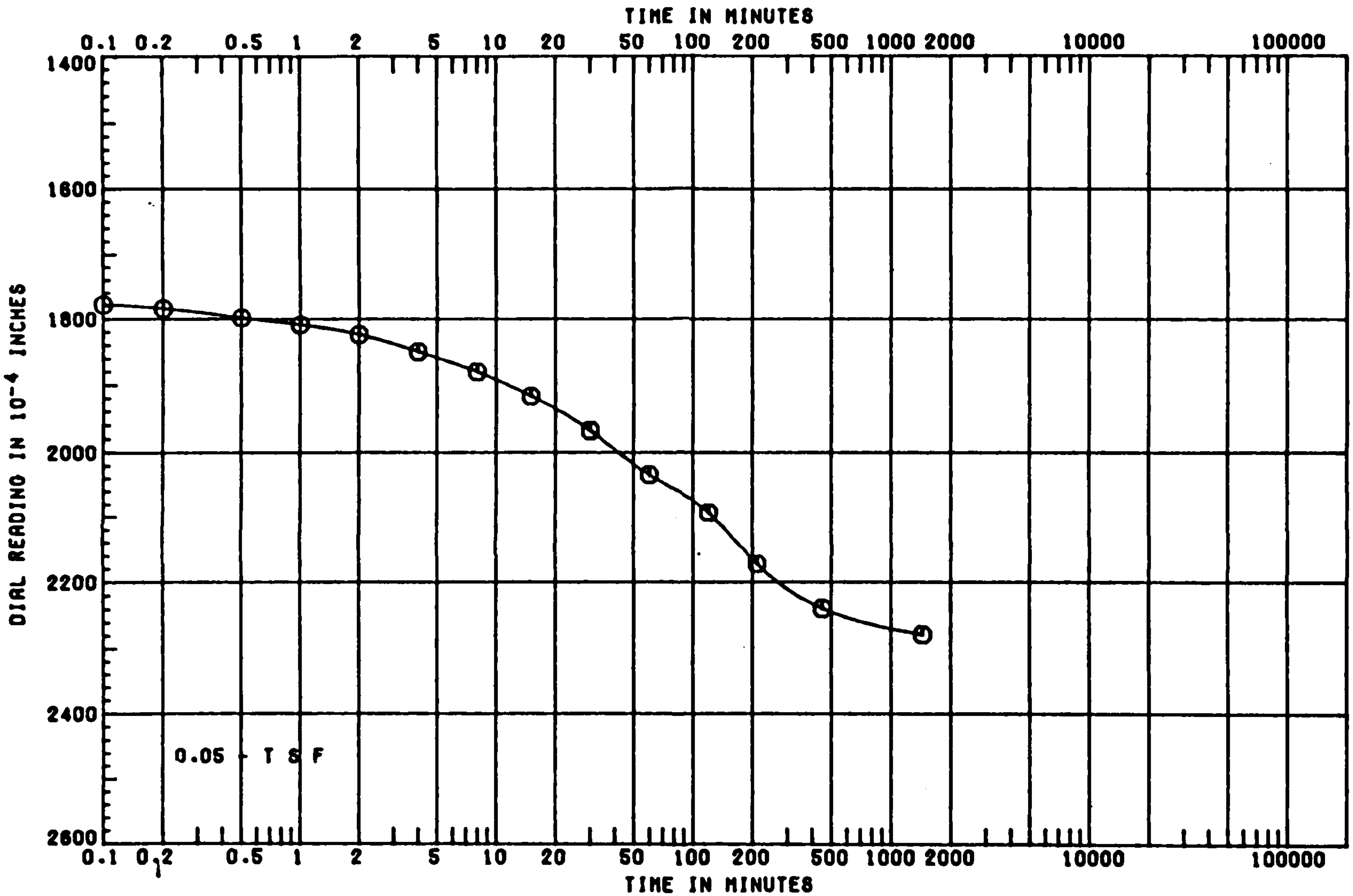
CONSOLIDATION TEST

TIME CURVES

SHEET 3 OF 10



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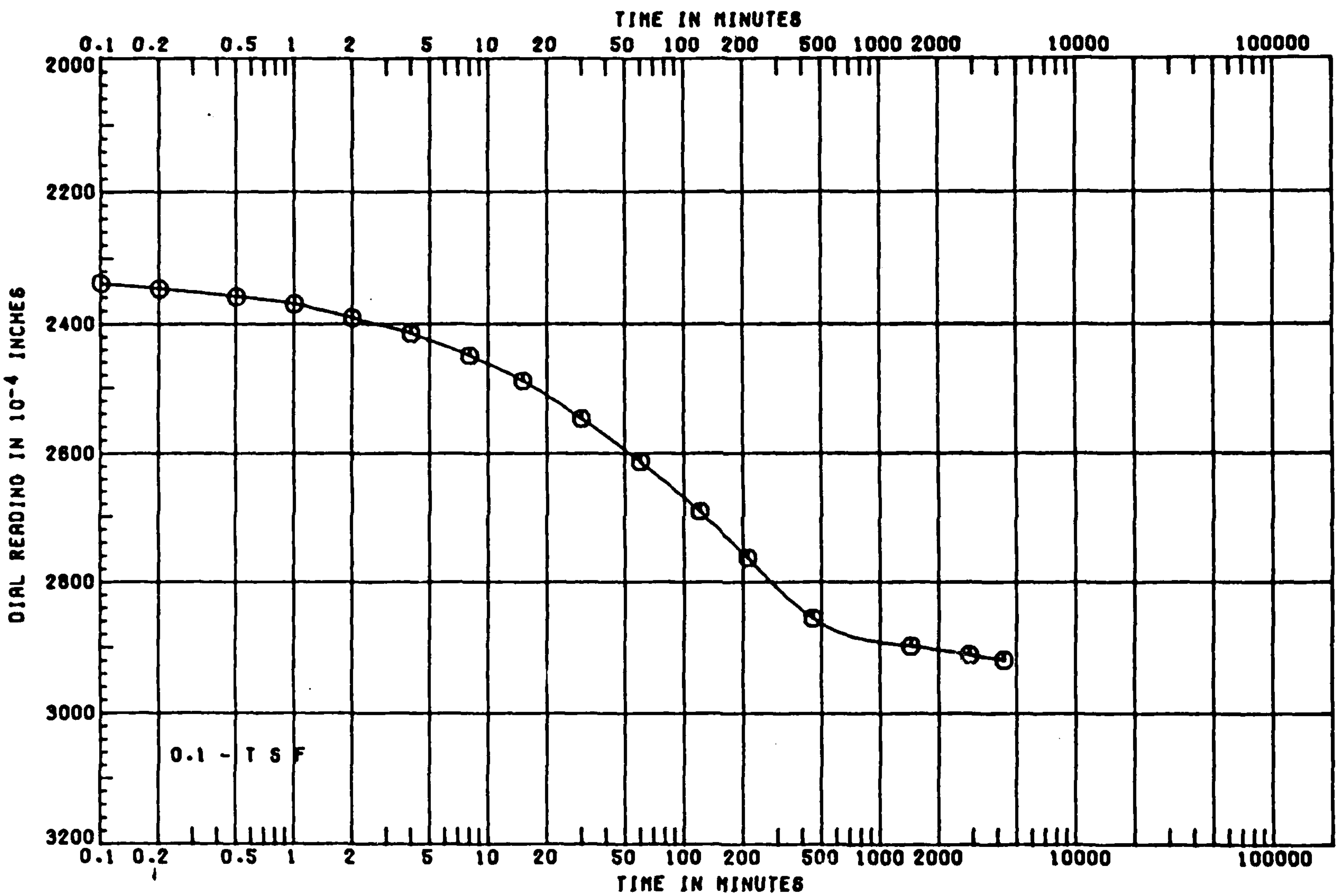
CONSOLIDATION TEST
TIME CURVES

SHEET 4 OF 10



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DEPTH/ELEV -	DATE 11 FEB 86

SHEET 5 OF 10

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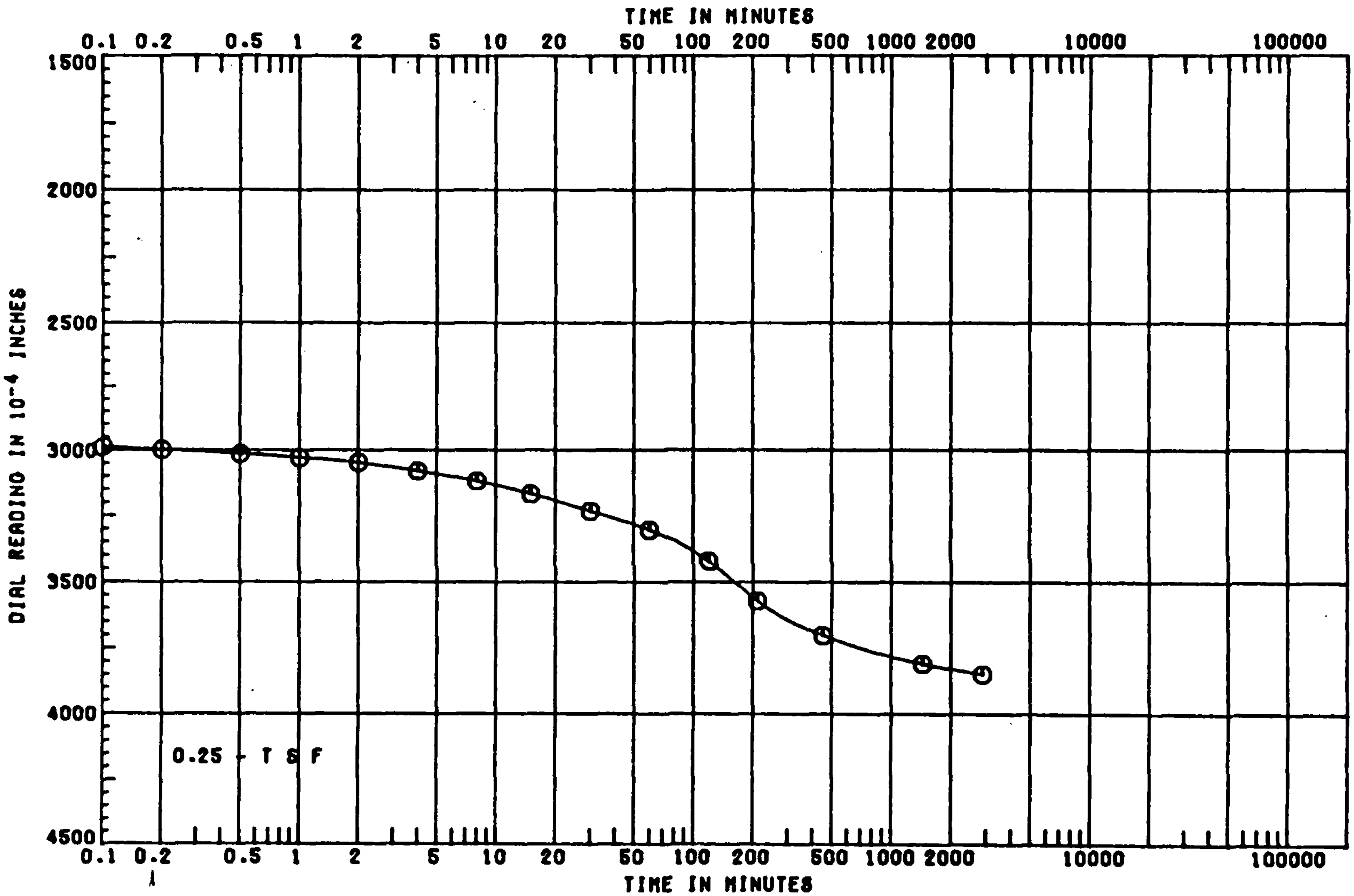

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BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 11 FEB 86

SHEET 6 OF 10

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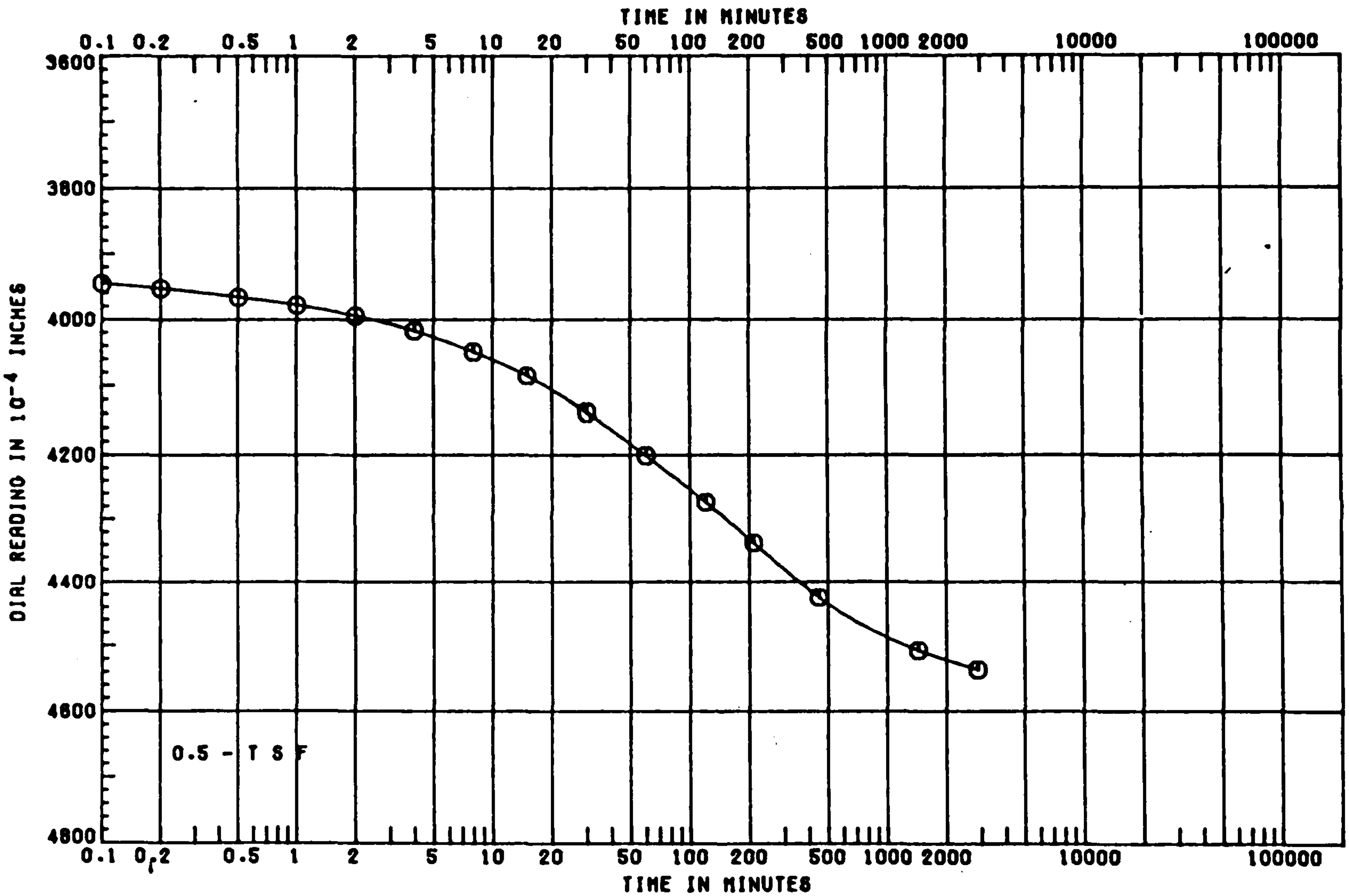
TIME CURVES



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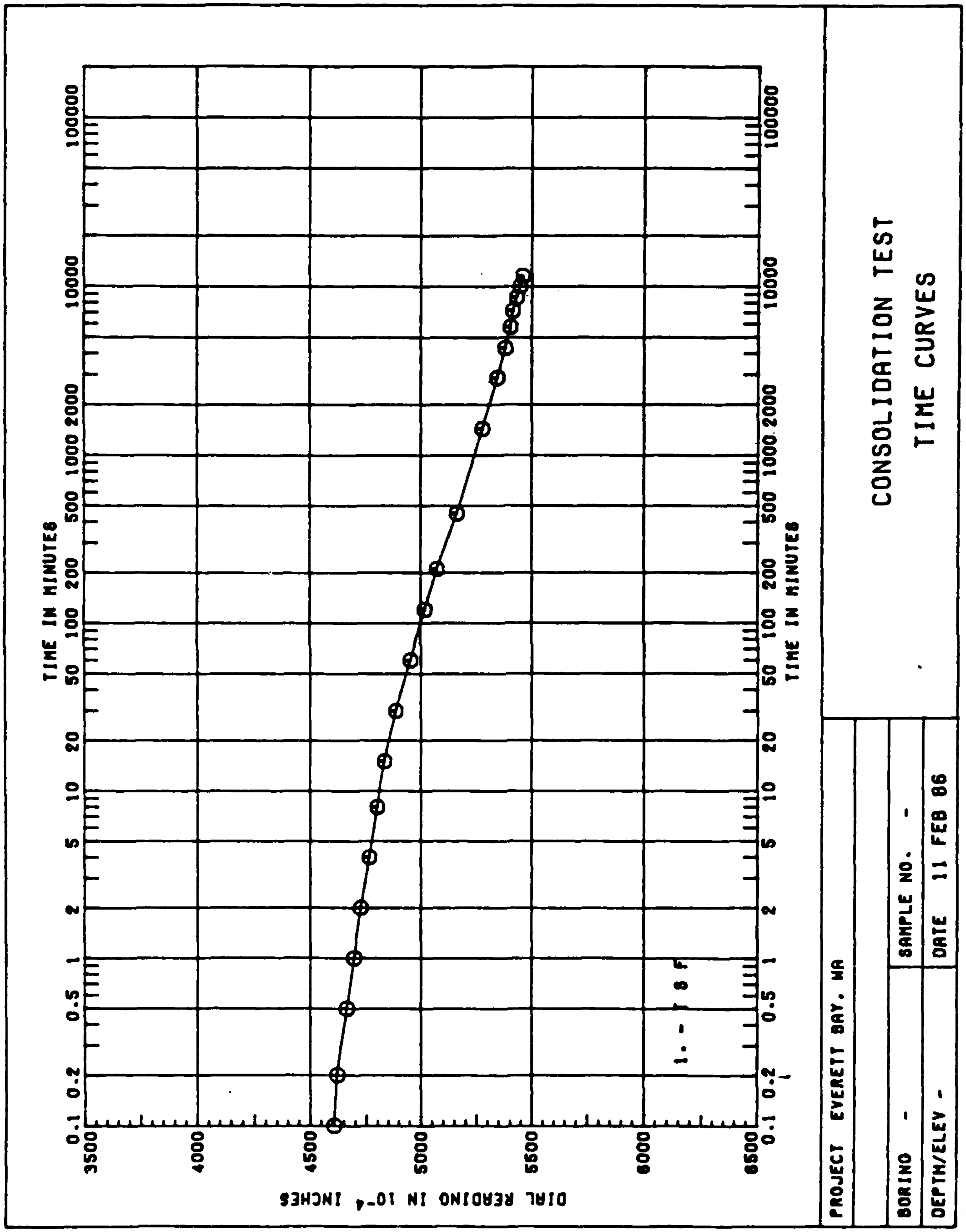
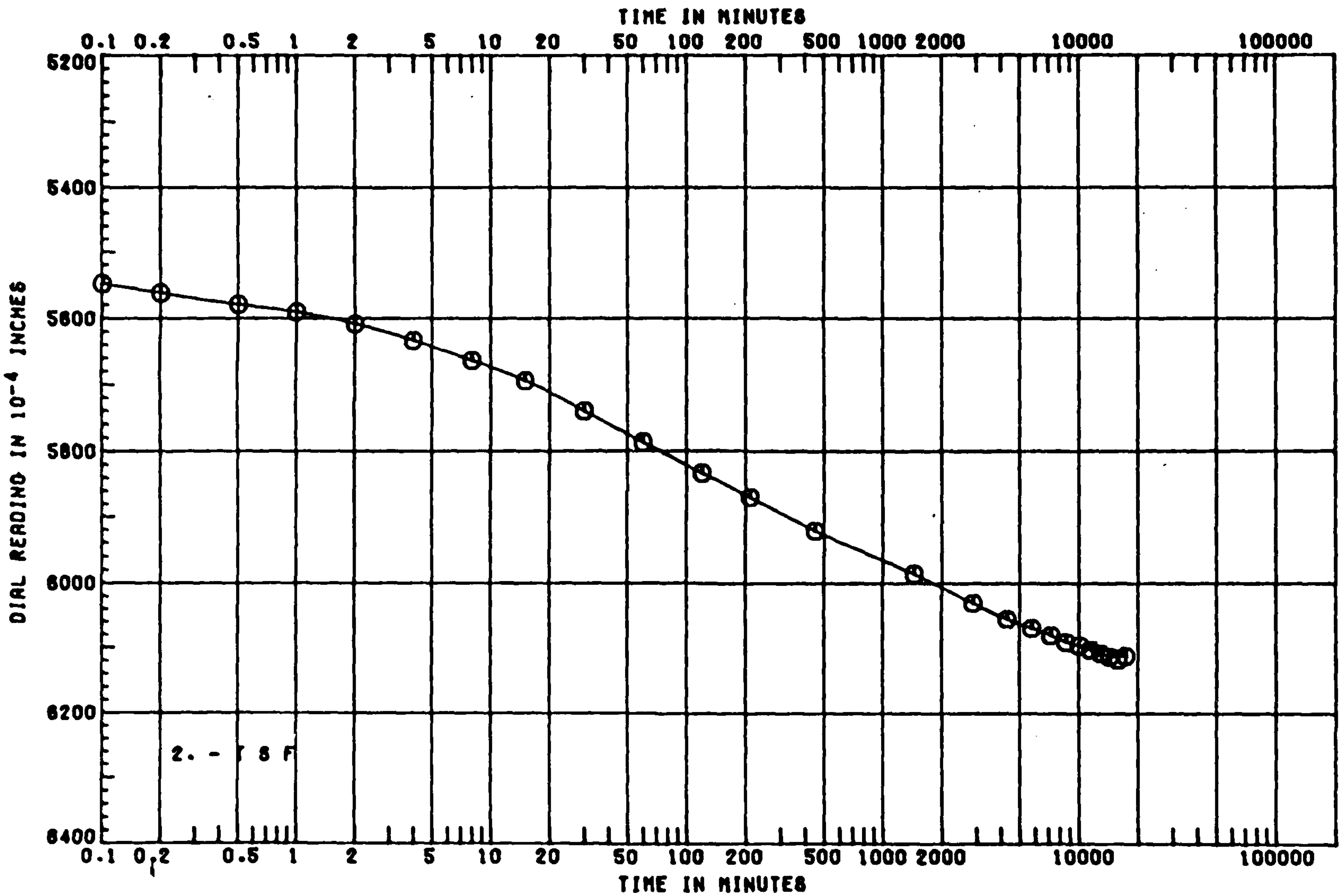
BORING -	SAMPLE NO. -	
DEPTH/ELEV -	DATE 11 FEB 86	

SHEET 7 OF 10


CONSOLIDATION TEST
TIME CURVES
TIME IN MINUTES
DIAL READING IN 10⁻⁴ INCHES
0.1 0.2 0.5 1 2 5 10 20 50 100 200 500 1000 2000 10000 100000
3500 4000 4500 5000 5500 6000 6500
1. - T S F
PROJECT EVERETT BAY, WA
BORING -
SAMPLE NO. -
DEPTH/ELEV -
DATE 11 FEB 86
SHEET 8 OF 10



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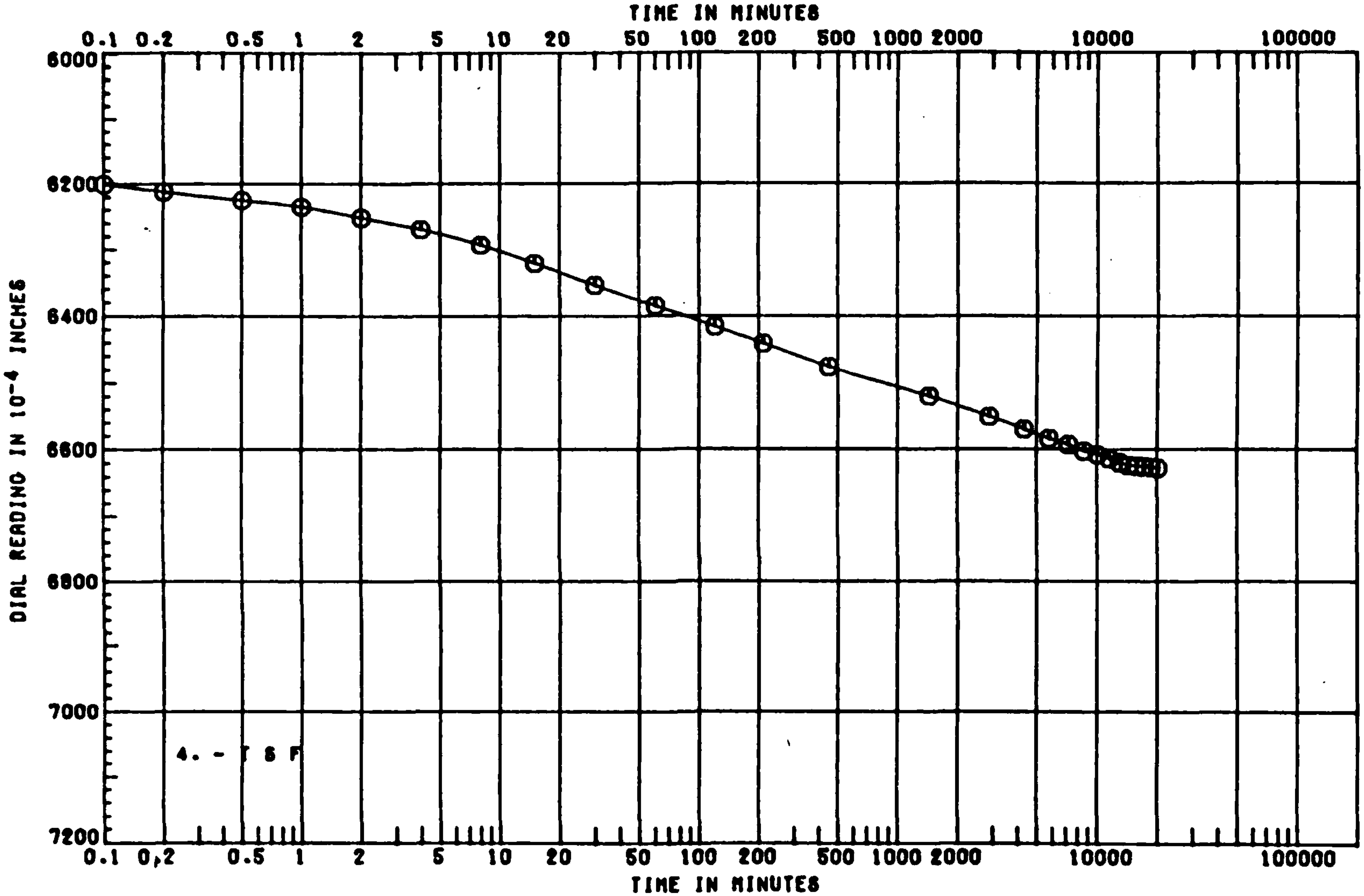
DEPTH/ELEV -	DATE 11 FEB 86

CONSOLIDATION TEST

TIME CURVES

SHEET 9 OF 10



PROJECT EVERETT BAY, WA		CONSOLIDATION TEST TIME CURVES
BORING -	SAMPLE NO. -	
DEPTH/ELEV -	DATE 11 FEB 86	

SHEET 10 OF 10

APPENDIX I: MONITORING PLANS

General

This appendix contains draft monitoring plans for dredging and disposal operations for the Everett Homeport project. Separate plans are included for dredging operations, contained aquatic disposal placement, contained aquatic disposal mound and cap behavior, and intertidal disposal. The level of detail in the plans is intended to provide guidance on monitoring and the level of effort involved in the monitoring. Since some of the alternatives for dredging and disposal are still under development, these plans cannot be considered final and must be refined once final scheduling and design for the project has been completed.

These monitoring plans have been revised from those presented in the Disposal Alternatives report to reflect more recent information on the proposed alternatives.

The objectives of the monitoring plans given here are the following:

a. To determine the degree of sediment resuspension at the point of dredging during representative dredging operations.

b. To verify modeling predictions of dredged material behavior to include mass release during open-water disposal for the CAD alternative.

c. To determine the area of deposition of dredged material on the bottom following each phase of disposal for CAD.

d. To determine the cap thickness immediately following disposal and after initial consolidation for CAD.

e. To determine the effectiveness of the cap in chemically isolating the contaminated sediments for CAD.

f. To determine contaminant releases from effluent, surface runoff, and leachate for confined upland or intertidal alternatives.

Since CAD is identified as the preferred alternative and designs for CAD have been proposed, the monitoring plans are more detailed for CAD.

Biological Monitoring

The monitoring plans described here are restricted to physical and chemical parameters. It is recognized that biological monitoring should be considered as a part of the overall monitoring effort. Biological monitoring should reflect the concerns of resource agencies and should be developed in cooperation with biologists familiar with local species and conditions. Plans for biological monitoring can be finalized once a disposal alternative and final site design is selected.

Monitoring Plan for Dredging Operations

Purpose and Scope

The purpose of this monitoring plan is to define the sediment resuspension and contaminant release of a dredge plant operating in contaminated sediments. The plan is oriented toward clamshell dredging which is the preferred method for the CAD alternative. The monitoring effort will identify the resuspension of sediments generated by the dredging operation and any possible release of contaminants from the sediment to the water column. A sample grid near the dredging operation will be defined where samples and measurements of the resuspended sediment plume will be collected. Discrete water samples, current measurements and other parameters will be obtained at the sample grid points. The intent of this plan is to intensely monitor representative dredging operations over a two day period. The procedures described in this section are not intended for routine use throughout the entire dredging project.

Sampling Procedure

Sampling Locations. There will be one day of background sampling followed by two days of sampling during the dredging operation. The sample grid will be completed three times during each sample day. Each sample set will be sampled in the same order as the previous set, such that the first station sampled on the first set will be the first station sampled on the second set. Background sampling will be done prior to the start of dredging and will include water samples for TSS determination and current measurements to describe the hydraulic regime of the area to be dredged.

The sample grid will consist of ten (10) sample stations arranged in two perpendicular transects. The first transect will be parallel to the direction of flow in the area to be dredged with seven (7) sample stations located at geometrically increasing distances from the point of dredging. Stations will be located 100, 200, 400, 800 and 1600 ft downcurrent from the point of dredging. One station 100 ft upcurrent from the point of dredging and a station on the dredge nearest the point of dredging will complete the first transect. The second transect will be perpendicular to the first and located 200 ft downcurrent from the point of dredging. It will consist of three (3) stations. A sketch showing the grid is attached, Figure I-1.

Water Column Samples for Suspended Solids. At each sample station, discrete water samples will be collected at the near-bottom (1 to 5 ft above bottom), middepth and near-surface (1 to 5 ft below the surface). These water samples will be analyzed for total suspended solids (TSS) only, and should be of sufficient volume (approx. 200 ml) to perform the analysis.

Current Measurements. After background data has established the general flow pattern, current measurements will be collected throughout the sample collection effort at the 100 ft upcurrent station, the 400 and 1600 ft downcurrent stations, and the 3 stations which comprise the second transect. The current measurements will be obtained at similar depths (surface, middepth and near bottom) as the water column samples.

Water Column Samples for Chemical Analysis. On the first day of sampling, during the dredging operation, water samples will be collected for water quality analyses. The samples will be collected at four of the stations along the first transect: 100 ft upcurrent of the point of dredging, at the station nearest the downcurrent side of the point of dredging (either on the barge or 100 ft downstream), and at the 200 and 400 ft downcurrent stations. This sample set will be collected once at each station except for the first station downstream from the dredge which will be sampled three times during the day. The water quality samples will be collected at the near surface, middepth, and bottom at each station. Three (3) replicates from each sampling depth will be obtained by sequential sampling at each depth. Each sample replicate will be of sufficient volume for the chemical analyses to be performed as outlined in this scope of work.

Labeling and Field Log. For the plume sampling, there are 10 sample stations. A sample number consisting of four components will be assigned to each sample. The four components are: date, station, depth, and time. The date will be represented by a two digit number depicting the day of the month. The station portion of the sample number will be assigned sequentially, such that the 100 foot upcurrent station will be 01, the station on the dredge 02, the

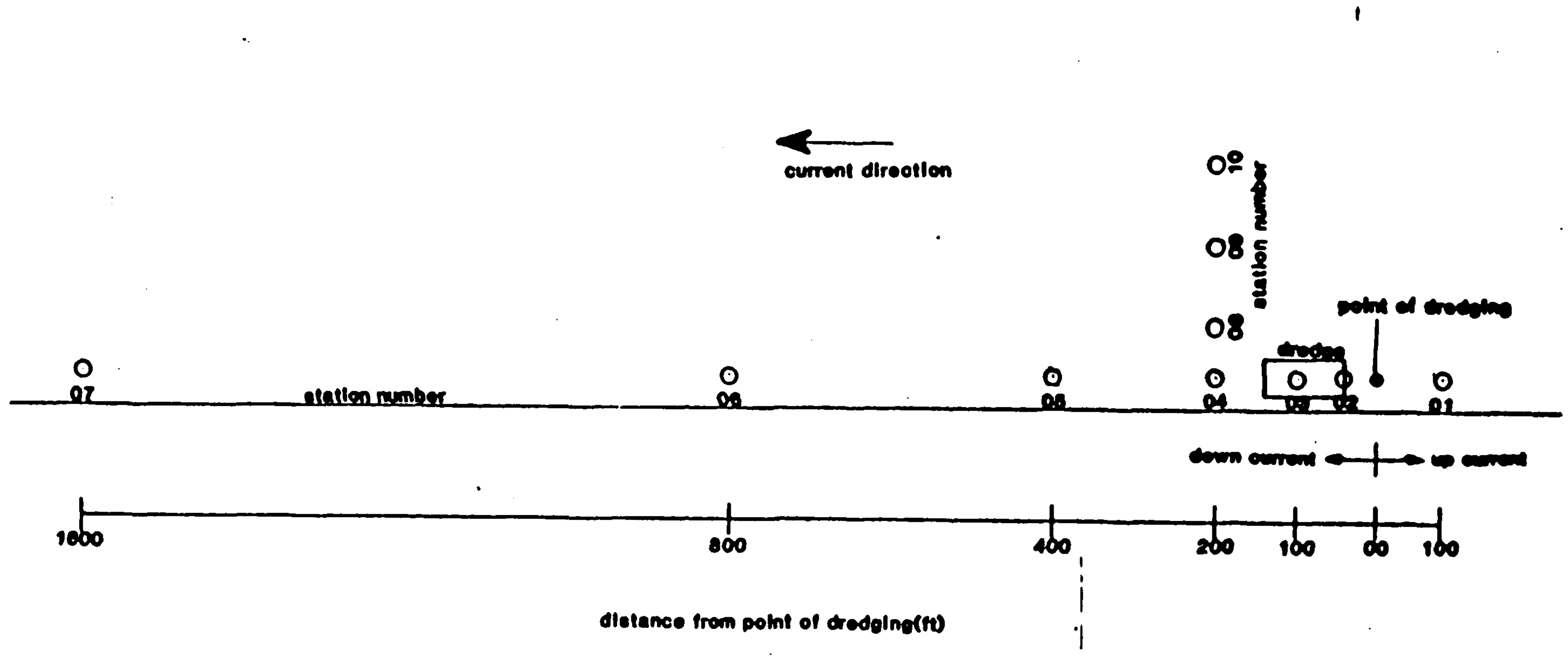


Figure I-1. Sample grid for monitoring of dredging operations, Everett Homeport.

station 100 ft downstream 03 and the rest as shown in figure 1. The depths will be similarly numbered, 1 for surface, 2 for middepth and 3 for bottom. The time will be incorporated into the sample number such that for a sample collected on the first day of the month and at 0800 at the 200 ft downstream station will be 01-04-02-0800 if it was obtained at middepth.

A field log will be kept to outline sampling procedures and identify each sample. The field log will be arranged into sample days. The beginning of each day will begin by recording the names of the persons collecting the samples, description of the weather condition, (approx. wind speeds and direction etc.), and description and or sketch of the dredging operation for that day. Each time the dredge makes a significant movement, such as changes in position in the channel, it will be recorded in the field log. Each sample will be identified in the field book by sample number, depth, time and distance from the point of dredging. Other events recorded each day will include: cycle time of the dredge bucket, current measurements, any interruptions of the dredging operation, water temperature, any ship movement in the vicinity of the field study, and any other event the data recorder feels to be pertinent to the field study. Similar procedures for labeling and field logging should be used in other portions of the monitoring.

Laboratory Testing

Total Suspended Solids. All the discrete water column samples will be analyzed for total suspended solids IAW the AWWA-WPCF-PHS Standard Methods (Total of 250 samples).

Chemical Analysis of Water Column Samples. All water quality samples collected at the station immediately downstream from the dredging operation (Total of 27) will be analyzed for TSS, dissolved chemical concentrations (filtered or centrifuged subsamples), and total chemical concentrations. A dissolved sample will be defined as that passing 0.45 micron filters. This will yield a total of 54 water samples for chemical analysis. Both the total and dissolved subsamples will be analyzed for metals, nutrients, PCB's and PAH's. A list of specific parameters for analysis will be necessary.

The remaining water quality samples (27) will be split; subsamples filtered or centrifuged, preserved, and retained for possible later chemical analysis.

Report

The contractor will summarize the data collected in a report to include tables of all test results, descriptions of the test procedures used, copies of sample logs and field notes, and any other information pertinent to the sampling and testing.

Monitoring Plan for Dredged Material Placement for the CAD Alternative

Purpose and Scope

The purpose of this monitoring program is to determine actual disposition of dredged material during disposal for the CAD alternative and to verify mathematical models used to predict such behavior. Verification of modeling assumptions regarding the behavior of material during descent to the bottom, surge along the bottom, and initial transport through diffusion will be accomplished by intensely monitoring several barge dumps using arrays of instrumentation in the water column and on the bottom. The area of deposition following each phase of disposal will be determined by comparisons of bathymetric surveys taken before and after each phase of disposal, supplemented by data from instrumentation on the bottom. The monitoring program outlined could be applied with modifications to most coastal dredged material disposal sites possessing similar water depths and currents.

The scope of work includes descriptions of the data to be collected to characterize the disposal site and the properties of the material in the disposal vessel as well as the data required to describe the descent of the material as it falls through the water column, spreads over the bottom as a density current, and finally is transported by the ambient current while undergoing turbulent diffusion. Descriptions of the instrumentation required to accomplish the monitoring program as well as the placement of instruments around the disposal point is also presented. This scope is written assuming that disposal will be from bottom-dump scows. If a different dredging method is selected, appropriate modifications to this plan must be made.

Field Data Collection Program

To provide insight into the fate of dredged material disposed at the designated disposal site as well as to furnish data for verifying mathematical models, field data must be collected throughout the placement processes that occur during several disposal operations* and for a short period of time after each operation. A major problem that must be overcome stems from the fact that dredged material placement occurs through a series of rapid three-dimensional processes that may be quite difficult to observe. The requirement for rapid and continuous observations of dredged material placement can best be met by optical transmittance and acoustic and water flow measurements**. Both continuous observations at one location and observation profiles made through the water column must be made. Comparison with suspended solids concentration measured in simultaneously taken water samples will assure reliability of transmissometer calibration. A survey echo sounder can be used to track dredged material through the water. If the boundary between the ambient water and water containing dredged material is a sharp one, the sounder permits flow velocities and layer thicknesses to be measured. Flow velocities of dredged material can also be measured directly with standard current meters. These methods of measurement will be used simultaneously during each disposal operation monitored.

Instrument Requirements

Transmissometers. The requirements of the transmissometer design are mechanical rigidity and sufficient strength to withstand forces encountered during the release of dredged material. It is also necessary that the instruments operate at much higher sediment concentrations than are usual for optical methods. A total of 6 transmissometers must be used simultaneously during the monitoring program.

Acoustic Transducers. Acoustic pulses of 200-kHz frequency return good echoes from small concentrations of fine-grain sediments. Based upon work by Proni***, standard echo sounder equipment should suffice to detect the presence of dredged material. For example, Raytheon survey fathometers operating at 200 kHz with an 8° cone angle might be used. A total of 9 transducers must be used simultaneously during the monitoring program.

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* For purposes of this monitoring program, a "disposal operation" is defined as the filling, transport, and subsequent release of a single load of dredged material.

** Bokuniewicz, H. J., et al, "Field Study of the Mechanics of the Placement of Dredged Material at Open-Water Disposal Sites," TR D-78-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

*** Proni, J. K. et al, 1976, "Acoustic Tracking of Ocean-Dumped Sewage Sludge," Science, Vol 193, pages 1005-1007.

Current Meters. Fluid flow measurements are needed to determine the background current at the disposal sites and to record the velocity of the bottom surge and the speed of descent of the dredged material. Measurements of speed and direction of the background current can be made with an Endeco current meter, or equivalent, mounted on taut moorings at the desired distances above the bottom. Several types of flowmeters could be used to measure the speed of flow in the bottom surge, e.g., a standard Price meter of the type designed to measure flow in rivers. At least one current meter and 7 flowmeters must be used simultaneously during the monitoring program.

Survey Equipment. The monitoring program includes detailed bathymetric surveys. A Ratheon survey echo sounder, or equivalent, could be used.

Water Pumps. Submersible electric pumps with a capacity of at least 0.01 m^3/minute must be used to collect water samples during each disposal operation. At least 6 pumps must be used simultaneously during the monitoring program.

Range and Bearings. The positions of observing points around the scow should be determined by electronic positioning equipment similar to Loran C positioning system or better. This equipment should be calibrated using fixed range markers and coordinates from navigational charts. Ranges can be taken with an optical range finder and bearing compasses can be used as a field check on the electronic positioning.

Deposition Samplers. Alternatives are available to measure the extent of depositions occurring from disposal activities. For example, one type sampler may consist of sediment collection vessels mounted at multiple levels on a tripod which will rest on the bottom. The lower vessels will reflect accumulation of material reaching the samplers due to the bottom surge. The uppermost vessel will reflect only the deposition of material due to transport-diffusion. A diagram of the sampler is shown in Figure I-2. (This sampler is identical to that used by Glenn Earhardt, Baltimore District, in similar studies.) As a supplement or alternate, a sediment profiling camera such as REMOTES (Remote Ecological Monitoring of the Seafloor), or comparable, can be used to measure the thickness of the deposited sediments. Use of deposition samples is critical in measuring the extent of thinner layers of deposited material which would not be observable by surveys.

Sediment Sampler. The properties of the dredged material in the barge are required for each disposal operation monitored. To determine properties

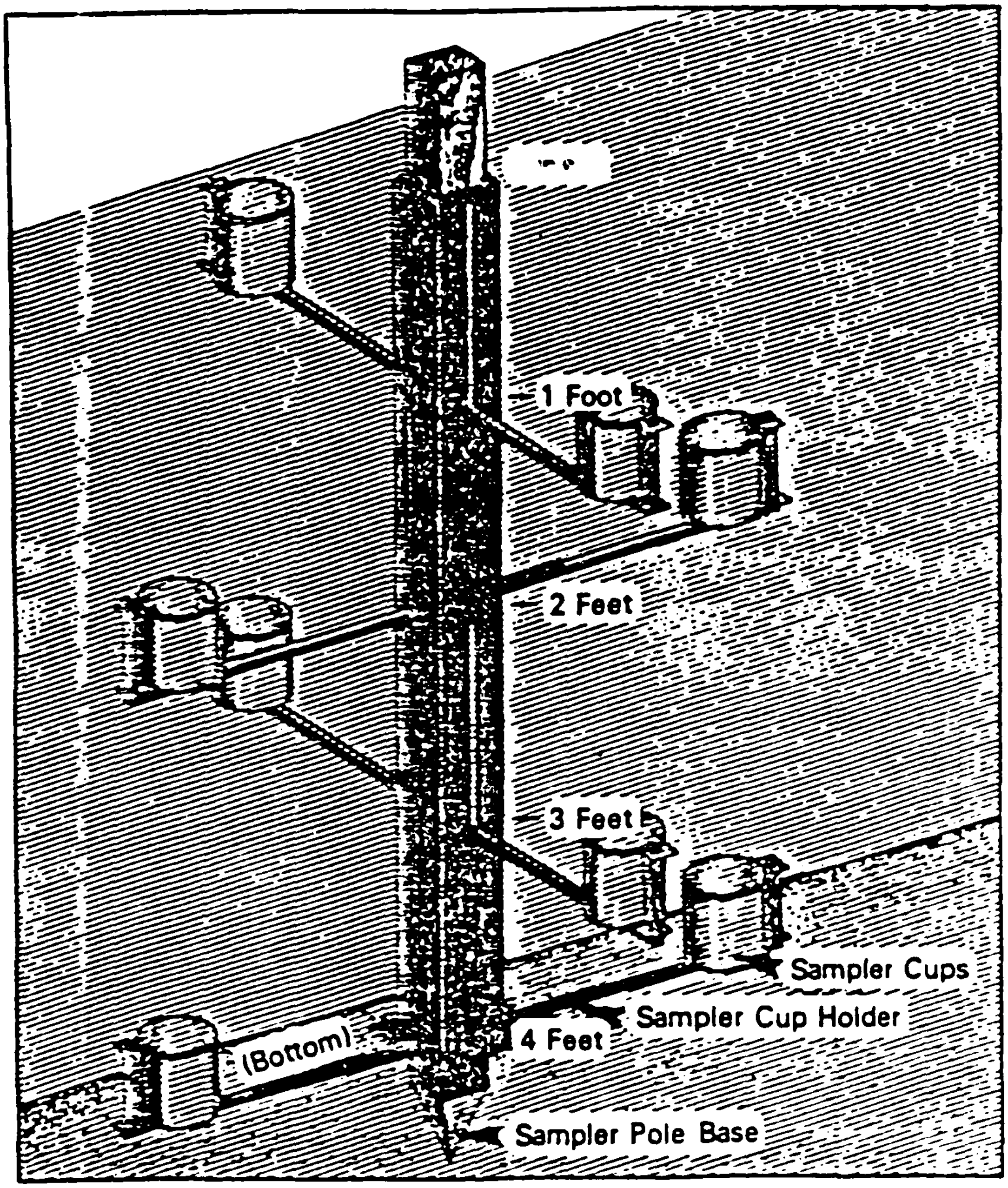


Figure I-2. Suggested deposition sampler, Everett Homeport.

of the material at various vertical locations in the barge, a syringe mounted on a long pole with the piston pointing up can be used. With this configuration, no material will enter until the syringe is at the desired depth and the piston is pulled. Samples of the dredged material from the surface can be taken with a scoop.

Timed Camera. A stationary camera with time-lapse capability will be used to record the filling of the barge and the subsequent release of dredged material from the barge during each disposal operation monitored. A scale will be attached to the inside wall of the barge so that estimates of volumes and rates of filling and release can be determined from the photographs.

Observation Boats. At least seven observation boats will be used simultaneously during the disposal operation sampling period. The boats should be large enough to accommodate three crew members, who will handle equipment and record data, plus all necessary equipment. The observation boats will serve as a working platform for the crew and should be stable under expected working conditions. The boats should also be able to anchor in the water depths anticipated at the site and equipped with electronic positioning equipment.

Description of Disposal Operations to be Monitored

The disposal barge will be stationary during the monitoring operation. A range of disposal operations consisting of varying volume and dredged material possessing different sediment and water content should be monitored (if applicable). In addition, disposals should be conducted at different times in the tidal cycle, reflecting the maximum and slack current velocities during the flood and ebb tides, and in different water depths (if applicable).

Data Collection Phases

Major factors affecting the short term fate of dredged material disposed in open water are the disposal site characteristics, the properties of the disposed material, and the type of disposal operation. Data concerning each factor must be collected. The behavior of the material can be separated into three phases: convective descent, during which the dump cloud or discharge jet falls under the influence of gravity; bottom collapse, occurring when the descending cloud or jet impacts the bottom; and passive transport-diffusion, commencing when the material transport and spreading are determined more by ambient currents and turbulence than by the dynamics of the disposal operation. Data describing the movement of the dredged material through each of these phases will be collected.

Bathymetry. Bathymetric surveys will be obtained prior to disposal and after the entire volume of dredged material has been placed in each phase. Phases to be surveyed include the berm (if used) first contaminated mound, first cap, second contaminated mound, and second cap. Other supplemental surveys would be desirable to determine progress during each phase.

The pre-disposal survey is to establish existing depth gradients and to serve as background of the site prior to initial disposal. The post disposal surveys will be used to help determine mound configuration and sediment volumes.

Disposal Site Characteristics. Current velocity and direction data from at least one station will be collected during the sampling period. Such data can then be converted to a local velocity field through a ratio of water depths. A sufficiently large density gradient in sufficiently deep water can result in arrest of the descent phase. Therefore, the vertical density profile at the time of maximum flood, ebb and slack water current velocities will be obtained at the deepest point in the disposal site. This will require the collection of salinity and temperature data.

Properties of Dredged Material. Data must be collected concerning the properties of the dredged material in the barge prior to all disposal operations which are monitored. Timed photographs should be taken as the barges are filled during dredging. Samples of dredged material, for subsequent laboratory analysis must be taken from the barges with the syringe sampler previously discussed. In most cases the material will not be uniformly distributed over the depth; therefore, samples should be taken at the surface, at mid-depth, and near the bottom. These samples will be analyzed for the following parameters; moisture content, Atterberg limits, bulk density, specific gravity of solids, void ratio and the particle size distribution. Chemical composition should also be determined.

Point of Discharge. Control of the point of discharge will be important throughout the entire disposal operation. Appropriate control for the point of discharge will be specified in the plans and specifications and will be used to establish the points of discharge during the monitoring. Control for the point of discharge could be established by pre-located taut-line buoy, electronic positioning with on-board computer printout, or other appropriate means. The disposal barge during placement of contaminated sediments should be stationary during the release phase for each dump. This will assist in keeping the dredged material mass in a clumped condition for descent.

Disposal Operation Data. The quantity of material and the mode of operation of the bottom-dump doors must be provided for each disposal operation monitored. Information concerning the time required to complete the discharge of material from individual barges as well as the time required for complete discharge is essential. In addition, the location of the doors below the water surface, the distance from the doors to the center of gravity of the dredged material, and the dimensions of the doors must be furnished. The rate of emptying of the barges can be determined by taking a series of timed photographs of the barges during discharge. Water level measured against a scale photographed in place in the barges can then be converted to volume of material with the aid of calibration curves available from builder's drawings. Timing of events during the monitoring efforts should be based on the time at which the scow doors are first opened. Observers should be placed on the scow to call or signal the time of discharge.

Descent Data. Processes that occur during the descent of dredged material through the water column determine the impact velocity at the bottom, the location of the impact point, and the amount of material that reaches the bottom. Field observations using transducers and a flow meter are intended to yield information on the descent velocity, size and entrainment of the descending cloud or jet. The instruments to provide this data may be deployed as shown in Figure I-3.

Release of much of the dredged material in the form of cohesive blocks or clods will occur if the material in the barges is cohesive and the water content is low. Evidence on the formation of clods during the release of the material must be provided. This can be obtained by either taking bottom photographs under the disposal vessel immediately after the disposal operation, through acoustic data or both. A transducer looking downwards alongside the disposal vessel will be used to detect the presence of clods during free fall.

Detailed information on the descent of the dredged material will be obtained with transducers and flowmeters. The transducers should be used to produce beams directed downwards, upwards, and sideways. From the transducer data, the speed of the descending cloud or jet can be determined. The speed

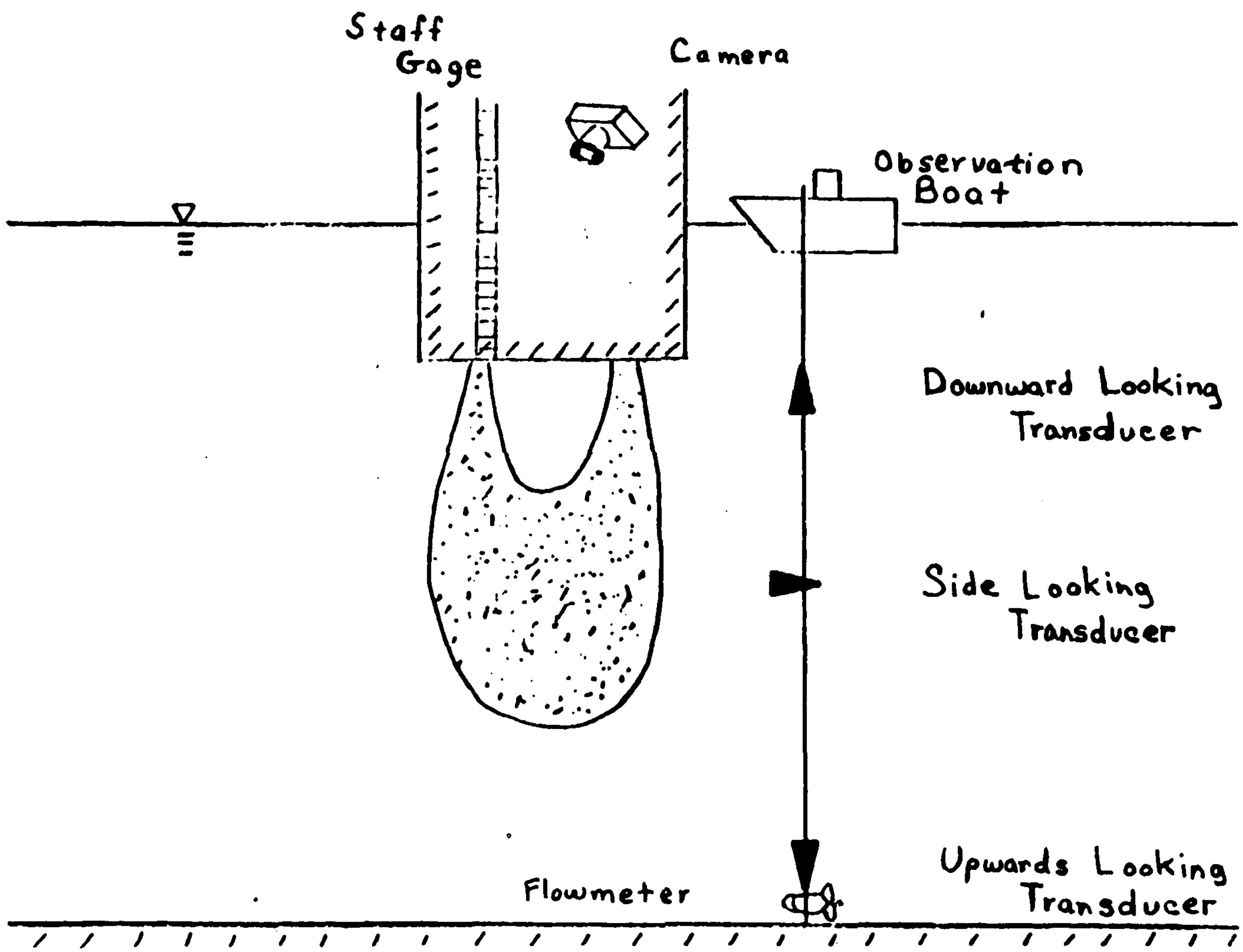


Figure I-3. Typical configuration of instruments to provide data on the descent phase, Everett Homeport.

of the descending jet of dredged material will also be measured with a flowmeter. A low threshold propeller should be used to enable the measurement of flow velocities from almost zero to perhaps 3-4 ft/sec. The flowmeter could be attached alongside the transducer as shown in Figure I-3.

Bottom Surge and Spread Data. Impact of the descending jet or cloud with the bottom deflects the flow of dredged material and entrained water to form a surge or density current which spreads away from the impact point. The surge spreads radially outward with both its thickness and speed decreasing as its radius increases. The entrainment of ambient water into the surge and friction eventually cause the velocity of the surge to decrease to the point where much of its contained sediment is deposited. The initial energy of the surge and the rate of energy dissipation determine the range of the surge, as well as the area of the bottom that will be covered by dredged material, the form, and the thickness of the deposit. To adequately describe the bottom surge it is necessary to know its velocity as a function of distance from the impact point, its thickness, and the concentration of solids contained. The rate at which the leading edge of the surge spreads outward from the impact area can be determined by noting the time at which the spreading surge of dredged material arrives at a number of stations various distances from the disposal vessel. Since the bottom surge resulting from the disposal of dredged material can be expected to spread over several hundred feet, the distribution of stations shown in Figure I-4 will be used. Since the disposal is made over an essentially flat area of the disposal site, the surge should be symmetrical about the impact point. The station located 200 feet up current of the descent impact point will be used to confirm this.

At each station, the arrival time of the surge will be detected with a transmissometer, a 200-kHz acoustic transducer, and a flow meter or a bottom-mounted recording current meter. A typical configuration of instruments required to characterize the bottom surge is shown in Figure I-5. The instruments must be secured in such a way as not to be displaced or damaged by the bottom surge.

The thickness of the surge and the change in thickness in time will also be measured by the acoustic transducers. Because of the suspended solids, the fluid in the bottom surge should return a good echo of the 200 kHz acoustic pulses.

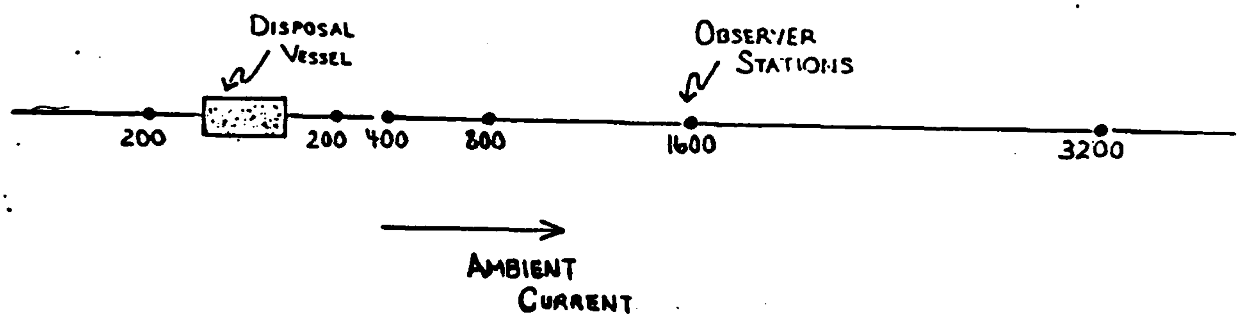


Figure I-4. Distribution of deposition samplers, Everett Homeport.

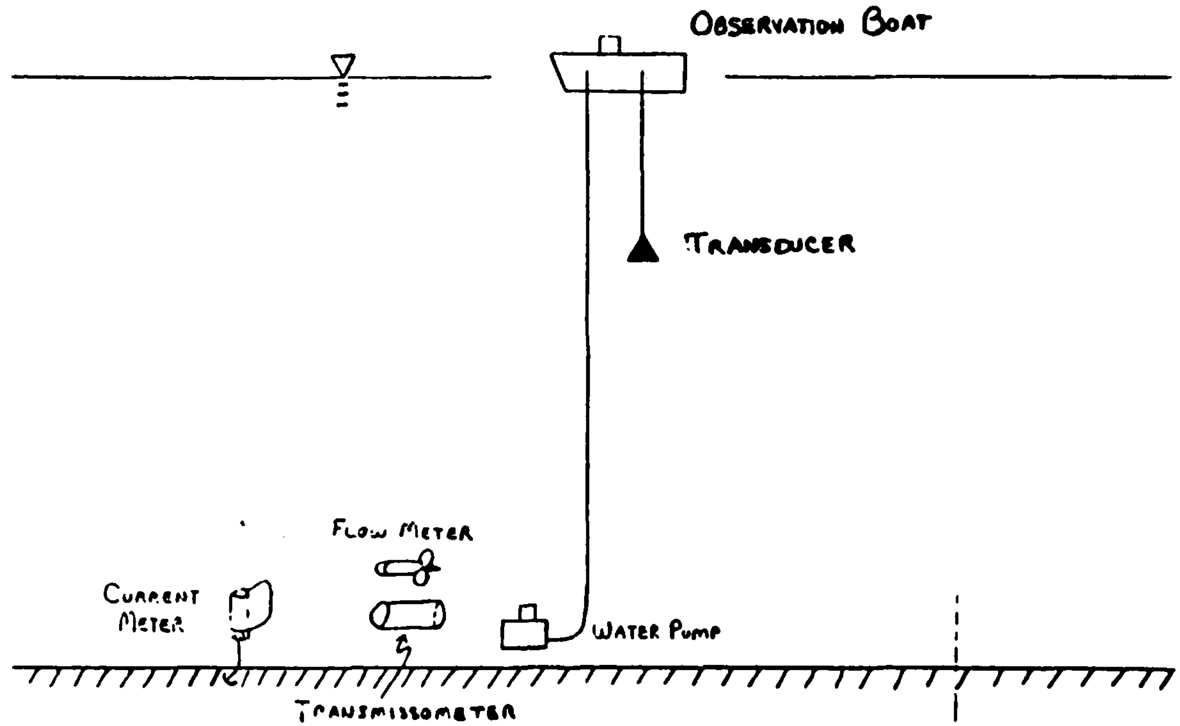


Figure I-5. Data collection stations for observing the bottom surge and transport-diffusion of the suspended sediment cloud, Everett Homeport

To monitor the concentration of suspended sediment in the bottom surge as well as the suspended sediment concentrations in the transport-diffusion phase, both transmissometers and water samples collected with submerged pumps will be employed. The transmissometers and pumps should initially be stationed about two feet above the bottom and continuously pump water to the observer boat above for purposes of monitoring the surge. Discrete water samples should be collected at the 200- and 400-foot stations at 30-second intervals for the first three to five minutes, and every minute thereafter until the surge has passed. Water samples obtained simultaneously with transmittance readings should provide a check on the transmissometer calibration, and will be particularly useful if the sediment concentration is too large to be measured by optical methods. The solids content of the water samples can be determined by filtration through millipore filters followed by weighing of the dried sediment. The bottom surge phase of the disposal operation should be over approximately fifteen minutes after its initiation. Additional sample volumes for water quality should be taken at the 200 feet station during this period.

Transport-Diffusion Data. To provide information on the longer term of transport and diffusion of the suspended sediment cloud remaining after the energy of the bottom surge has been dissipated, sediment concentration and cloud thickness data should continue to be collected at all stations until the next disposal event. During this period, alternating transmissometer readings and water samples should be collected. The data should be obtained throughout the water column at near surface, mid-depth, and near bottom. A sampling interval of perhaps three to five minutes will probably be sufficient.

Deposition Data. Deposition samplers should be installed or sediment profile samples collected at the same locations shown on the grid in Figure I-4 to determine the quantity and distribution of settling from the disposal operation. A bathymetric survey of the dredged material mound should also be obtained at the time of the deposition data collection.

Water Quality Samples

Samples for water quality analysis will be collected at the station nearest the downcurrent side of the point of disposal. The water quality samples will be collected at the near surface, middepth and bottom at each station. Three (3) replicates from each sampling depth will be obtained by sequential sampling at each depth. Each sample replicate will be of sufficient volume for the chemical analyses to be performed as outlined in this scope of work. will be analyzed for TSS, dissolved chemical concentrations (filtered or centrifuged subsamples) and total chemical concentrations. Dissolved samples will be defined as that passing 0.45 micron filters. This will yield a total of 9 water samples for chemical analysis for each disposal operation monitored. Both the total and dissolved subsamples will be analyzed for metals, nutrients, PCB's and PAH's. A list of specific parameters for analysis will be necessary.

Data Analysis and Report

All data collected by the contractor will be furnished; however, the contractor will also analyze the data to provide the following information in either graphical or tabular form for each disposal operation monitored:

a. Water depths over the disposal site and a description of the relative roughness of the bottom.

b. Magnitude and direction of ambient current as a function of time and position in the water column at the background current station. The water depth at the current station must be provided.

c. Vertical profile of ambient density at maximum flood and ebb current velocities and slack water periods of the tidal cycle.

d. Amount of dredged material disposed in each disposal operation, bulk density, vertical variation of density in the hopper, grain size distribution, void ratio, and Atterberg limits of the material in the hoppers or scow. Drawings of the disposal barge showing the bottom doors and a detailed narrative describing the actual disposal operations, e.g., time required for disposal to be completed, etc. In addition, visual observations of the wind and sea conditions should be provided.

e. Time required for the disposed cloud or jet of material to strike the bottom, its growth while falling through the water column, its velocity at bottom encounter and an estimate of the amount of solids that falls as clods and the average fall velocity of those clods must be provided.

f. Time history of the radial spreading of the bottom surge and a time history of the flow velocity, surge thickness and suspended sediment concentrations at each of the stations.

g. Thickness of deposited material obtained from the deposition samplers. In addition, from the bottom photographs and the resurvey information the volume of material deposited.

A written report describing the monitoring conducted, and the results will be provided within 60 calendar days of the completion of monitoring. This report will include narrative descriptions of the conditions during monitoring, equipment utilized, monitoring techniques employed, results, and any other data pertinent to the monitoring effort.

Summary

The fate of dredged material released at an open water disposal site is determined by disposal site characteristics, properties of the material, and by the nature of the disposal operation. The objective of this monitoring program is to follow the path of the dredged material, to determine how much material reaches the bottom, in what form, and how long it takes for the placement processes controlled by the factors above to go to completion. Results from the field data collection will provide quantitative information on how much material will be retained in the site from individual disposal operations and the distribution of that material on the bottom. In addition, the detailed data collected during the descent, bottom collapse and transport-diffusion phases will aid greatly in the calibration of mathematical models for predicting the short term physical fate of dredged material during open water disposal operations.

Monitoring Plan for Mound and Cap Behavior

General

This plan is intended to provide data for determining the final cap thickness immediately following disposal and after initial consolidation and the effectiveness of the cap in chemically isolating the contaminated sediments. This will be accomplished by physical and chemical analysis of core samples taken through the cap at various time intervals. Information on material type, density, and void ratios must be obtained at various times before, during, and after the dredging and subsequent disposal and capping operations in order to quantify the amount and condition of materials involved. The monitoring effort would be similar to that carried out for the recent capping demonstration project on the Duwamish Waterway. Determination of the materials' in-situ engineering properties over time are necessary. Also chemical analysis of the sediments and the pore water will yield information on possible contaminants and any discernible migration of these contaminants through the cap into the water column. Several types of activities are necessary to obtain the required information.

In situ samples of the sediments must be obtained before dredging, during storage/transport in the barge, and at several times after placement at the disposal site. Core borings of the sediment/dredged material will provide information concerning types of materials involved in this disposal operation; this information will be useful in predicting anticipated behavior of the material and in interpreting/understanding observed field behavior, i.e. rate of consolidation and possible erodibility of the sediments. Sampling will also provide data on void ratios/densities of the material at various times during the dredging/disposal operation; this will allow determination of the (average) effect of various dredging/disposal activities on sediment characteristics. Void ratio data will provide needed information about the conditions existing when consolidation begins.

Sampling and Materials

Portions of the sampling requirements may be covered in other monitoring plans or sufficient data may be available from previous samples. However, all required sampling is discussed in this monitoring plan. Samples will be taken at selected locations within the contaminated shoal to be dredged within representative transport barges and at the disposal site. All core samples will be taken with a Vibrocore sampler or equivalent core sampler. A twenty foot vibracore sample, or a shorter sample if refusal is reached before 20 feet, will be taken at each sampling location. Within the barge, grab samples will be taken during barge loading. Portions of all samples taken prior to disposal operations will be available for chemical analysis, as deemed necessary by sediment chemists. Samples taken subsequent to disposal will be collected for the dual purposes of geotechnical analysis and chemical analysis.

Vibracore samples of the foundation soils will be obtained from the disposal site before the disposal operation begins. Vibracore samples will be obtained at stations corresponding to these shown in Figure I-4. The borings should be centered in the disposal site in the upslope to downslope direction. These samples are necessary for delineation of foundation materials from dredged material in future borings collected at the disposal site. Prior knowledge of the foundation material to be expected at the disposal site will be invaluable in identification of the foundation-dredged material interface, particularly if any intermixing of materials occurs during disposal or sampling operations.

After placement of both the contaminated material and the capping material, core borings will be taken at specified time intervals to provide profiles of engineering properties. This will provide a means of monitoring any changes in the capped site in both the spatial and time dimensions.

Initial samples at the capped site will be taken utilizing the vibracore sampler. Whether or not this sampler is used for future core borings on this project is dependent upon (1) quality of the samples obtained initially from the capped site and (2) continued availability of the equipment. Twenty foot samples will be taken at locations selected to correspond with settlement plates which will have been placed in the disposal site before sampling occurs. Vibracore samples will be taken of locations. The schedule for sampling should be: immediately after cap placement, and then at 6, 12, and 18 months after cap placement.

Laboratory Testing (Geotechnical)

The vibracore borings will be visually inspected and photographed soon after completion of the sampling operation. Portions of each boring will be selected for laboratory testing. Soil classification will be determined for each sample; testing will include water content, Atterberg limits, specific gravity, and grain size distribution (hydrometer and/or sieve analysis). Consolidation tests will also be performed on selected samples. The number of samples selected for testing will be dependent upon results of the visual examination of the cores.

Settlement Plates

Deployment and monitoring of settlement plates in the mound is desirable to differentiate between mound consolidation and mound erosion. Designs for settlement plates, monitoring requirements, diving plans, etc. were necessary for similar mound monitoring conducted at the Duwamish demonstration recently conducted in the Seattle District.

It is recognized that the water depth at the proposed CAD site would present significant problems for such a monitoring effort. Final decisions on deployment and monitoring of settlement plates should be made only after final

CAD site design is complete and a more through evaluation of the potential problems for monitoring can be made.

Chemical Migration Through Cap

Problem. Capping contaminated dredged material with clean material to reduce the ecological impact of dredged material disposal in open water has been conducted on an experimental basis in the New England Division and Seattle District. These studies have shown that capping is technically feasible and that the caps appear to be stable under normal tide and wave conditions (O'Connor, 1982; SAI, 1982). Results of laboratory studies conducted at WES during the past 4 years to evaluate the effectiveness of capping in isolating contaminated dredged material have demonstrated that capping can isolate contaminated dredged material over a period of from 40 to 360 days. It is believed, however, that capping slows, but does not prevent, the transfer of contaminants to the overlying water over a prolonged period (O'Conner, 1982).

Objective. The objective of this phase of the study is to evaluate the movement of contaminants into the cap material from the underlying contaminated sediment and determine the effectiveness of the cap in preventing contaminant transfer to the overlying water.

Approach. Movement of contaminants through the cap and their rate of movement should be determined using a combination of water column and sediment core sampling. As contaminants move into the clean cap material from the contaminated sediment, they will be adsorbed by the clean material. As the adsorptive capacity of the lower cap layer is reached, the contaminants continue to move upward into cap sediment with remaining adsorptive capacity. Over time, the cap should become progressively more contaminated if contaminants are moving from the underlying material, and a discernible contaminant wave should be observed. Once the contaminants have exceeded the adsorptive capacity of the cap, they will diffuse into the overlying water. To track and quantify these contaminant movements, cores and water samples should be taken as soon after capping as possible (within one month), then at 12 and 24 months after capping.

Water samples must be obtained from as near the bottom as possible (within 1 meter) and should include four (4) samples taken in a transect across the site and an equal number of samples taken at an appropriate reference site. These samples must be filtered or centrifuged to remove particulate matter.

Sediment samples for chemical analysis will be obtained from vibracores. Four to 6 cores in a transect will be needed. Sampling will be concentrated in the cap material and the upper 30 cm of capped sediment. Beginning at the surface of the core, 23-4 cm sections will be taken in each core. This will ensure that all cap material to the clean/contaminated interface will be sampled despite localized variations in the cap depth. In addition, one sample of capped material will be taken at a depth of 6 ft.

References

O'Connor, J. M., 1982. Evaluation of Capping Operations at the Experimental Mud Dump Site New York Bight Apex, 1980. Synthesis Report for U.S.A.E. Waterways Experiment Station, Vicksburg, MS.

Science Applications, Inc. 1982. DAMOS Progress Rept. to U.S. Army Engineers New England District. Science Applications Inc., Newport, R.I.

Monitoring Plan for Intertidal Disposal

Monitoring efforts for intertidal disposal sites should include effluent monitoring during filling operation, surface water monitoring during a representative storm event, and leachate monitoring using observation wells.

Effluent Monitoring

Since the effluent discharged during filling operations potentially accounts for the majority of contaminant release from an intertidal site, routine monitoring should take place throughout the filling operations. The routine monitoring could be limited to suspended solids and perhaps representative chemical parameters to determine the overall efficiency of the site in retaining contaminants. The routine samples should be taken and analyzed on a daily basis for suspended solids and parameters such as dissolved oxygen. Routine samples should be taken on a weekly basis for chemical analysis. Each routine sample should be composited from several grab samples of the effluent taken from the discharge weir overflow. In addition to the routine sampling, a more intensive sampling effort should be carried out during one representative filling day early in the disposal operation. This sampling effort will be used to verify the accuracy of the modified elutriate test as a predictive technique for the project. On the intensive sampling day, a total of 12 influent and 12 effluent samples should be taken on an approximately hourly basis. This will provide a basis for establishing the contaminant retention efficiency of the site and provide a basis of verifying the total contaminant mass release from the site.

All samples taken for chemical analysis should be analyzed for total and dissolved concentrations of the parameters of concern in addition to suspended solids. Early routine monitoring can verify which parameters are likely to be present in the effluent, and costs of monitoring could be subsequently reduced by eliminating other parameters from the analysis.

Surface Runoff Monitoring

Monitoring of surface runoff quality should be conducted for a representative storm event. It is assumed that runoff water from storms would be ponded in the site by control of the weir boarding, and water would only be released once suspended solids had settled from the ponded water to the greatest possible degree. Therefore, the monitoring should be conducted by sampling directly from the pond during or shortly after the storm event. Three replicate samples would be taken from the pond at the weir structure. The samples would be analyzed in the same manner as effluent samples taken during filling as described above.

Groundwater Monitoring

Escape of contaminants from nearshore disposal sites can occur due to the close proximity to and movement of water adjacent to the site. Monitoring of contaminant escaping into adjacent waters and groundwaters is complex and costly. Tidal fluctuations at nearshore sites may affect the direction and flow of groundwater through the disposal sites. Since the contaminated dredged material will be placed at or below the groundwater level, the contaminants will be in direct contact with the groundwater, and the potential for contaminant migration will exist. The results of testing have indicated that the contaminants are sediment bound as long as the material remains saturated, however, groundwater monitoring to confirm this would be required. If the installation of liners to prevent contaminant migration is required, then monitoring to evaluate the effectiveness of the liner system both below and outside of the site would be necessary.

Groundwater monitoring wells should be established around the entire site at both the East Waterway and Snohomish sites. From preliminary sketches, the total diked perimeter of the 100 acre Snohomish Channel site is approximately 7600 feet and the East Waterway site is approximately 4000 feet. If wells are spaced at 500 foot intervals, this would require the installation of 15 wells for the Snohomish Channel and 8 wells for the East Waterway. These wells should be screened in the water carrying stratum around the site. Additionally wells may also be installed in the dikes to monitor seepage through the dikes. Monitoring wells installed inside the disposal areas will evaluate leachate percolating through the base of the disposal site. Monitoring wells installed outside the dikes when compared to wells through the dikes could be used to evaluate the dilution factor at the dikes.

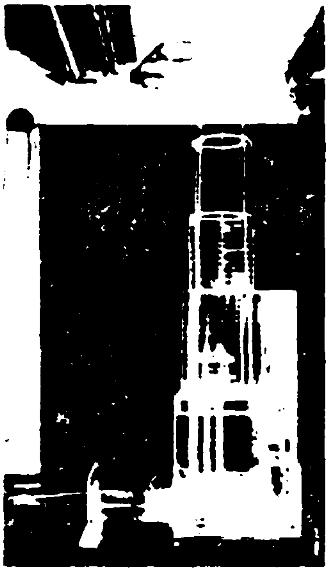
The contaminants of concern have been identified by the Seattle District as: chromium (Cr), nickel (N), copper (Cu), zinc (Zn), arsenic (As), lead (Pb), cadmium (Cd), mercury (Hg), polychlorinated biphenols (PBC), polynuclear aromatic hydrocarbons (PAH), and 1- and 2-methylnaphthalene. Sampling should begin before dredged material placement to evaluate background conditions. Background conditions should be evaluated for tidal and seasonal fluctuation. The sampling frequency should be more frequent during the beginning of the dredging project to evaluate the initial impact of the contaminated sediments in the disposal sites. After disposal operations are completed and the clean caps are in place, sampling may be performed less frequently unless evidence of contaminant migration is seen.

Action threshold levels for contaminants of concern may be established to indicate the probability of exceeding chronic saltwater criteria at the dike face. This would indicate a failure of the disposal site and controls to adequately contain the contaminants and may justify initiating a remedial action. A monitoring program frequency and threshold level similar to the program used at the Port of Seattle for the Terminal 91 confined disposal of contaminated sediments may be used.

A detailed monitoring program cannot be developed without detailed data as to dike layout and construction, control measures to be constructed, and dredged material placement schedules. When this data becomes available or is developed along with more detailed information as to the hydrogeology of the site a more detailed monitoring program outlining well placement and sampling strategy can be developed.

APPENDIX B

US Army Corps of Engineers



HYDRAULICS LABORATORY

MISCELLANEOUS PAPER HL-86-

TECHNICAL SUPPLEMENT TO DREDGED MATERIAL DISPOSAL STUDY U.S. NAVY HOMEPORT, EVERETT, WASHINGTON

by

Stephen A. Adamec, Jr.
Billy H. Johnson
Michael J. Trawle

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631
Vicksburg, Mississippi 39180-0631

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Seattle, Washington 98124-2255

ABSTRACT

Results from a series of numerical model runs predicting the short-term fate of contaminated and uncontaminated dredged materials disposed in open water are presented. Results for two types of disposal methods are presented, a bottom dump of contaminated material and a capping operation with uncontaminated material using hydraulic dredging and pipe discharge. Long-term predictions of disposal mound configuration and capping thicknesses based on hand calculations are also presented. Three current conditions and four dredged material clumping percentages were simulated for the bottom dumping of the contaminated material. Three discharge pipe configurations and four pipe discharges with varying density were simulated for the capping operation with uncontaminated material. The conditions tested were intended to represent typical conditions for the disposal of material at the proposed Navy Homeport site at Everett, Washington.

General conclusions from the modeling are:

a. For a single 4000 cubic yard barge dump of material, more than ninety-eight percent of the disposed contaminated material will deposit within one hour for all tests at 265 feet. The disposed contaminated material will deposit within an area of 800 by 1000 feet with a maximum thickness of approximately 0.60 feet.

b. More than ninety percent (at a discharge rate of 30 cubic yards of solids per minute) of the disposed uncontaminated capping material from each sweep of the confined surface discharge will deposit within an hour. The swath of deposition will be less than 300 feet wide with a maximum thickness of approximately 0.09 feet. Bottom impact velocities will be less than 0.5 feet per second.

c. More than ninety-five percent (at a discharge rate of 30 cubic yards of solids per minute) of the disposed capping material from the 50 and 150 foot stationary downpipe capping operations will deposit within an hour. The area of deposition will have a radius of less than 100 feet with a maximum thickness of approximately 2.0 feet. Bottom impact velocities will be less than 1.1 feet per second for the coarsest fraction of material.

d. Long-term disposal of 836,000 cubic yards of material (97,000 contaminated and 739,000 uncontaminated) in the first dredging season and 2,469,000 cubic yards (831,000 contaminated and 1,638,000 uncontaminated) in the second dredging season will generate a disposal mound with a final radius of approximately 2400 feet, a side slope of approximately 1V on 30H and a cap thickness of approximately 4 feet.

PREFACE

This report describes supplemental information regarding an evaluation of dredging and disposal alternatives for the proposed U.S. Navy Homeport at Everett, Washington. The U.S. Army Engineer District, Seattle is assisting the Navy in preparing a dredging plan for approximately 928,000 cubic yards of contaminated sediments which require dredging as a part of the project. This report is an addendum to the Corps Sediment Testing and Disposal Alternatives Evaluation.

The report was prepared by the following personnel of the WES Hydraulics Laboratory (HL): Mr. Steven A. Adamec, Dr. Billy H. Johnson, and Mr. Michael J. Trawle.

Director of WES was COL Allen F. Grum, CE, Technical Director was Dr. Robert W. Whalin.

EVERETT HARBOR DREDGED MATERIAL DISPOSAL STUDY

PART I: INTRODUCTION

Background

1. The U.S. Navy has proposed to site a Carrier Battle Group (CVBG) Homeport at Puget Sound in the East Waterway of Everett Harbor, Washington (figure 1). Construction of the Homeport facility will involve dredging and disposal of contaminated and uncontaminated sediments from the East Waterway. A total of 3.3 million cubic yards of material would be dredged. Approximately 928,000 cubic yards of that total has been defined as "dredge contaminated" by the Navy. The dredge contaminated material would be removed using a mechanical dredge. Removal of the remainder of the approximately 2.4 million cubic yards would be by hydraulic dredge. The Navy has selected the Deep Delta site in Port Gardner for contained aquatic disposal (CAD) as its preferred disposal alternative. The disposal site under consideration is located in water depths averaging approximately 265-400 ft (figure 2). Currents range from 0.1 to 0.2 fps and generally run from southeast to northwest. A key factor in the feasibility of disposal at this site is the ability to adequately cap approximately 900,000 cubic yards of contaminated material with approximately 2,000,000 cubic yards of uncontaminated material. This procedure will require accurate placement of contaminated and uncontaminated material within a defined boundary at the site without significant dispersal. In June 1984, the Navy contracted with the Seattle District to provide technical assistance in developing the dredging and disposal plans. This report presents the results and interpretations of a numerical modeling study, performed by the Waterways Experiment Station for the Seattle District in support of the District's assistance to the Navy.

Objective

2. The objective of this investigation was to predict the short-term fate of both contaminated and uncontaminated material which may be dredged and disposed in the Everett/Port Gardner Harbor area. These results were combined

with field experience from previous Corps dredging projects to predict the overall dimensions of the disposal area upon completion of the dredging operations.

Approach

3. The approach used was to simulate the open water bottom dump barge disposal of dredged material using the numerical model DIFID (Disposal from Instantaneous Dump). The model predicted the deposition pattern of disposed material for each of the conditions tested as well as suspended sediment concentrations in the lower water column. DIFID was then modified to simulate the proposed capping operations. The model predicted bottom impact velocities, deposition patterns and suspended sediment concentrations throughout the water column.

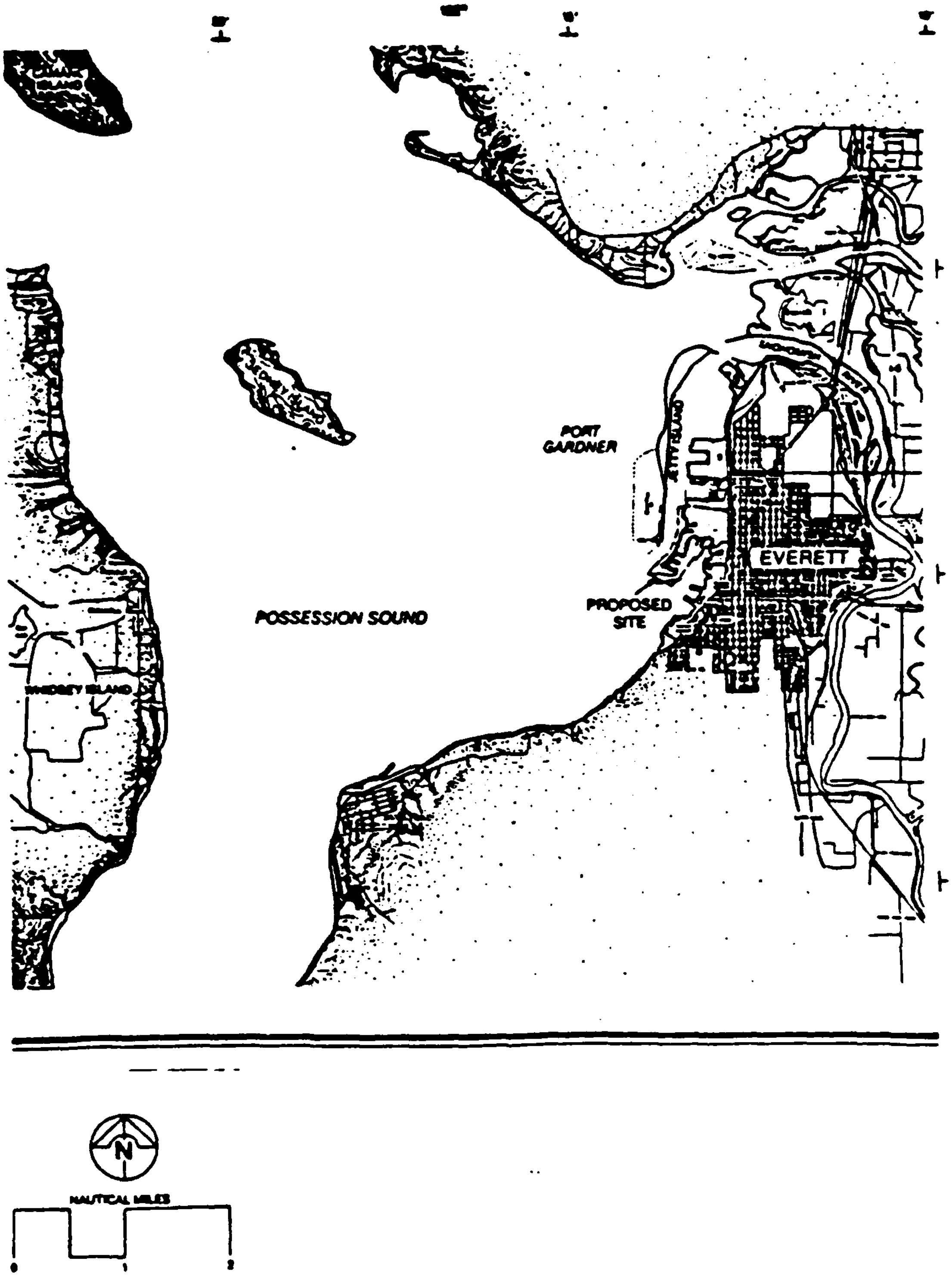

Figure 1. Location of homeport.

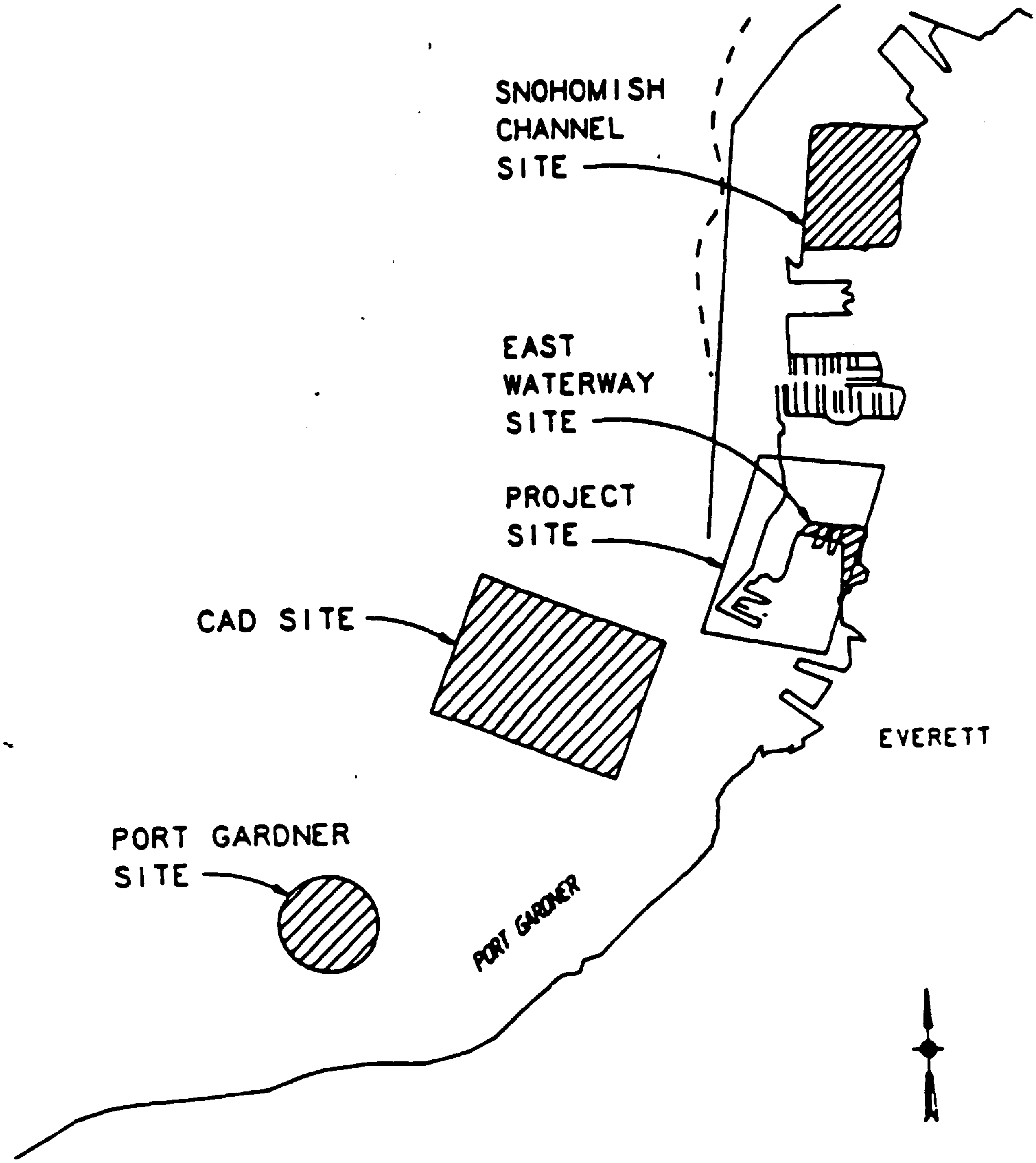

Figure 2. Location of known alternative disposal sites, as of April 1986.

PART II: THE NUMERICAL MODEL, DIFID

Description

4. DIFID was developed by Brandsma and Divoky (1976) for the US Army Engineers Waterways Experiment Station (WES) under the Dredged Material Research Program. Much of the basis for the model was provided by earlier model development by Koh and Chang (1973) for the barged disposal of wastes in the ocean. That work was conducted under funding by the Environmental Protection Agency (EPA) in Corvallis, Oregon. Modifications to the original model have been made by Johnson and Holiday (1978) and Johnson (in preparation).

5. In the simulation of a bottom dump barge disposal operation, the behavior of the disposed material is assumed to be separated into three phases: convective descent, during which the dump cloud falls under the influence of gravity; dynamic collapse, occurring when the descending cloud impacts the bottom and long-term passive dispersion, commencing when the material transport and spreading are determined more by ambient currents and turbulence than by the dynamics of the disposal operation. Figure 3 illustrates these phases.

6. During convective descent, the dumped material cloud grows as a result of entrainment and may descend at a velocity exceeding 10 fps. The model assumes that none of the dumped material is lost to the water body during this phase. (This assumption is supported by dredged material disposal monitoring in the lower part of Grays Harbor in 1982, in which no increase in suspended sediment concentrations were observed within the water column at a station located 1000 meters from the dump site.* The fact that nothing was detectable indicates that loss to the water column during descent was minimal). Eventually, the material reaches either the bottom or a neutrally buoyant position in the water column. In 100 ft of water, the convective descent phase for typical maintenance material is completed in a few seconds after dumping. However, in 800 ft of water, the convective descent is computed to last about 2 minutes. When the vertical motion is arrested, a dynamic spreading or collapse in the horizontal direction occurs.

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* Personal communication between Mr. Dave Schuldt, Corps of Engineers, Seattle District and Dr. James Phipps, Dept. of Geology-Oceanography, Grays Harbor College, March 1986.

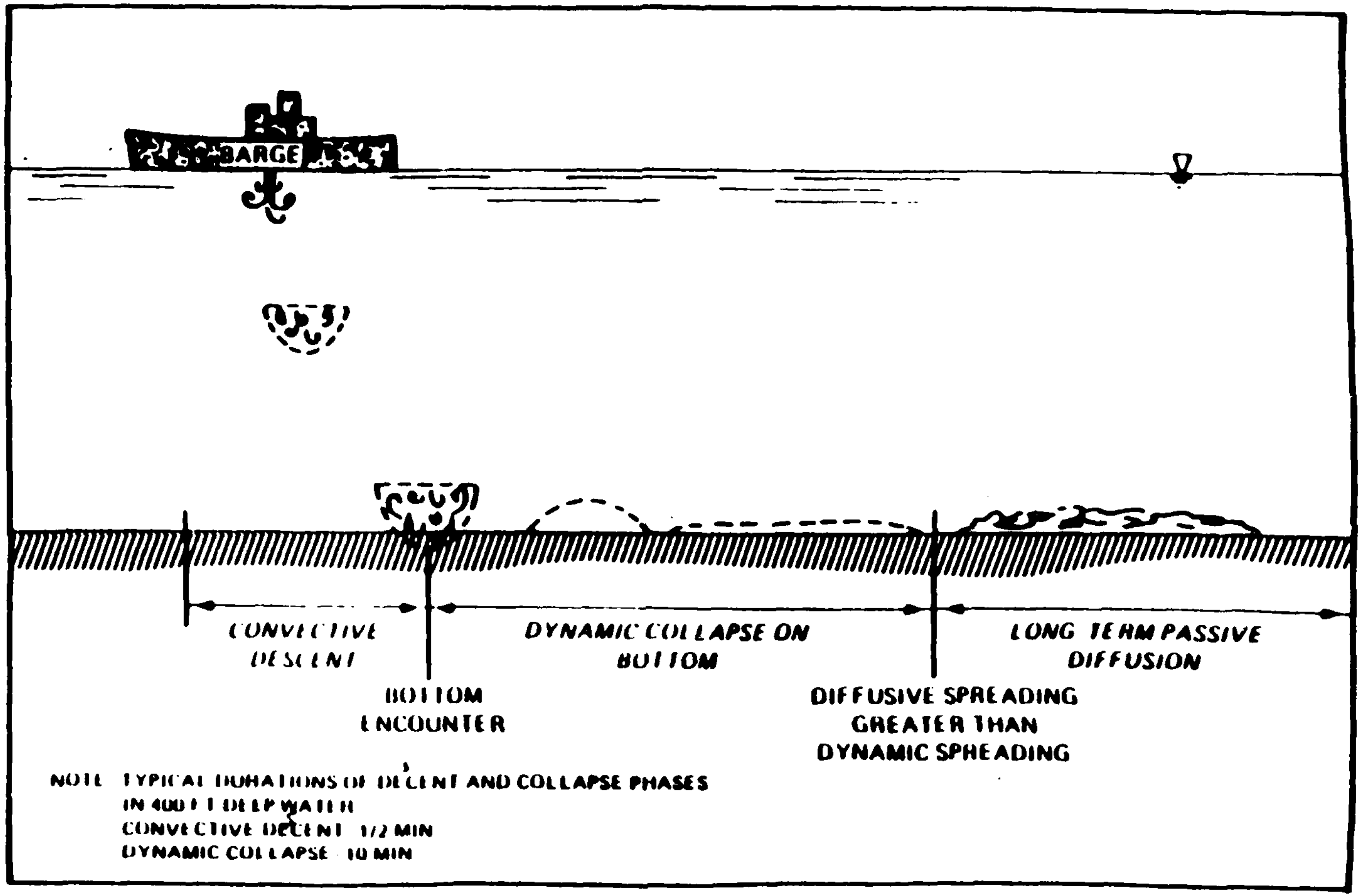

Figure 3. Illustration of idealized bottom encounter after instantaneous dump of dredged material (from Brandsma and Divoky, 1976)

7. The basic shape assumed for the collapsing cloud in the water column is an oblate spheroid. For the case of collapse on the bottom, the cloud takes the shape of a general ellipsoid which is several hundred feet in diameter. A frictional force between the bottom and the collapsing cloud is included at this point in the simulation. After approximately 10 minutes, when the rate of horizontal spreading or vertical collapse in the dynamic collapse phase becomes less than an estimated rate of change due to turbulent diffusion, the collapse phase is terminated and the long-term transport-diffusion begins. During the collapse, the model requires that the settling velocity for each solid fraction (sand, clay/silt, wood chips, clumps) be specified. In many cases, a significant portion of the material remains in "clumps" that may have a settling velocity of perhaps 1 to 5 fps. This is especially true for the Puget Sound area, where much of the dredging is done by clamshell, and can be true in the case of hydraulically dredged material if consolidation takes place in the hopper during transit to the disposal site. As these particles leave the main body of material, they are stored in small clouds that are assumed to have a Gaussian distribution. The small clouds are then advected horizontally by the imposed current field.

8. During this diffusion phase, which lasts approximately 50 minutes, the clouds grow both horizontally and vertically as a result of turbulent diffusion.

9.. Throughout the simulation, settling of the suspended solids occurs at each grid point of the model, and the amount of solid material deposited on the bottom and a corresponding thickness are determined. The model assumes that no subsequent erosion of material from the bottom occurs.

Required Input Data

10. The required input data to DIFID can be grouped into (a) a description of the ambient environment at the disposal site, (b) characterization of the dredged material, (c) data describing the disposal operation, and (d) model coefficients.

11. The first task is that of constructing a horizontal grid over the disposal site. The model grid used in this study is shown in Figure 4. The

ambient conditions imposed on the grid model for these tests were represented by a constant density and, with the exception of run #7, a depth-averaged time invariant current velocity.

12. Although the model has the capability to handle dredge material composed of as many as 12 fractions, the dredged material for these tests was characterized by three solid fractions. For each solid fraction, its concentration by volume, density, fall velocity, voids ratio, and an indicator as to whether or not the fraction is cohesive must be specified. In addition, the bulk density and aggregate voids ratio of the material must be prescribed. The bulk density is the density of the slurry in the barge. The aggregate voids ratio is actually a bulking factor used to convert the mass of deposited material to a thickness of deposition.

13. Disposal operations data required include the position of the barge on the horizontal grid, the volume of material dumped, and the loaded and unloaded draft of the disposal vessel.

14. There are 14 model coefficients in DIFID. These required coefficients include entrainment coefficients, drag coefficients, and turbulent dispersion coefficients. Default values that reflect the model developer's judgment are contained in the code. Computer experimentation such as that presented by Johnson and Holliday (1978) has shown that results appear to be fairly insensitive to many of the coefficients. The most important coefficients are drag coefficients in the convective descent and collapse phases as well as coefficients governing the entrainment of ambient water into the dredge material cloud. The values selected for the convective descent entrainment and drag coefficients in this study were based upon experimental work done by Bowers and Goldenblatt (1978) and upon a limited verification of DIFID using field data from the Elliott Bay/Duwamish disposal operation.

15. Model limitations should be considered in the interpretation and use of model results. These limitations include: (a) limited knowledge of appropriate values for the various model coefficients, (b) imprecise specification of settling velocities for the dumped material, (c) representation of real disposal operations in an idealized fashion. A detailed description of the theoretical aspects of DIFID is given by Brandsma and Divoky (1976).

Elliott Bay Application

Bokuniewicz et al.(1978)

16. During February 1976, personnel from Yale University, under contract to WES, collected data during a series of barge disposal operations at the Duwamish disposal site in Elliott Bay near Seattle, Washington. The dumps were made from a 530 cubic yard barge and the material possessed an average bulk density of 1.50 g/cc with the solid material being composed of 55 percent silt/clay and 45 percent sandy material. Although the data collected for comparison with computed results from the dredged material model were very limited, it is believed that verification of the model using field data in an area physically near the current disposal areas of interest lends credibility to model results in these areas.

17. When attempting to apply the dredged material models to real disposal operations, a basic problem is that of determining how to apply the models so that an actual operation can be represented by the idealized methods of disposal considered in the models. For example, there are no dredged material disposal operations in which all of the material leaves the disposal vessel instantaneously. However, for the case of a barge dump such as that made at the Duwamish site in Elliott Bay, all of the material normally leaves fairly quickly. If the water depth is sufficiently large, such a dump resembles a hemispherical cloud falling through the water column by the time the bottom is encountered and thus can be adequately modeled by the instantaneous dump model.

18. Upon release of the material during the Duwamish site disposal operation, a time of 25 seconds was observed for the leading edge of the disposal cloud to strike the bottom at a depth of 197 feet. With the convective descent drag coefficient increased from its default value of 0.5 to 1.0, the model computed a time of 23 seconds. The speed of the front of the bottom surge at 160 feet from the point of the dump was recorded to be 20 cm/sec. With an increase in the drag coefficient in the bottom collapse phase from 1.0 to 1.5 and a bottom friction coefficient of 0.06, the simulated rate of spreading of the cloud on the bottom was computed to be 22 cm/sec. During field monitoring, suspended solids data were recorded at 3 feet above the bottom at a point 300 feet downstream of the dump point. At 600 seconds after the dump, the recorded suspended sediment concentration was 64 mg/l. The corresponding computed concentration from the dump model at the same location and time was

75 mg/l. These results were obtained with the vertical diffusion coefficient for a well-mixed water column computed from:

$$AKY\emptyset = 8.6 \times 10^{-3} \frac{UZ^2(H - Z)^2}{H^3}$$

where

AKYO = Vertical diffusion coefficient

U = Ambient velocity, fps

Z = Water depth at which the value of the coefficient is desired, ft

H = Total water depth, ft

19. The ambient current near the bottom of the Duwamish site was 0.3 fps and the water depth averaged 197 feet. All coefficients other than those discussed above retained their default values.

20. Proper material characterization is extremely important in obtaining realistic model predictions. The results discussed above were obtained by assuming that 30 percent of the clay/silt consisted of clumps, 65 percent flocculated as cohesive material and the remaining 5 percent retained individual particle characteristics with a settling rate of 0.0025 fps. The use of consolidated clumps is consistent with the field observations of the Yale group.

21. In summary, the disposal model does not precisely describe the detailed structure of the impact and subsequent bottom surge observed during the field studies. However, with proper material characterization and selection of values for the more sensitive model coefficients, the lateral spread and suspended sediment concentrations can be reasonably estimated by the disposal model.

PART III: TEST PROGRAM AND RESULTS

Test Conditions for Contaminated Material Disposal

Grid size

22. The model grid used for all tests is shown in Figure 4, which represents an area of 4,000 by 4,000 ft. Each grid cell represented an area of 200 by 200 ft. The grid was oriented with its horizontal axis approximately parallel to the bottom depth contours.

Dump size

23. The dump size used in all simulations was 4,000 cu yd.

Duration of simulations

24. The duration of each test simulation was 3,600 sec (1 hour) after the barge dump.

Dump spot

25. The location of the dump spot is shown in Figure 4.

Model coefficients

26. The model coefficients used in these runs were established from the original ›del development and from the Elliott Bay/Duwamish disposal site application.

Ambient currents

27. Depth-averaged current speeds of 0.1 fps and 0.5 fps were used. A single bottom dump simulation was run with a two-layer velocity profile provided by a Navy subcontractor. The upper layer extended from the surface to a depth of 120 feet and was assigned a current velocity of 0.19 fps toward 125 degrees. The lower layer extended from 170 to 265 feet and was assigned a velocity of 0.16 fps toward 286 degrees. The velocities in the transition layer between 120 and 170 feet varied linearly between those in the upper and lower layers.

Material type

28. The material tested consisted of 22 percent fine sand, 25 percent wood and 53 percent clay/silt. Bulk density of the material was 1.25 gm/cc and the water content was 250 percent. The clay/silt fraction was modeled as cohesive material. A fourth fraction, clumps, was modeled as a 30, 50 or 70 percent composite of wood, sand and silt/clay.

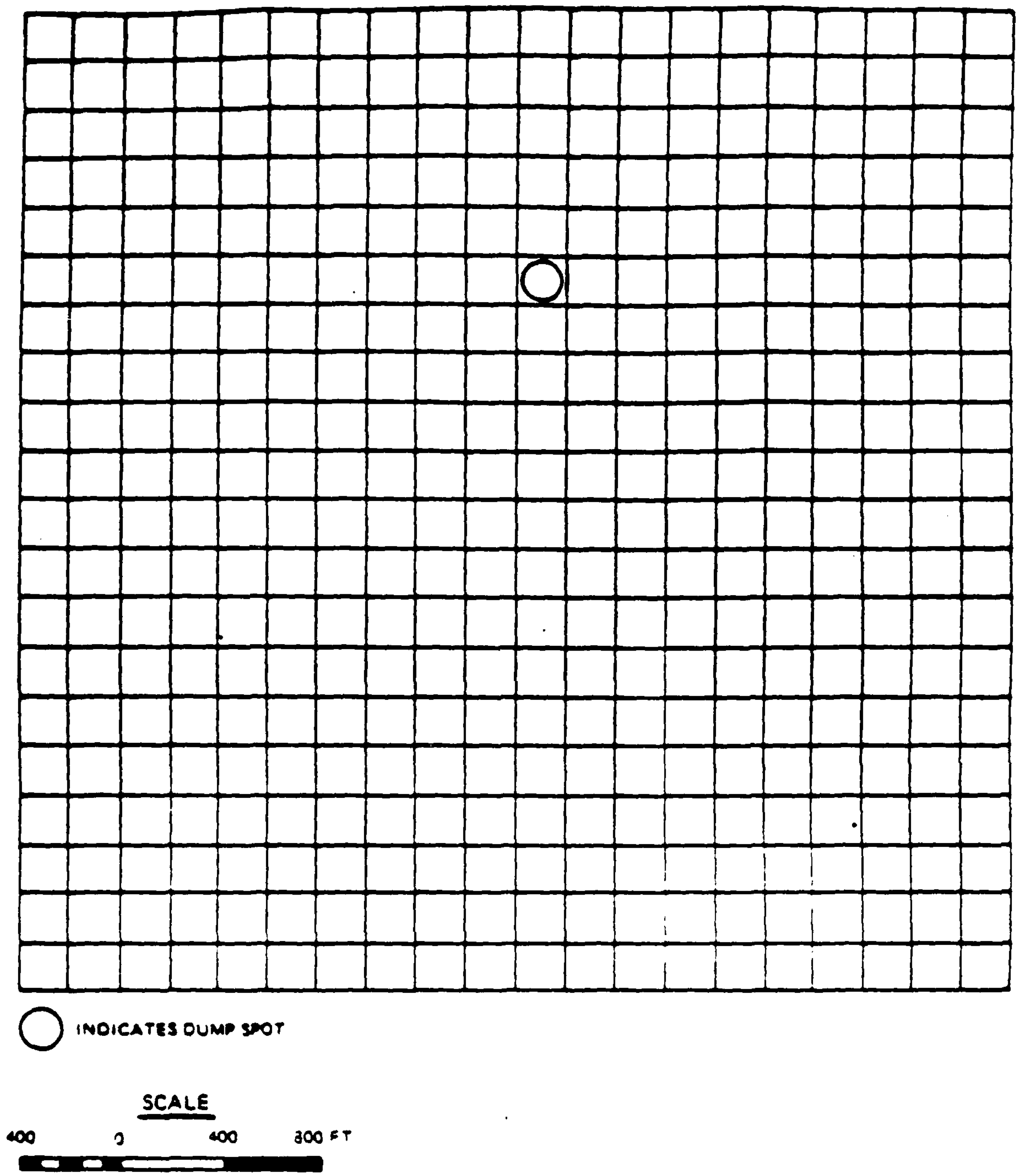

Figure 4. DIFID numerical grid.

Dump methods

29. Two dump methods were modeled, a bottom dump disposal at the surface and a disposal through a vertical pipe extending 250 feet below the surface.

Test Results

Bottom Dump Disposal

30. Results from the model tests are shown as deposition patterns in Plates 1 to 7. These deposition patterns demonstrate the predicted extent and thickness of material deposited from a single 4,000 cu yd disposal operation for the portion of the dumped material which had deposited after 60 minutes. Suspended percentages after 30 and 60 minutes for each simulation are shown in Table 1. The deposition of material (solids volume) predicted by the model is converted to thickness of deposition by the use of an aggregate voids ratio. The equation used by the model to convert solids volume deposited to thickness of deposition (Brandsma and Divoky, 1976) is

$$TH = \frac{1 + AVR}{AREA} \times VOL$$

where

TH = average grid cell thickness (ft)

AVR = aggregate voids ratio

AREA = grid cell size (200 x 200 ft^2)

VOL = solids volume (cu ft)

Vertical Pipe Disposal

31. Basic assumptions in this disposal operation are

a. A 10 ft diameter pipe will extend 250 feet below the water surface.

b. A total load of 4000 cubic yards of material will be dropped into the pipe at the rate of 10 cubic yards per minute.

c. The ambient velocity near the bottom was specified to be either 0.1 or 0.5 feet per second.

d. The disposed material has a bulk density of 1.25, a voids ratio of 0.8 and is composed of 22% sand, 25% wood chips and 53% silt-clay.

Table 1

Suspended Sediment Percentages After 1/2 Hour for Bottom Dump Disposal

Run #	Current Speed (fps)	Clump Factor (%)	Suspended Fractions: Sand (%)	Silt-Clay (%)	Wood (%)	Composite (%)
1	0.1	0	3.4	2.2	0	1.9
2	0.5	0	12.7	3.5	0	4.6
3	0.1	30	3.3	2.3	0	1.9
4	0.5	30	10.7	3.6	0	4.3
5	0.1	50	3.2	2.4	0	2.0
6	0.1	70	2.8	2.6	0	2.0
7	stratified (0.2 max.)	0	3.4	2.2	0	1.9
22	0.1	0	6.5	4.1	0	3.6

Suspended Sediment Percentages After 1 Hour for Bottom Dump Disposal

Run #	Current Speed (fps)	Clump Factor (%)	Suspended Fractions: Sand (%)	Silt-Clay (%)	Wood (%)	Composite (%)
1	0.1	0	0.7	2.0	0	1.2
2	0.5	0	3.6	2.0	0	1.9
3	0.1	30	0.8	2.1	0	1.3
4	0.5	30	3.1	2.1	0	1.8
5	0.1	50	0.8	2.2	0	1.3
6	0.1	70	0.8	2.3	0	1.3
7	stratified (0.2 max.)	0	0.6	2.1	0	1.2
22	0.1	0	1.1	3.9	0	2.3

32. The initial effort in numerically modeling this disposal operation involved an attempt to modify the semi-continuous model, DIFHD, under the assumption that the operation should be treated as a continuous surface source with a "feeding" of material into the bottom collapse phase from material passing through the end of the pipe. This effort was discontinued after realizing that such an approach would likely yield an unreasonably large lateral spread of material on the bottom. This large lateral spread would be caused by an extended bottom collapse phase which would last the full 400 minutes required to complete the disposal operation.

33. Since the disposal operation is actually a series of small instantaneous dumps, it was decided to employ the instantaneous dump model, DIFID, with a superposition of results to yield the final deposition pattern on the bottom. This was accomplished through a series of 8 individual model runs. Results from each run were then used to represent 50 drops of 10 cubic yards each with all 8 runs representing a single 4000 cubic yard barge-load.

34. At the end of the first run (50 drops) the material was deposited in a circular pattern with a radius of approximately 23 feet. At the end of this run it was assumed that the thickness of the bottom deposit, computed from

$$TH = \frac{1+BVOIDS}{\pi R^2} \begin{array}{l}\text{(Total volume of solids)} \\ \text{in 50 drops}\end{array}$$

would decrease to 75% of its value due to consolidation. At the end of the next 50 drops the thickness of the previous 50 drops would decrease another 25%. The first seven runs of 50 drops each were consolidated twice in this manner with the last run being consolidated once.

35. Once the deposition pattern for the first 50 drops was established, DIFID was rerun, but with a nonzero bottom slope determined by the thickness of deposit and the bottom spread. This resulted in a greater spread of material on the bottom for the second run. Although the numerical model cannot simulate the actual flow of material down the sides of a bottom mound, this approach seems reasonable as an attempt to simulate the effect of the mound. This same procedure of consolidating the previous 50 drops, determining a

bottom slope and rerunning the model was carried out 8 times to represent a total of 400 drops (4000 cubic yards) of material through the pipe.

36. It should be noted that no entrainment was allowed in the convective descent phase since the radius of a 10 cubic yard hemispherical cloud is 5.05 feet, i.e., approximately the radius of the pipe. In reality, some entrainment would actually occur, resulting in an elongated shape for the cloud falling through the pipe. However, a basic assumption of the model is that the material falls as a hemispherical cloud in the convective descent phase. Modifications to change this assumption were beyond the scope of this study. With these limitations, the basic effect of the pipe was to translate the disposal from the surface to the end of the pipe with the cloud now possessing a computed descent velocity.

37. Results from the vertical pipe disposal operation are presented in Table 2. As illustrated in Plate 8, the final deposition of material on the bottom is contained within a radius of approximately 50 feet from the end of the disposal pipe. The maximum thickness is computed to be approximately 3.5 feet under the pipe with a gradual tapering of the bottom thickness to about 1 foot at the outer boundary of the deposited mound.

38. These results hold for both velocity conditions, 0.1 and 0.5 feet per second. Since the material is subjected to ambient current conditions for only 15 feet of descent to the bottom, displacement of the cloud during descent is insignificant. Once the bottom collapse phase begins, the ambient current does transport small clouds as they are formed. However, since settling takes place during each time step in the model before the transport, material from these runs was always deposited on the ocean floor before it could be transported by the current. Remember that no erosion of material deposited on the bottom is allowed in the model. The only other way that the ambient current can influence model results is through its effect on the estimated rate of vertical diffusion, which can sometimes be the deciding factor in terminating the collapse phase. However, neither current condition was large enough to influence the collapse termination in these runs. Therefore, the results presented hold for both current conditions tested.

Table 2

Deposition Amounts for Vertical Pipe Disposal

After Dumps #	Thickness, feet at Radius (R) from Pipe				
	R=23 ft	R=36 ft	R=43 ft	R=49 ft	R=52 ft
50	1.63	-	-	-	-
100	1.88	0.66	-	-	-
150	2.18	0.96	0.46	-	-
200	2.41	1.19	0.69	0.34	-
250	2.66	1.44	0.94	0.59	0.33
300	2.91	1.69	1.19	0.84	0.58
350	3.16	1.94	1.44	1.09	0.83
400	3.41	2.19	1.69	1.34	1.08

Limitations

39. Factors which affect the required disposal area size, but which are not addressed by the model include:

a. The model treats each of three sediment fractions, (sand, clay/silt, and wood chips), separately. Model results indicate that the sand fraction had the longest settling time. In the actual disposal process, as the clay/silt particles flocculate and fall through the water column, with a settling velocity greater than that attached to the sand fraction, they will probably entrap and carry a significant portion of the fine sand to the bottom more rapidly than depicted by the model.

b. The ability of the model to accurately portray the material fate decreases as the percent of material in suspension decreases and as the time into the simulation increases. At the point where the percent suspended becomes less than perhaps 2% and the time exceeds perhaps 3,600 seconds, other uncertainties such as how much material dissociates from the cloud in the descent phase and the influence of turbulent diffusion in the vertical become important factors that are not clearly understood.

c. If the contaminated material is associated primarily with clay/silt fraction, the area required for a CAD site may be dictated by the range of this material rather than by the fine sand fraction which has the lowest settling rate and tends to remain in near bottom suspension for the longest period of time.

d. In an actual disposal operation, the material leaving the barge may differ considerably from that being modeled. Factors such as the relative quantities of the various fractions (sand, clay/silt, wood chips) of material, water content, the percent of clumps, and time for the material to leave the barge, all significantly affect the spread of material on the bottom. Conditions assumed for the model represent a worst case (maximum dispersion) condition.

Test Conditions for Capping Material Disposal

Hydraulic discharge

40. The proposed Navy dredging plan anticipates capping of contaminated sediments with underlying native material. Samples of this native material indicate that because the insitu water content is very low, the material may be too dense to be useable as a capping material. If a clamshell dredge and bottom dump barge were used, large clumps of the uncontaminated material would impact with the bottom at a high rate of speed, and could displace or resuspend the previously placed contaminated material. However, by hydraulically

dredging the native material, a mixture suitable for use in capping can be obtained. Twelve model runs were made to simulate possible methods of depositing the capping material.

Dump methods

41. Three capping methods were simulated -- a moving surface pipe discharge, a pipe discharge into a stationary 50 foot downpipe and a pipe discharge into a stationary 150 foot downpipe. The diameter of the downpipe was 10 feet. All capping runs were made using a modified version of DIFID where a capping operation is represented by a series of discrete clouds. Each cloud settles through the water column at the average descent velocity as determined from a normal application of DIFID to a single small cloud. As the series of individual clouds settle they are transported by the ambient current and grow as a result of entrainment. The radius of the cloud is determined from

$$R = R_o + \alpha_m D$$

where

R_o = Initial radius, ft

D = Distance from release point, ft

and α_m is an entrainment coefficient determined from figure 5. For the material used in these runs a value of 0.3 was selected.

Grid size

42. The model grid use for all tests represented an area of 2000 by 2000 feet. Each grid cell represented an area of 100 by 100 feet.

Duration of simulation

43. The duration of each simulation was 3,600 seconds (1 hour) after initiation of the capping operation.

Discharge rate

44. Pipe discharge rates of 20, 30, 40 and 50 cubic yards per minute were simulated for each of the three dump methods. Bulk densities for the material discharged at these rates were 1.25, 1.1833, 1.1167 and 1.05 respectively.

Dump spot

45. The dump operation for the confined surface discharge consisted of a 1400 foot "sweep" down the center of the grid, top to bottom. This sweep was intended to simulate a capping operation with a moving surface pipe

discharge. The pipe moved across the water surface at 0.5 fps, traversing a 1400 foot path in approximately 2800 seconds. The effective discharge radius after hitting the scatter plate at the end of the discharge pipe was assumed to be 20 feet.

46. The 50 and 150 foot downpipes were stationary and were located at the center of the numerical grid. The radius of each discrete cloud was taken as the pipe radius with the insertion location of each cloud being the end of the pipe.

Model coefficients

47. The model coefficients used in these runs were the same as those used in the contaminated material disposal runs. These coefficients were established in the original model development and during the Elliot Bay/Duwamish disposal site application.

Ambient currents

48. A depth-averaged current of 0.1 fps with an assumed direction from SE to NW was simulated.

Material type

49. The uncontaminated capping material consisted of 30 percent fine sand and 70 percent silt/clay. This material was modeled as a single cohesive fraction with no clumps. The capping modifications made in DIFID allow for only one material fraction.

Test Results

Confined surface discharge

50. Results from the model tests are shown as deposition patterns in Plates 9 through 12. These deposition patterns demonstrate that for a confined surface discharge the majority of deposition occurred within a 300 foot wide swath along the line of movement of the discharge pipe. Maximum cap thickness for a single pass of the surface discharge pipe was approximately 0.09 feet at the 30 cy/minute discharge. A one-foot thick cap would be generated within approximately 11 passes, or 8.6 hours. Suspended percentages after 60 minutes for each simulation are shown in Table 3. Suspended concentrations at 4 points in the water column for each simulation are shown in Tables 6A-6C. Bottom impact velocities of the disposed material are shown in Table 5.

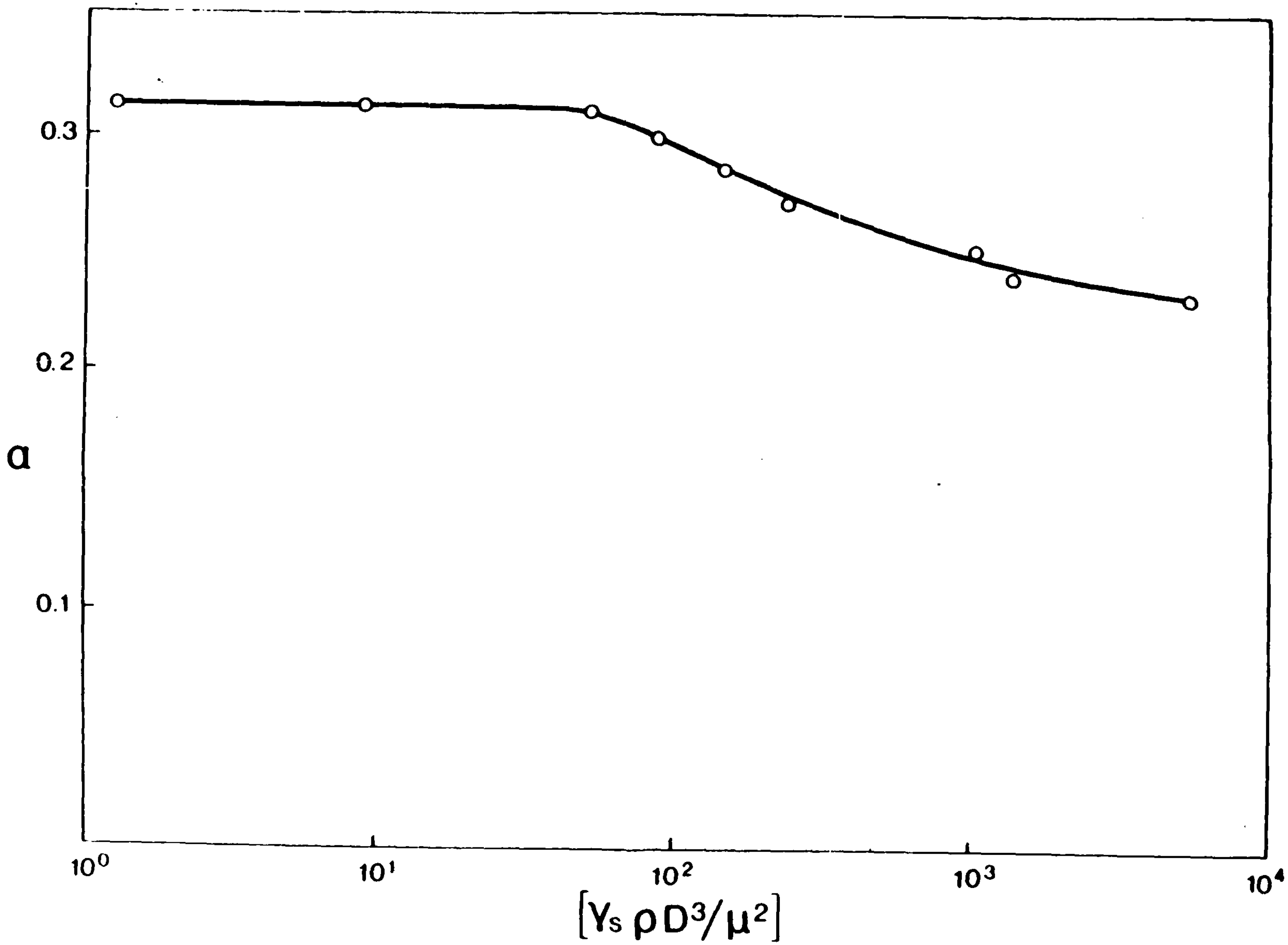

Figure 5. Graph representing α. (Taken From Krishnappan, 1975)

Stationary downpipe discharge

51. Results from the model tests are shown as deposition patterns in Plates 13 through 20. For the 50-foot downpipe runs a maximum cap thickness of 1.8 feet was generated within a radius of less than 100 feet from the center of the downpipe. For the 150-foot downpipe runs the maximum cap thickness was 2.0 feet. These results indicate that a 1-foot cap would generated after approximately 30 minutes. Suspended percentages after 60 minutes for each simulation are shown in Table 3. Suspended concentrations at 4 points in the water column for each simulation are shown in Tables 6A-6C. Bottom impact velocities of the disposed material as determined from a normal application of DIFID to a single small cloud are shown in Table 5.

Extension to Multiple Dumps

52. The dump model predicts the area of deposition for the disposal of one barge of dredged material. It does not simulate the effects of mounding or settlement, and cannot be used to predict the size and shape of the disposal area after a large amount of material has been deposited. An estimate of the final configuration of the disposal mound was made based on previous field measurements of mound slopes by the New England Division of the Corp of Engineers at other disposal sites. Since the proposed dredging plan extends over two dredging seasons, the sequence of dredging operations was taken into consideration. This sequence includes initial placement of a relatively small amount of contaminated material and immediate capping with uncontaminated material. After approximately 9 months, a much larger amount of contaminated material would be disposed at the same site and immediately capped with a large quantity of uncontaminated material.

53. Because the exact amounts to be dredged in each sequence were not known as this report was being prepared, an example scenario is presented in which representative quantities are used for each portion of the dredge/disposal sequence. Figure 6 shows the predicted disposal mound configuration. Basic assumptions are:

a. In situ initial dredging of contaminated material of 100,000 cubic yards, (density 1.25 = 15% solids).

b. In situ initial dredging of uncontaminated material of 500,000 cubic yards, (density 1.88 = 50% solids).

Table 3

Suspended Sediment Percentages After 1 Hour for Capping Runs

(Discharge, cy/min)	20	30	40	50
Capping Method				
Contained Surface	11.1	9.4	15.5	32.0
50' Downpipe	3.7	4.2	10.9	26.3
150' Downpipe	0.5	0.4	1.6	9.3

Table 4

Test Conditions for all Model Runs

Run #	Material Type	Water Content * Bulk Density	Dredging Method	% Clumps or Production Rate	Disposal Method	Current Speed (f.p.s.)	Water Depth ft	Results on Plate #
1	C	250/1.25	Clamshell	0%	Barge	0.1	265	1
2	C	"	"	0%	"	0.5	265	2
3	C	"	"	30%	"	0.1	265	3
4	C	"	"	30%	"	0.5	265	4
5	C	"	"	50%	"	0.5	265	5
6	C	"	"	70%	"	0.5	265	6
7	C	"	"	0%	"	stratified	265	7
8	C	"	"	0%	250'D.P.	0.1	265	8
9	C	"	"	0%	250'D.P.	0.5	265	8
10	U	50/1.88	Hydraulic	20 cy/min	S.C	0.1	265	9
11	U	"	"	30	S.C	0.1	265	10
12	U	"	"	40	S.C	0.1	265	11
13	U	"	"	50	S.C	0.1	265	12
14	U	"	"	20	50'D.P.	0.1	265	13
15	U	"	"	30	50'D.P.	0.1	265	14
16	U	"	"	40	50'D.P.	0.1	265	15
17	U	"	"	50	50'D.P.	0.1	265	16
18	U	"	"	20	150'D.P.	0.1	265	17
19	U	"	"	30	150'D.P.	0.1	265	18
20	U	"	"	40	150'D.P.	0.1	265	19
21	U	"	"	50	150'D.P.	0.1	265	20
22	C	250/1.25	Clamshell	0%	Barge	0.1	400	21

C = Contaminated Material 25% Wood Chips, 22% Sand, 53% Clay/Silt.
U = Uncontaminated Material 30% Sand, 70% Clay/Silt
* = In Situ Percent Water Content and Bulk Density
SC = Surface Contained Hydraulic Discharge
DP = Downpipe Discharge

Table 5

Bottom Impact Velocities (in fps) for Capping Material

(Discharge, cy/min)	20	30	40	50
Capping Method				
Contained Surface	0.46	0.47	0.41	0.24
50' Downpipe	0.63	0.64	0.57	0.32
150' Downpipe	1.09	1.09	0.94	0.54

Table 6A

Suspended Concentrations (mg/ℓ) for Contained Surface Discharge

Discharge Rate (cy/min)	(Depth, feet)	15	95	175	255
20		-	-	-	31.8
30		-	-	-	42.4
4C		-	-	-	39.8
50		-	-	-	31.8

Table 6B

Suspended Concentrations (mg/ℓ) for 50-foot Downpipe

Discharge Rate (cy/min)	(Depth, feet)	15	95	175	255
20		-	15.4	63.6	18.6
30		0.3	23.3	92.8	26.5
40		2.7	95.4	265.0	79.5
50		6.6	103.4	214.7	63.6

Table 6C

Suspended Concentrations (mg/ℓ) for 150-foot Downpipe

Discharge Rate (cy/min)	(Depth, feet)	15	95	175	255
20		-	-	0.7	-
30		-	-	0.5	3.7
40		-	1.6	4.5	1.3
50		0.6	7.2	12.2	3.7

c. In situ final dredging of contaminated material of 800,000 cubic yards.

d. In situ final dredging of uncontaminated material of 1,500,000 cubic yards.

e. Average bottom slope = 1:50 to the south.

f. Mound assumes a truncated cone shape with maximum side slopes of 1V on 100H relative to bottom, (i.e. 1:30 on downslope side).

g. Initial voids ratio of 4.5 for both contaminated and uncontaminated material after placement in the disposal mound.

h. Clamshelled contaminated material with surface dump from barges.

i. Hydraulically dredged capping material with uniform surface disposal using scatter plate.

j. Invariant disposal location for contaminated material disposal (point dumping using taught-line buoy).

k. Top of truncated cone will be approximately equal in radius to the area of deposition of the contaminated material.

l. Ultimate consolidation of 50 percent for both contaminated and uncontaminated material in mound after disposal.

Calculations for long-term mounding are as follows:

For initial disposal - 100,000 cy contaminated material with bulk density 1.25 (15% solids).

$$\text{vol of solids} = (15\%)\ (100{,}000\ \text{cy}) = 15{,}000\ \text{cy} = 4 \times 10^5\ \text{ft}^3$$

$$V_b = \text{vol occupied on bottom} = (1 + \text{voids ratio})\ (\text{vol of solids})$$
$$= (1 + 4.5)\ (4 \times 10^5\ \text{ft}^3) = 2.3 \times 10^6\ \text{ft}^3$$

$$V_m = \text{mound vol} = \text{vol of truncated cone} = \frac{\pi R^2 H}{3} - \frac{\pi r^2 h}{3} = V_b$$

$r = 500'$ (radius of mound top from model runs)

$h = \frac{1}{100} r = 5'$ (top portion of cone that is missing)

H = height of cone without truncation

R = radius of cone base = $100H$

$$V_m = \frac{\pi R^2 H}{3} - \frac{\pi\ (500\ \text{ft})^2\ (5\ \text{ft})}{3} = 2.3 \times 10^6\ \text{ft}^3$$

$$= \frac{\pi}{3} (100H)^2 H - 1.3 \times {}^6 ft^3 = 2.3 \times 10^6 ft^3$$

$$H^3 = 344 ft^3$$

$$H = 7.0'$$

$$R = 100 H = 700'$$

$$H_{mound} = H - h = 2.0'$$, therefore mound is 2.0 ft high.

For initial cap - 500,000 cy uncontaminated material bulk density 1.88 (50% solids)

vol of solids = (50%) (500,000 cy) = 250,000 cy = 6.75×10^6 ft^3

V_b = Vol occupied on bottom = (1 + voids ratio) (vol of solids)

$= (1 + 4.5) (6.75 \times 10^6) = 3.7 \times 10^7$ ft^3

plus previously placed material = 4.06×10^7 ft^3

using previous procedure, $H^3 = 4.00 \times 10^3$ ft^3

H = 16.0 ft, R = 1600'

Truncated cone height = H - 5'

16' - 5'

= 11'

For 9 mos settlement, assume based on field experience 50%± consolidation. Cap thickness after 9 mos. = (0.50) (11') = 5.5' ≈6' with a volume of 2.3×10^7 ft^3

Mound height calculations for the final disposal of 800,000 cy contaminated material (bulk density 1.25, 15% solids), and cy of uncontaminated capping material (bulk density 1,88, 50% solids) are carried out in a similar manner. Results of these calculations, adjusted for 1:50 bottom slope, are shown on fig 6.

54. Assuming 50% of consolidation for newly-disposed material, new mound thickness is now approximately 12 feet, with a cap thickness of approximately 4 feet.

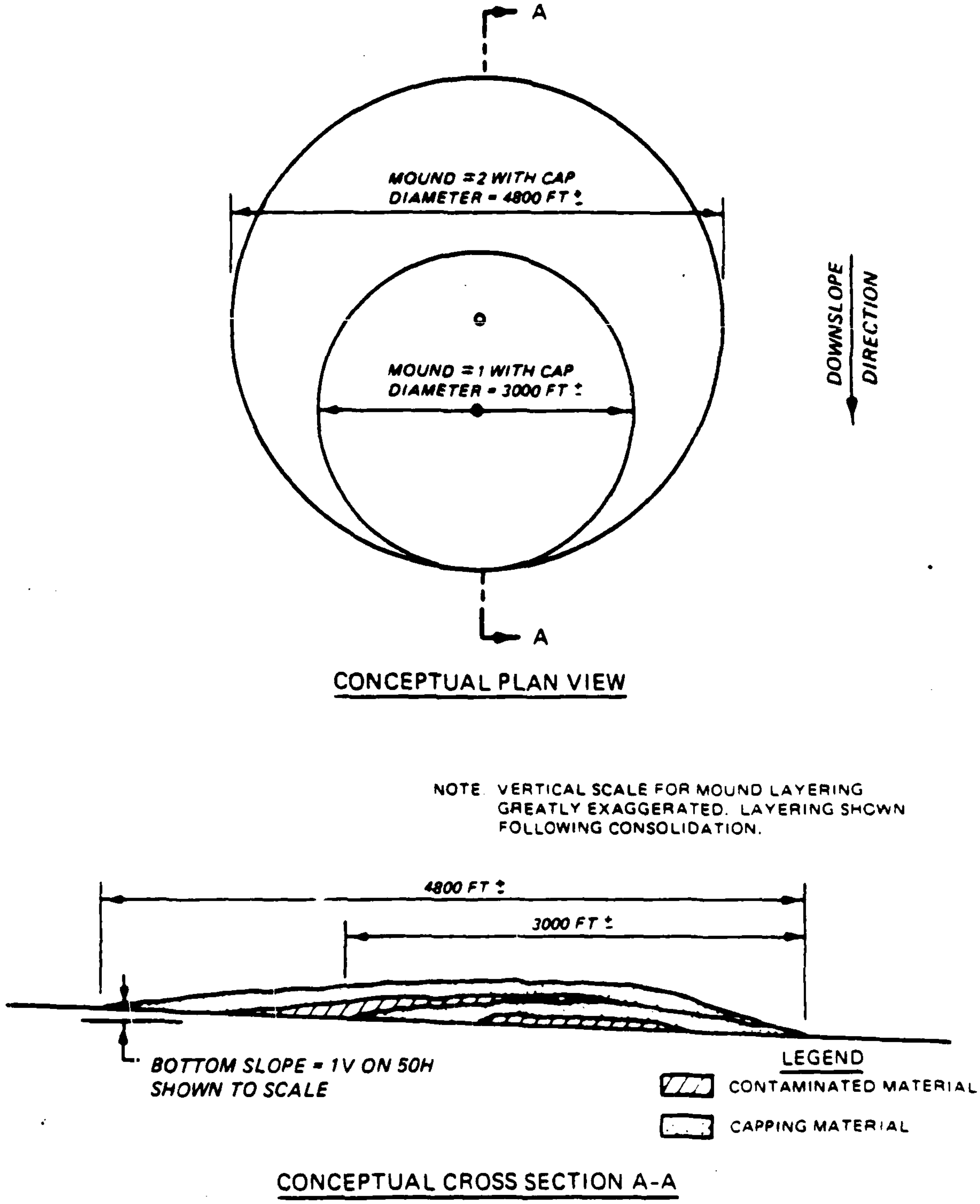

Figure 6. Final disposal mound configuration.

Conclusions

General conclusions from the modeling are:

a. More than ninety-eight percent of the disposed contaminated material will deposit within one hour for all conditions tested. The disposed contaminated material will deposit within an area of 800 by 1000 feet with a maximum thickness of approximately 0.60 feet for a single 4000 cubic yard barge of material. If a 250 ft long by 10 ft. diameter downpipe is used, the area of deposition is approximately 50 feet in radius with a maximum thickness of approximately 3.5 feet.

b. More than ninety percent (at a discharge rate of 30 cubic yards per minute) of the disposed capping material from each sweep of the confined surface discharge will deposit within an hour. The swath of deposition with be less than 300 feet wide with a maximum thickness of approximately 0.09 feet. Bottom impact velocities will be less than 0.5 feet per second.

c. More than ninety-five percent (at a discharge rate of 30 cubic yards per minute) of the disposed capping material from the 50 and 150 foot stationary downpipe capping operations will deposit within an hour. The area of deposition will have a radius of less than 100 feet with a maximum thickness of approximately 2.0 feet. Bottom impact velocities will be less than 1.1 feet per second.

d. Long-term disposal of 600,000 cubic yards of material (100,000 contaminated and 500,000 capping) in the first dredging season and 2,300,000 cubic yards (800,000 contaminated and 1,500,000 capping) in the second dredging season will generate a disposal mound with a final radius of approximately 3500 feet long and 2400 feet wide, with a side slope of approximately 1V on 30 H and a cap thickness of approximately 4 feet.

Limitations of the numerical model DIFID and the various assumptions that have been made in modeling the various disposal operations have been discussed. These should be taken into proper account when the works and practices that may depend upon the results of this study are planned.

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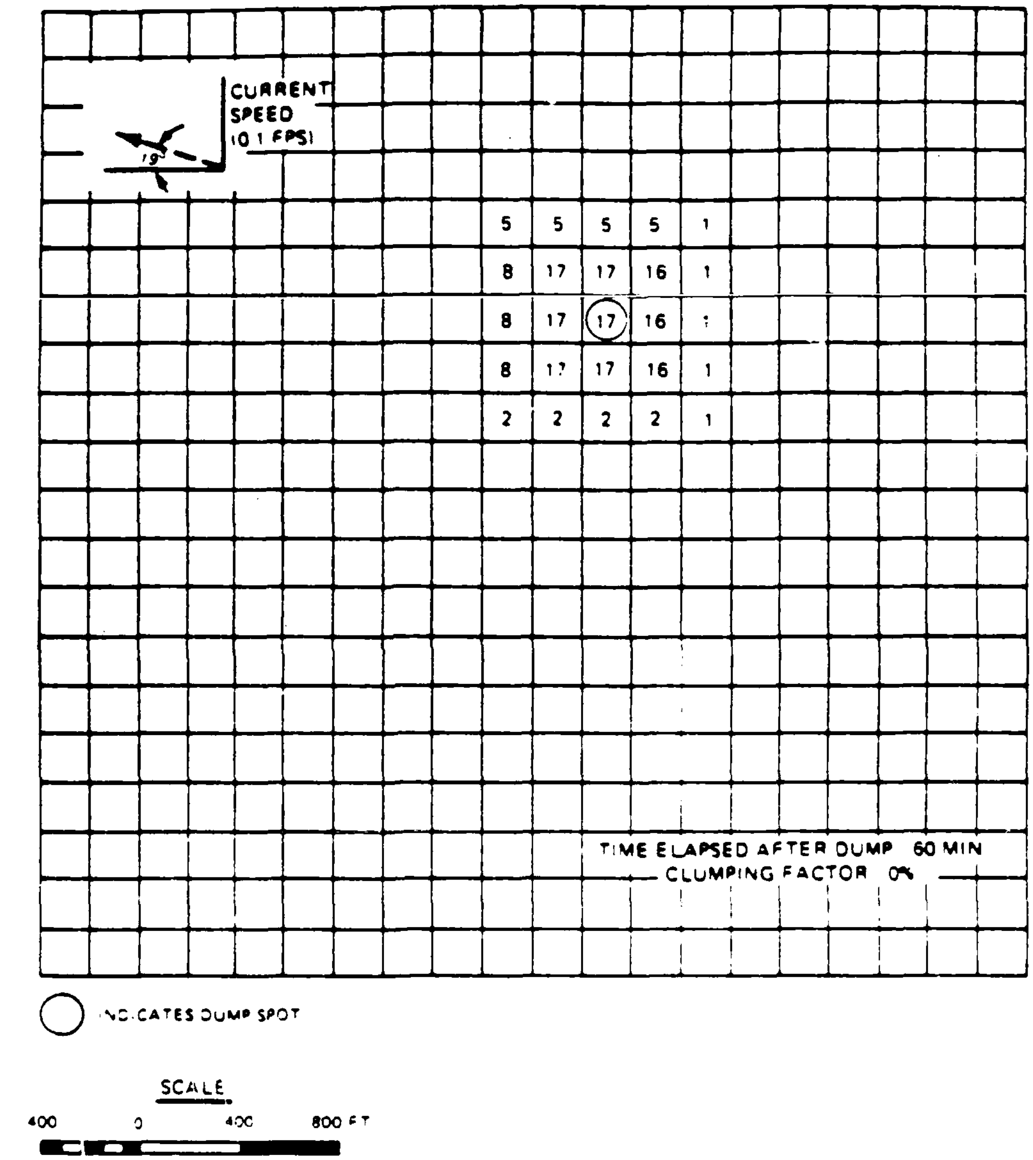
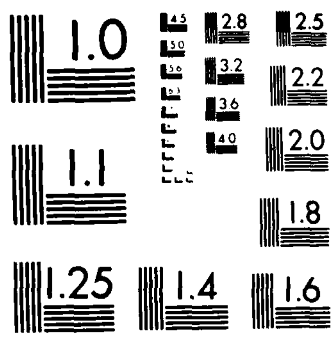


DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

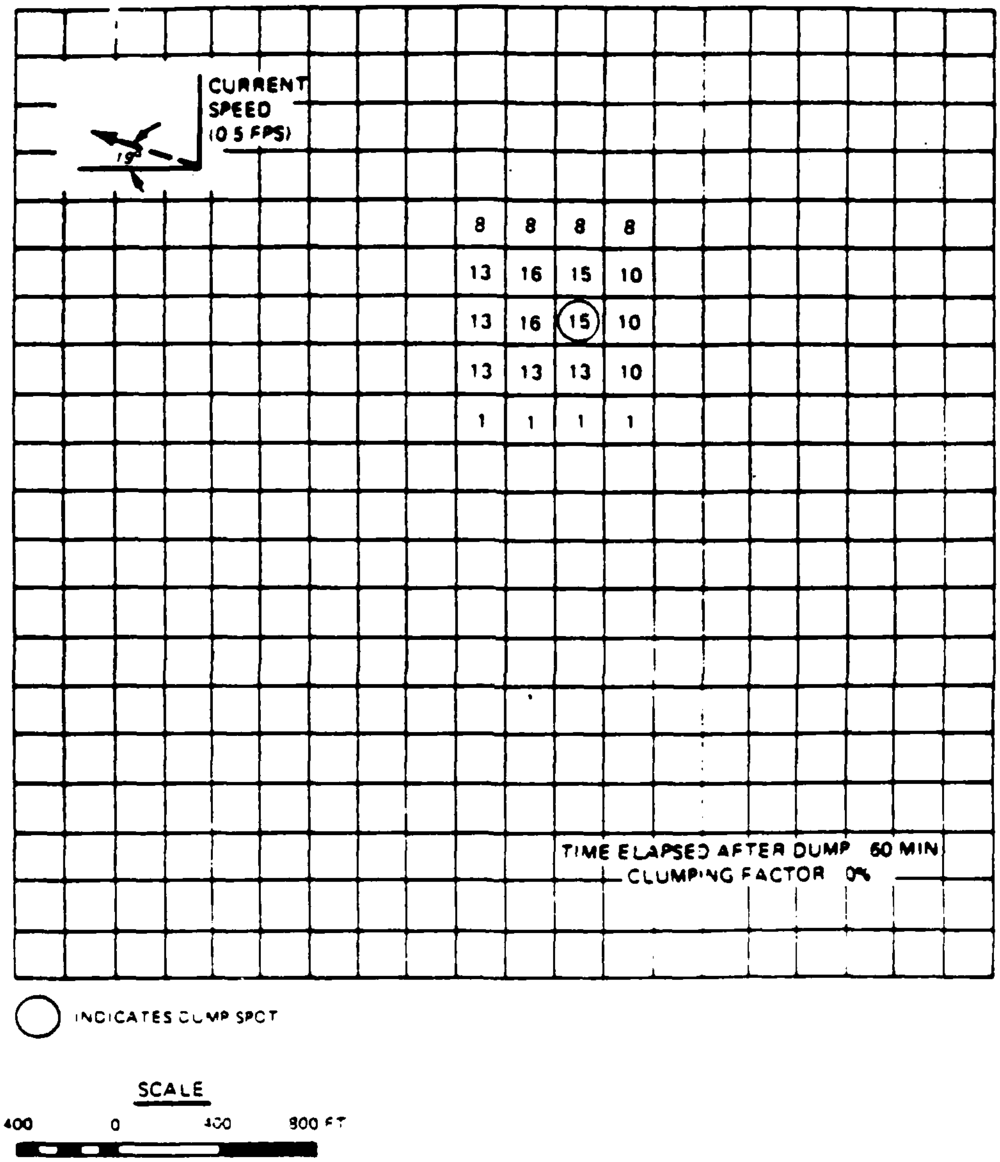
PLATE 1

AD-A175 114 CARRIER BATTLE GROUP (CVBG) HOMEPORTING IN THE PUGET SOUND AREA WASHINGTON STATE TECHNICAL APPENDICES(U) CORPS OF ENGINEERS SEATTLE WA SEATTLE DISTRICT NOV 86 4/7

UNCLASSIFIED F/G 6/6 NL

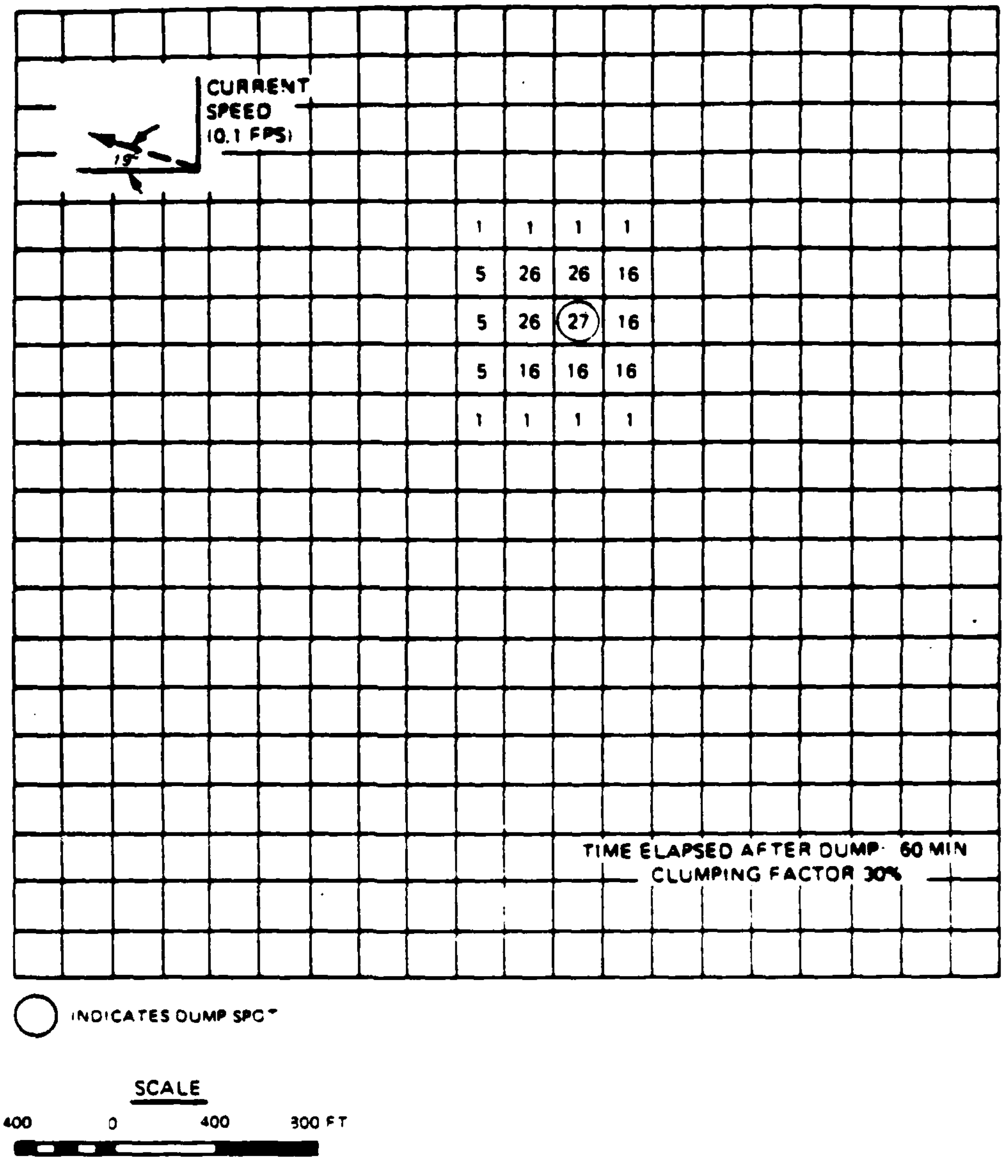


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

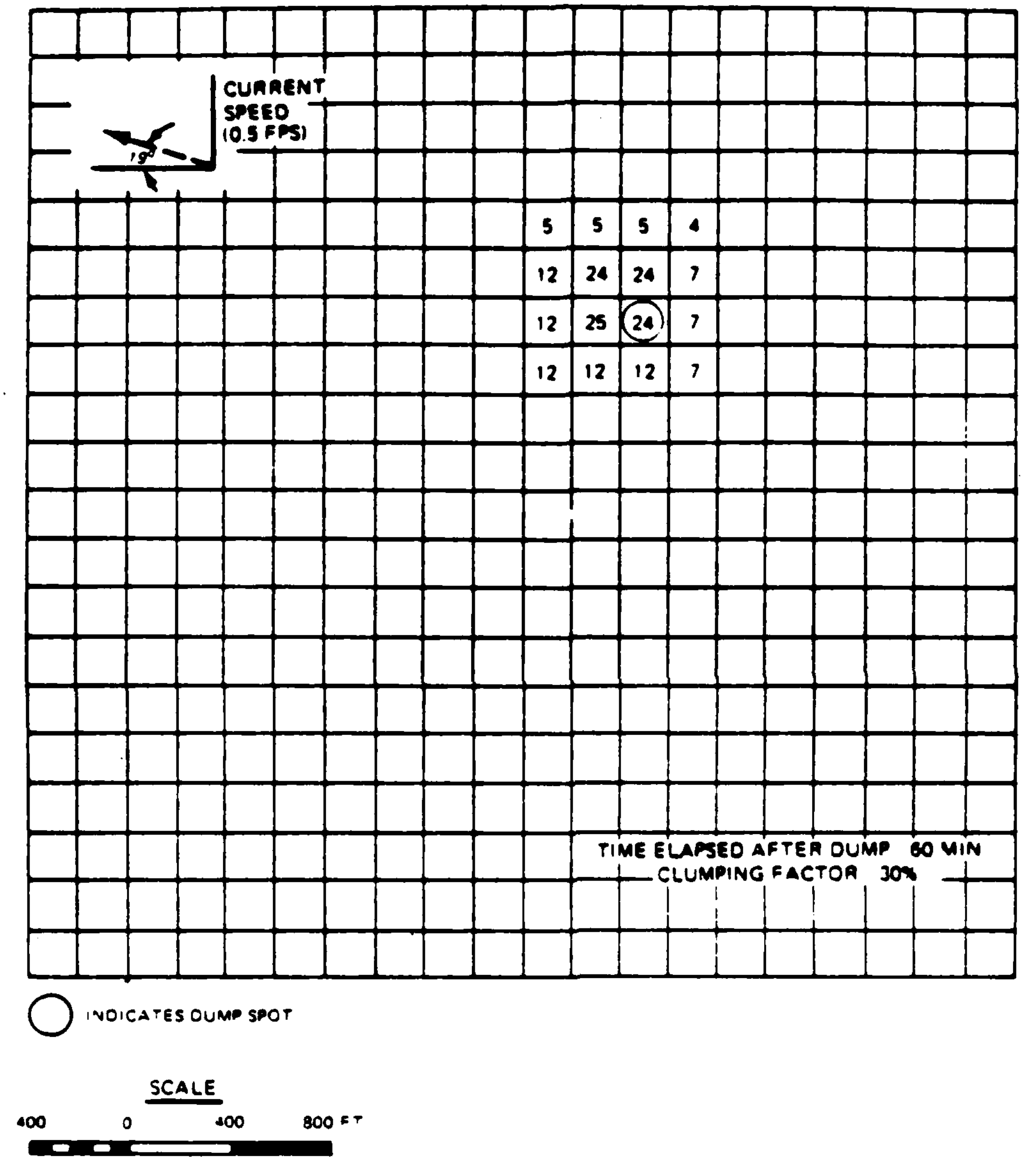


DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

PLATE 2

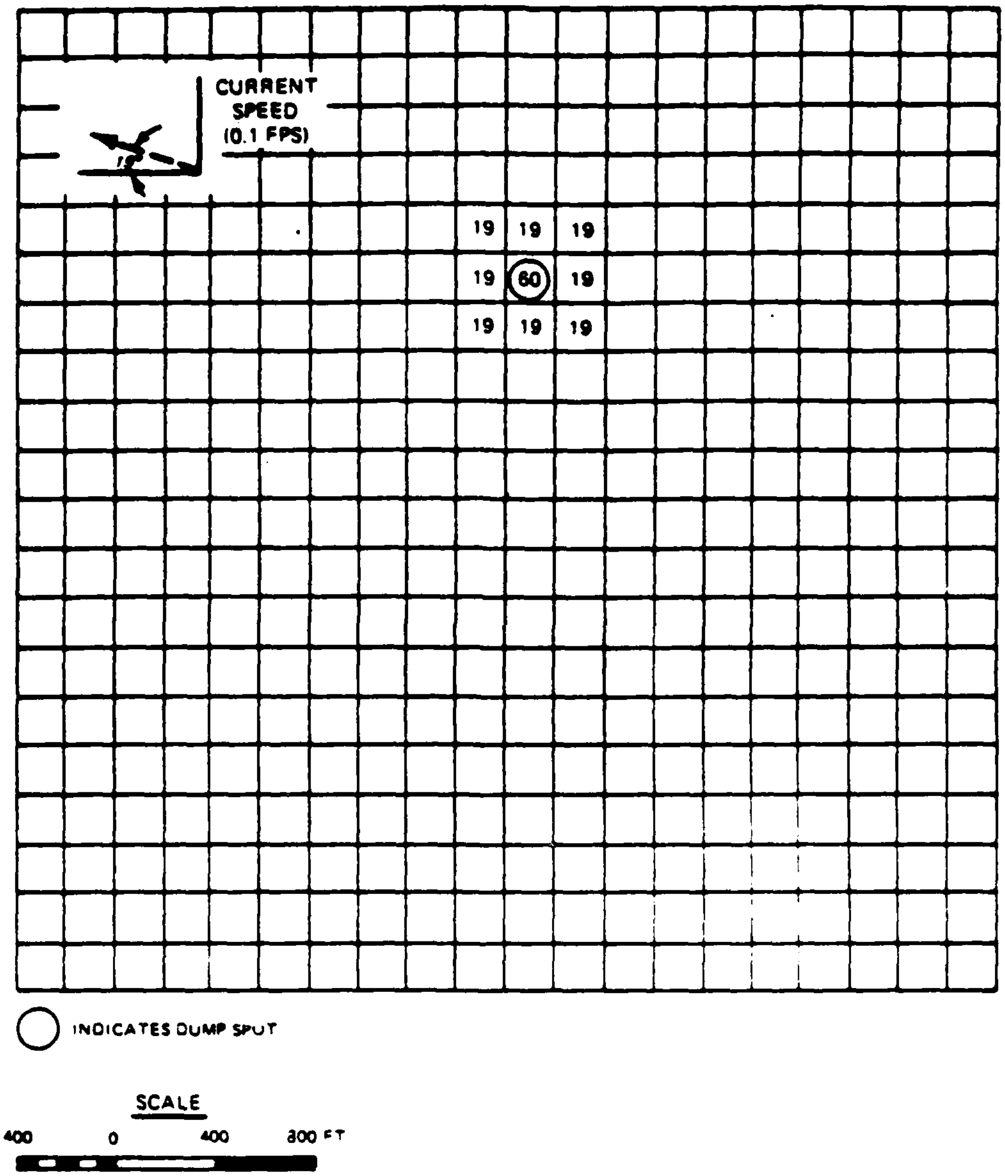


DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)



DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

PLATE 4



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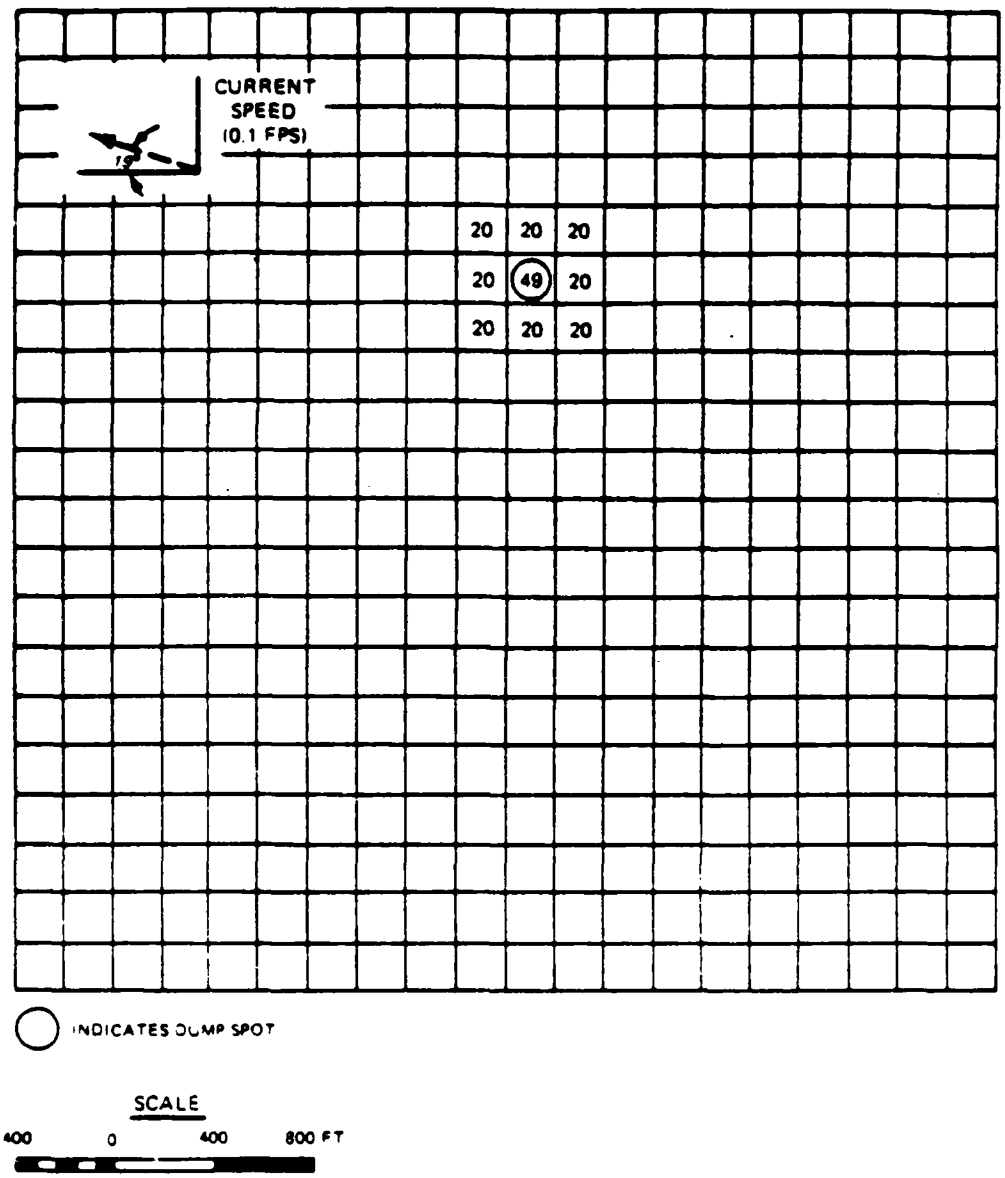

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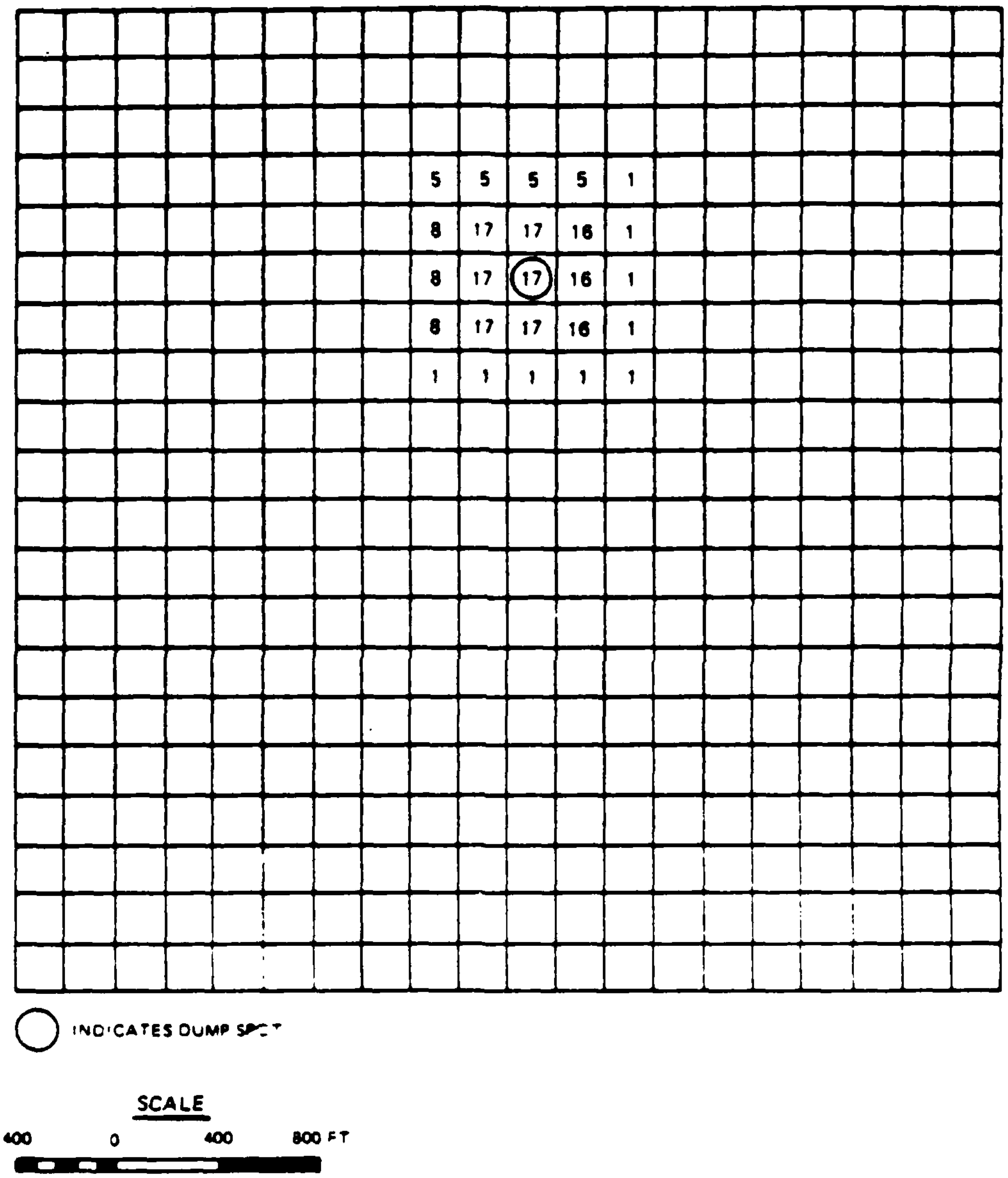

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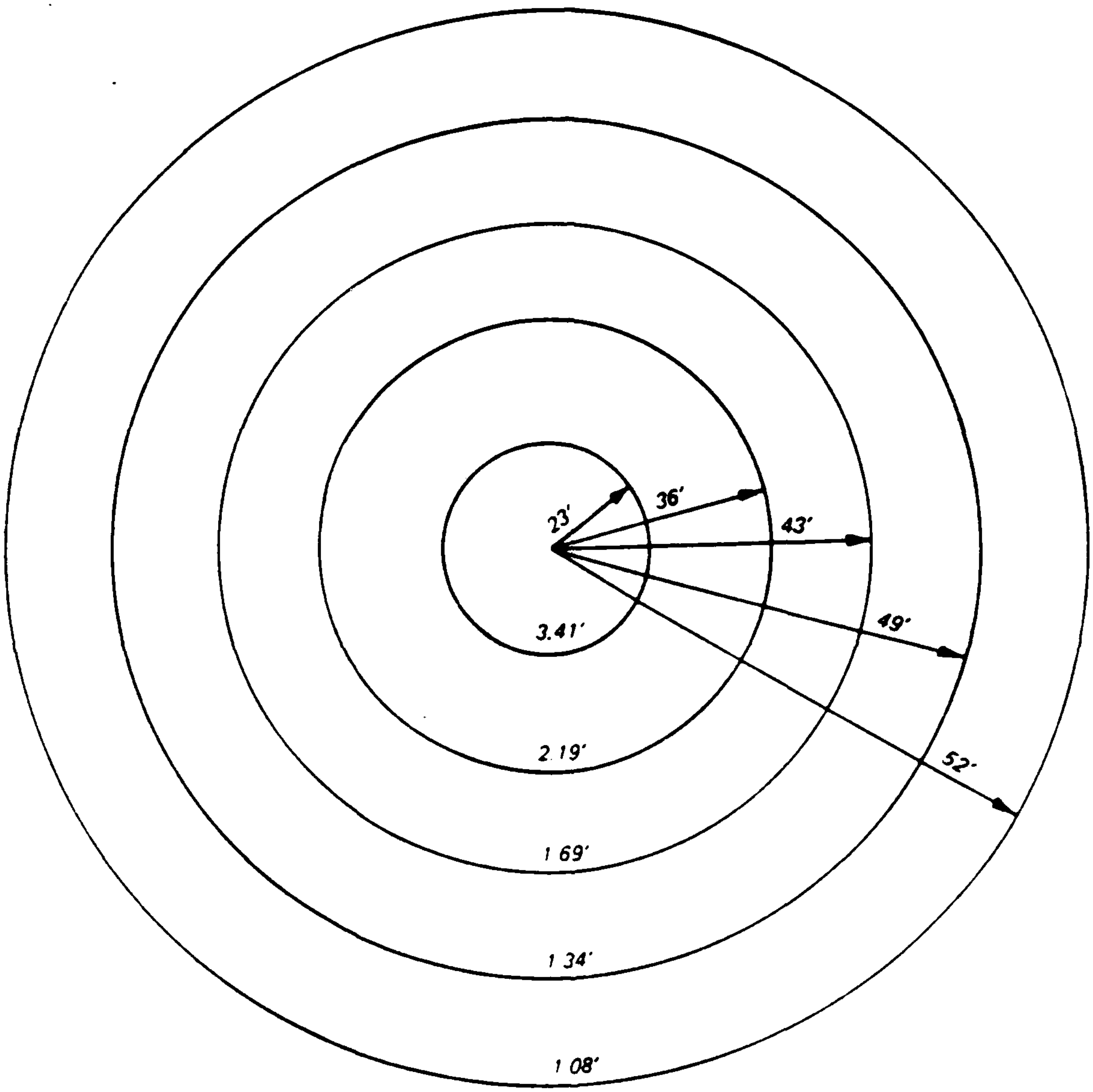
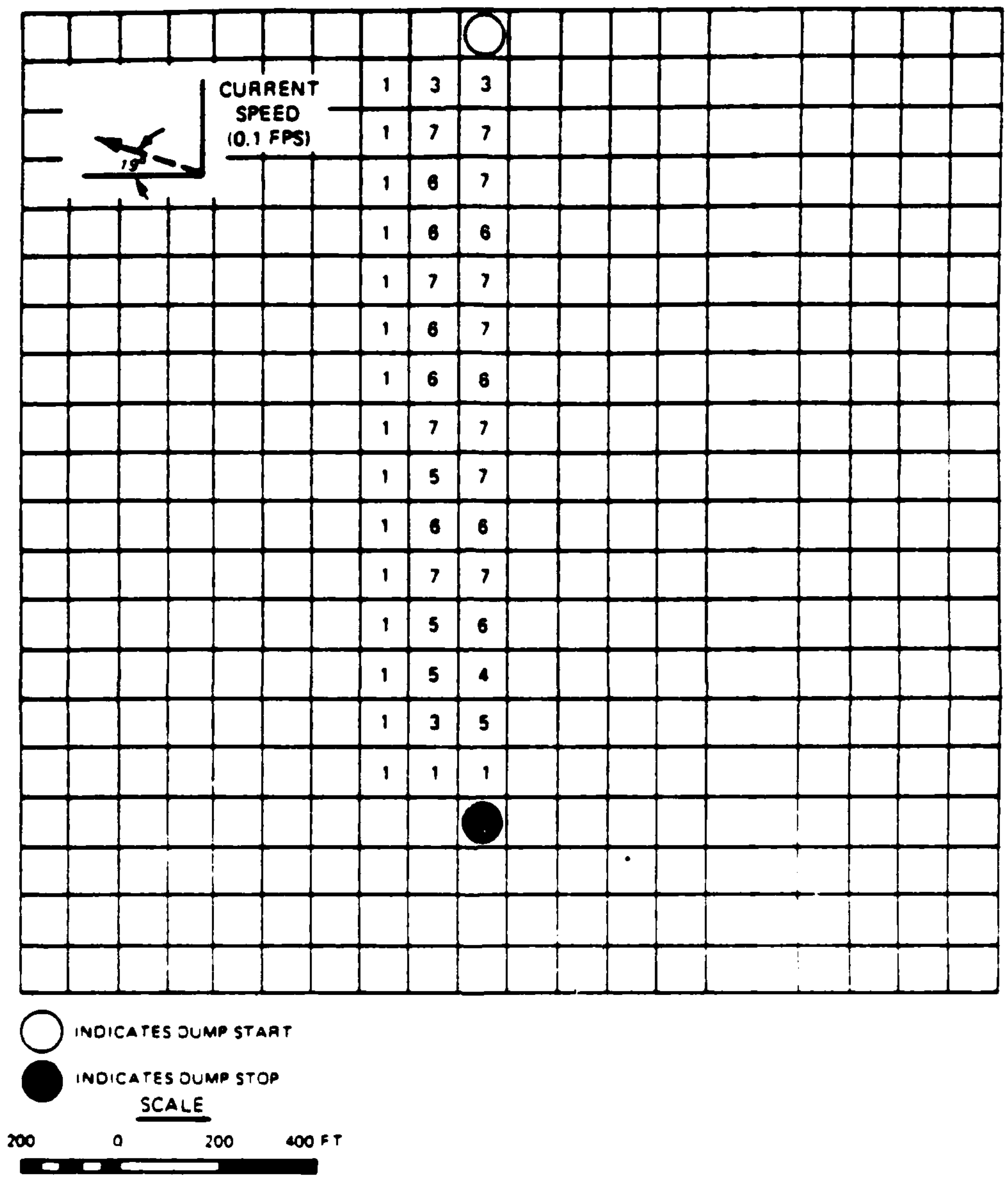
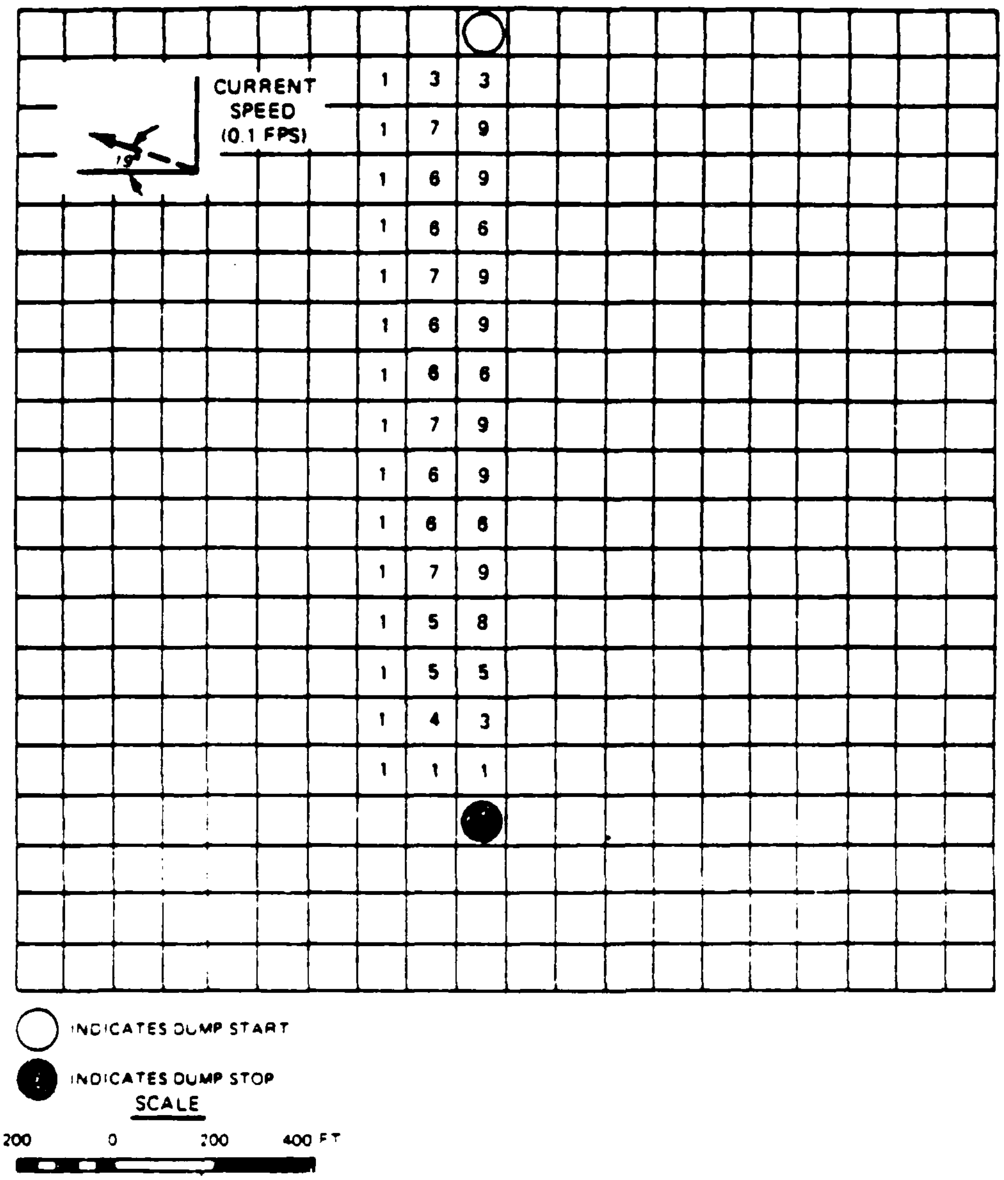


PLATE 8

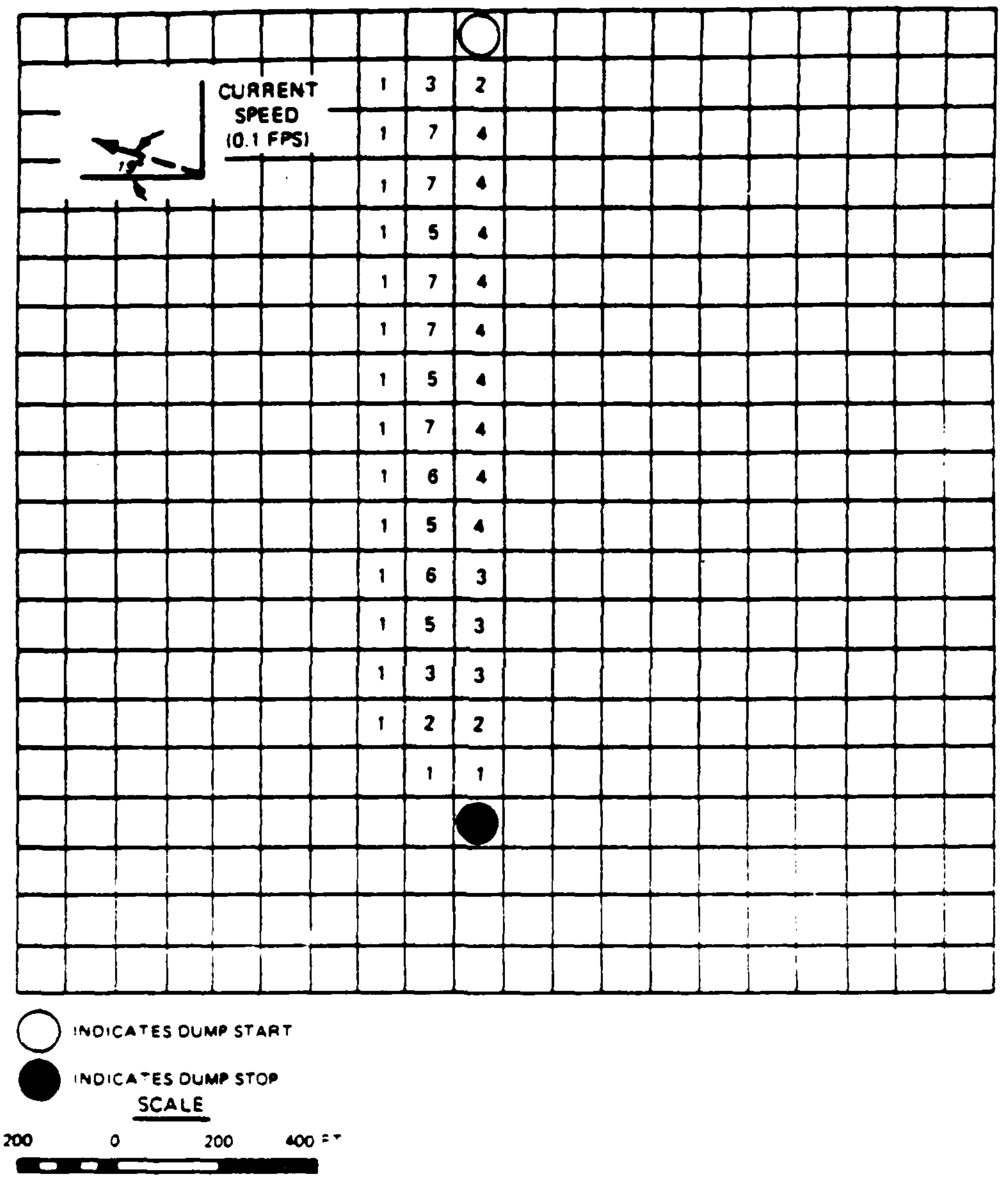


DEPCSITION PATTERN
(IN HUNDREDTHS OF A FOOT)



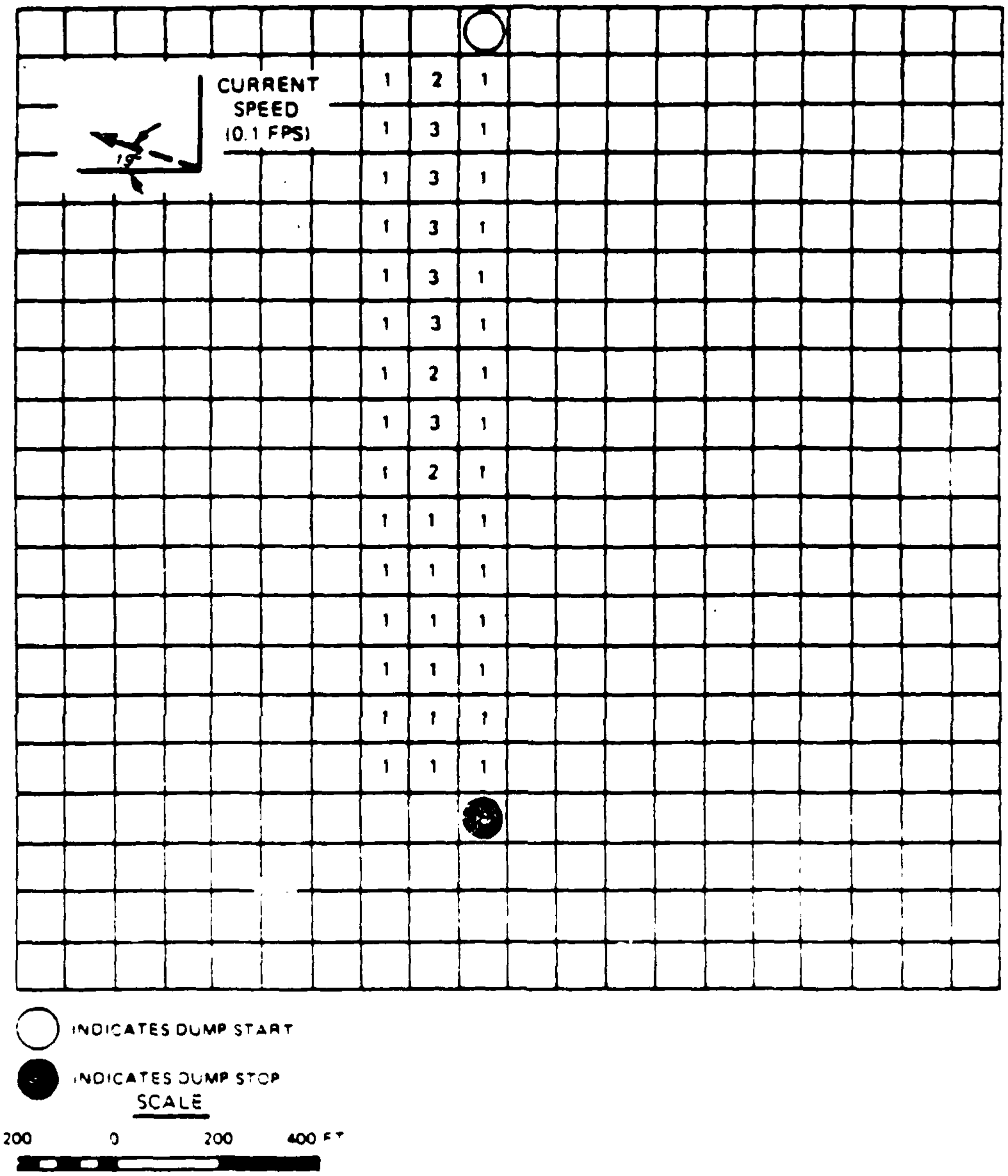
DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

PLATE 10



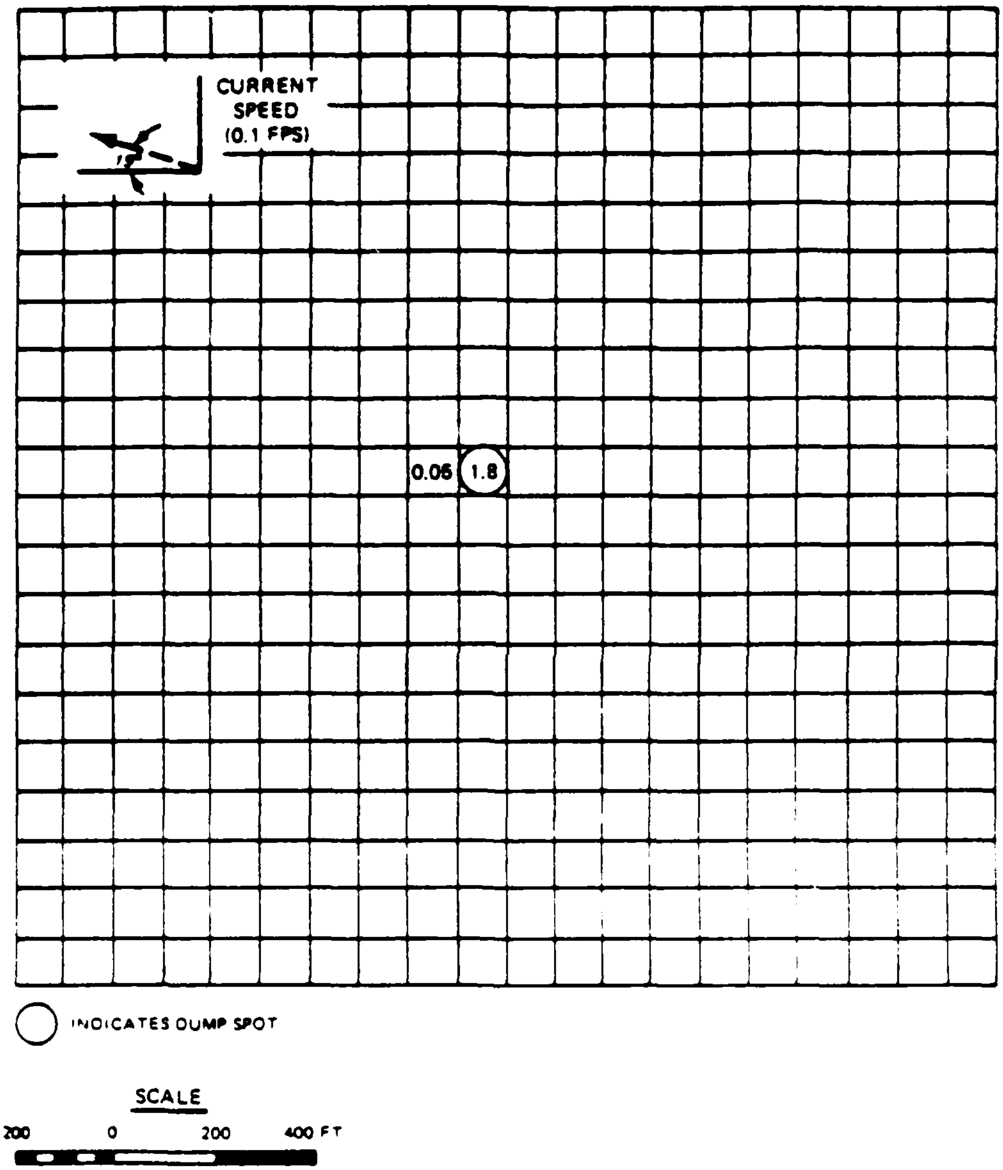
DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

PLATE 11



DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

PLATE 12



DEPOSITION PATTERN
(IN FEET)

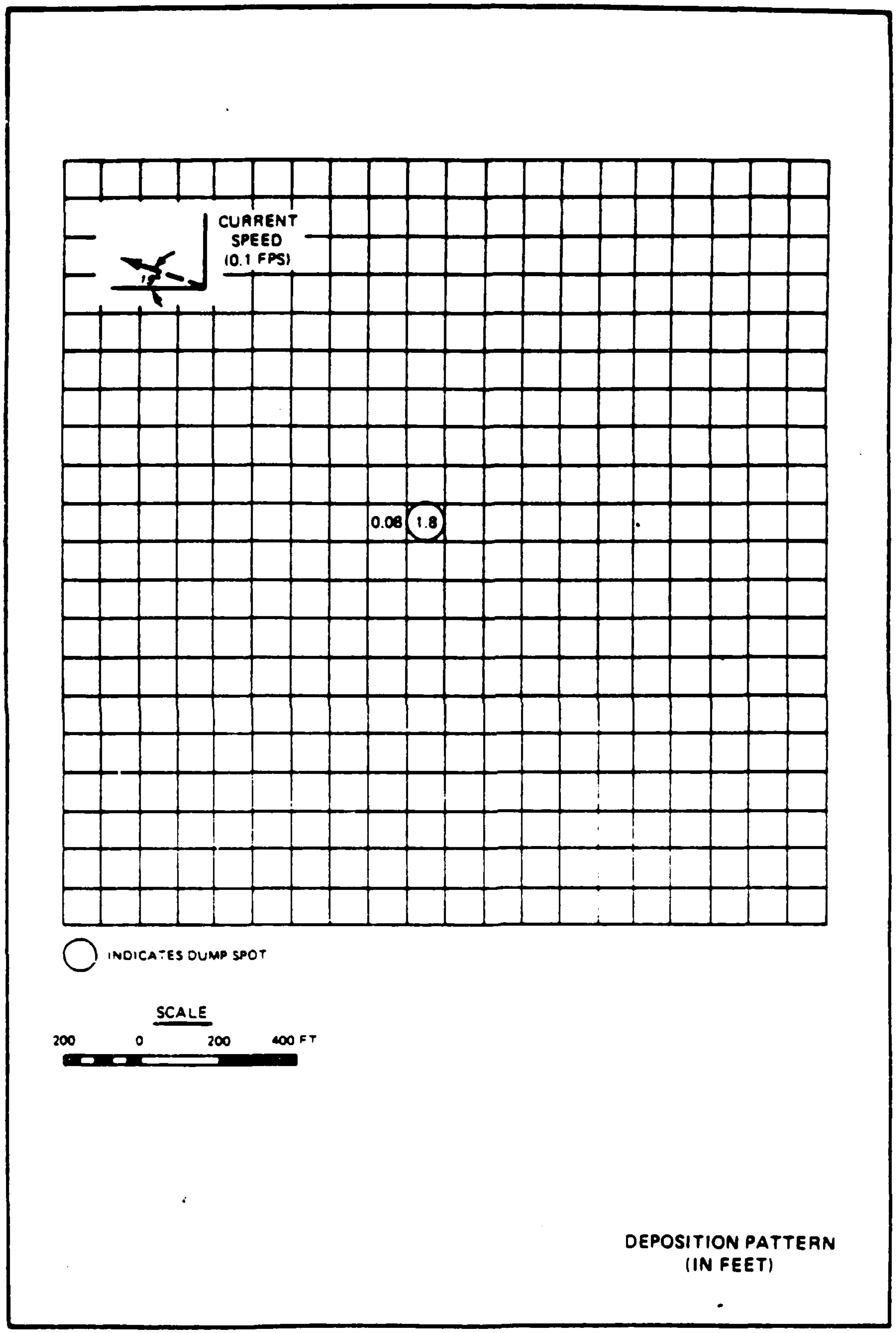
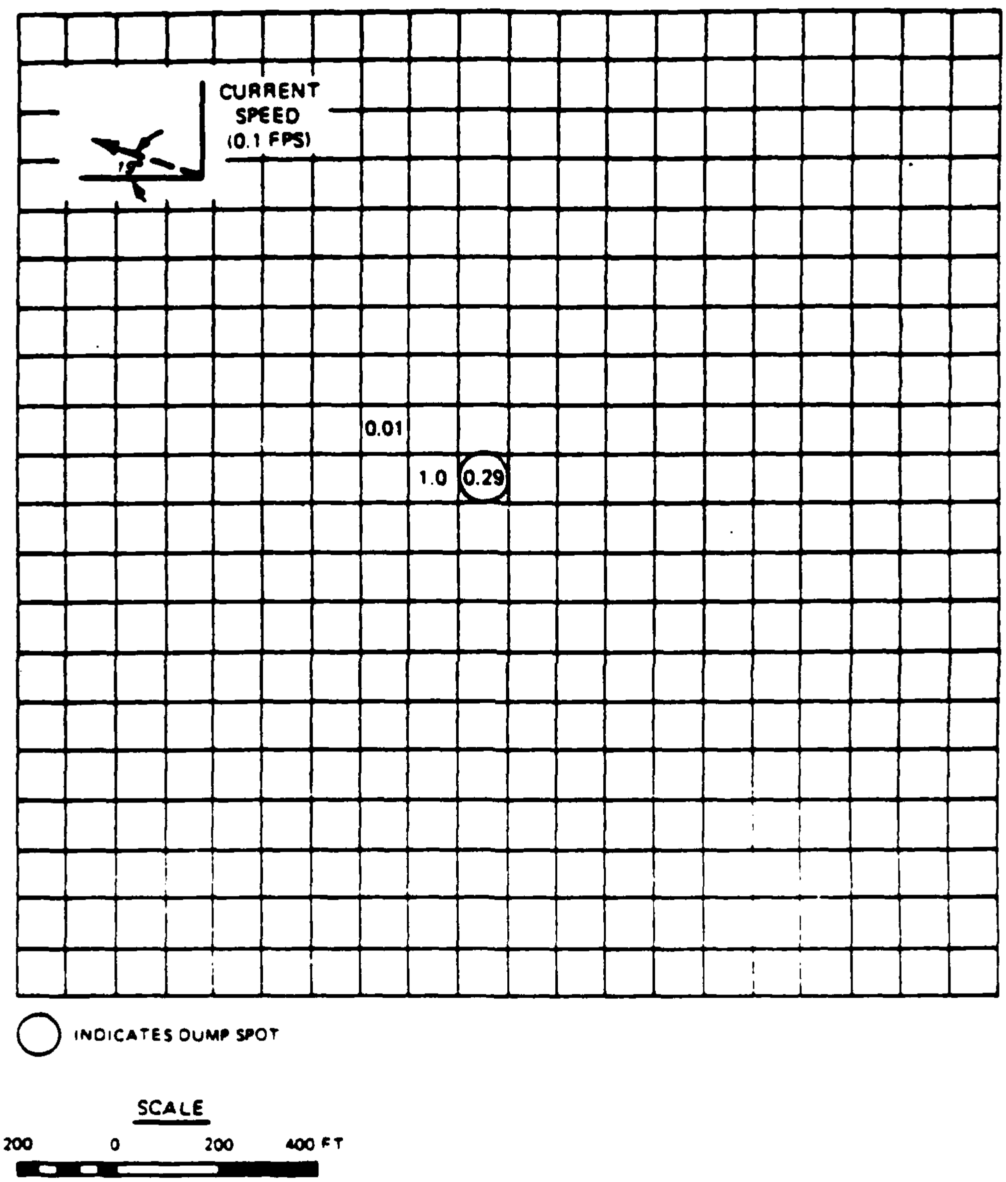
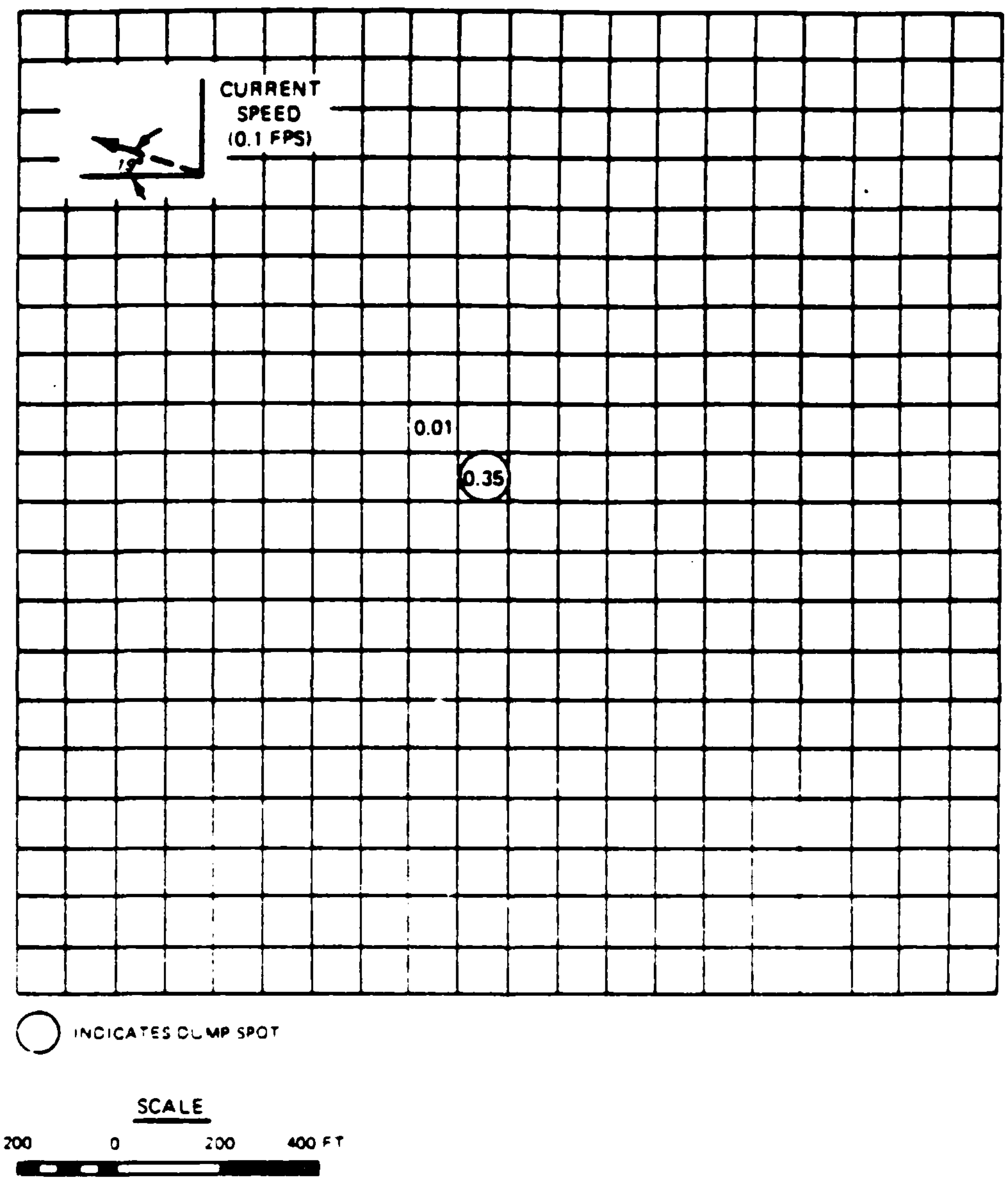

CURRENT
SPEED
(0.1 FPS)
0.08
1.8
INDICATES DUMP SPOT
SCALE
200
0
200
400 FT
DEPOSITION PATTERN
(IN FEET)

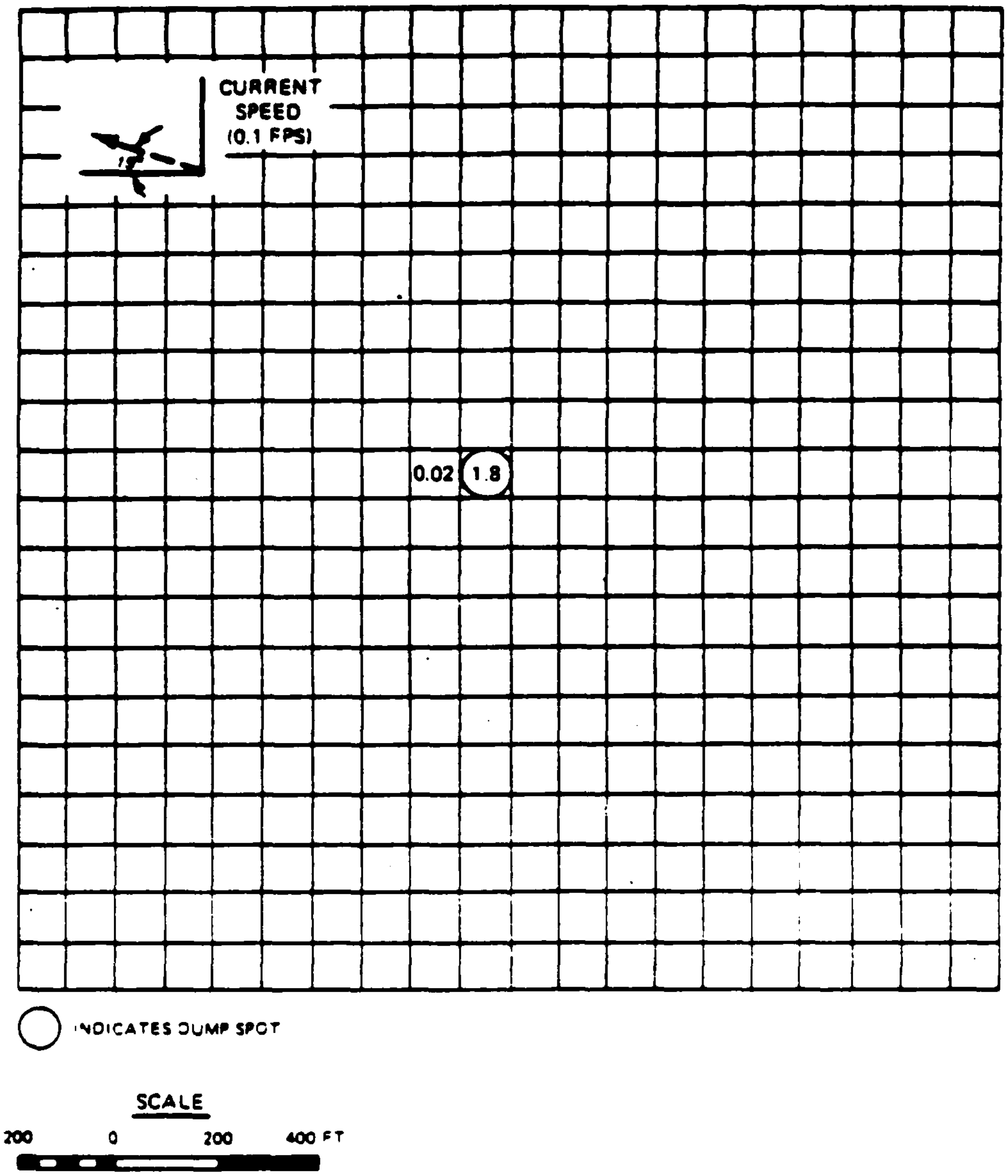
PLATE 14



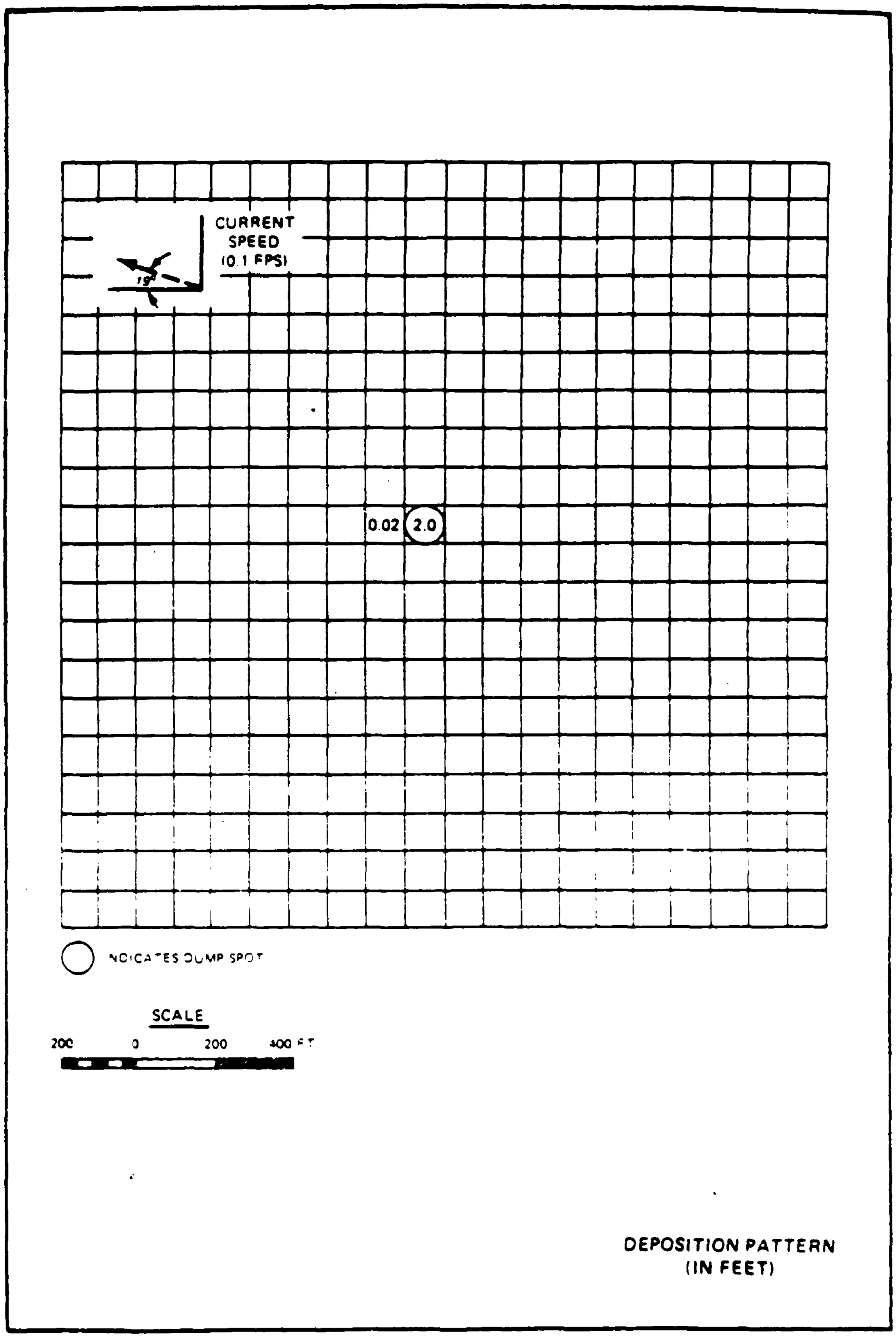
DEPOSITION PATTERN
(IN FEET)



DEPOSITION PATTERN
(IN FEET)

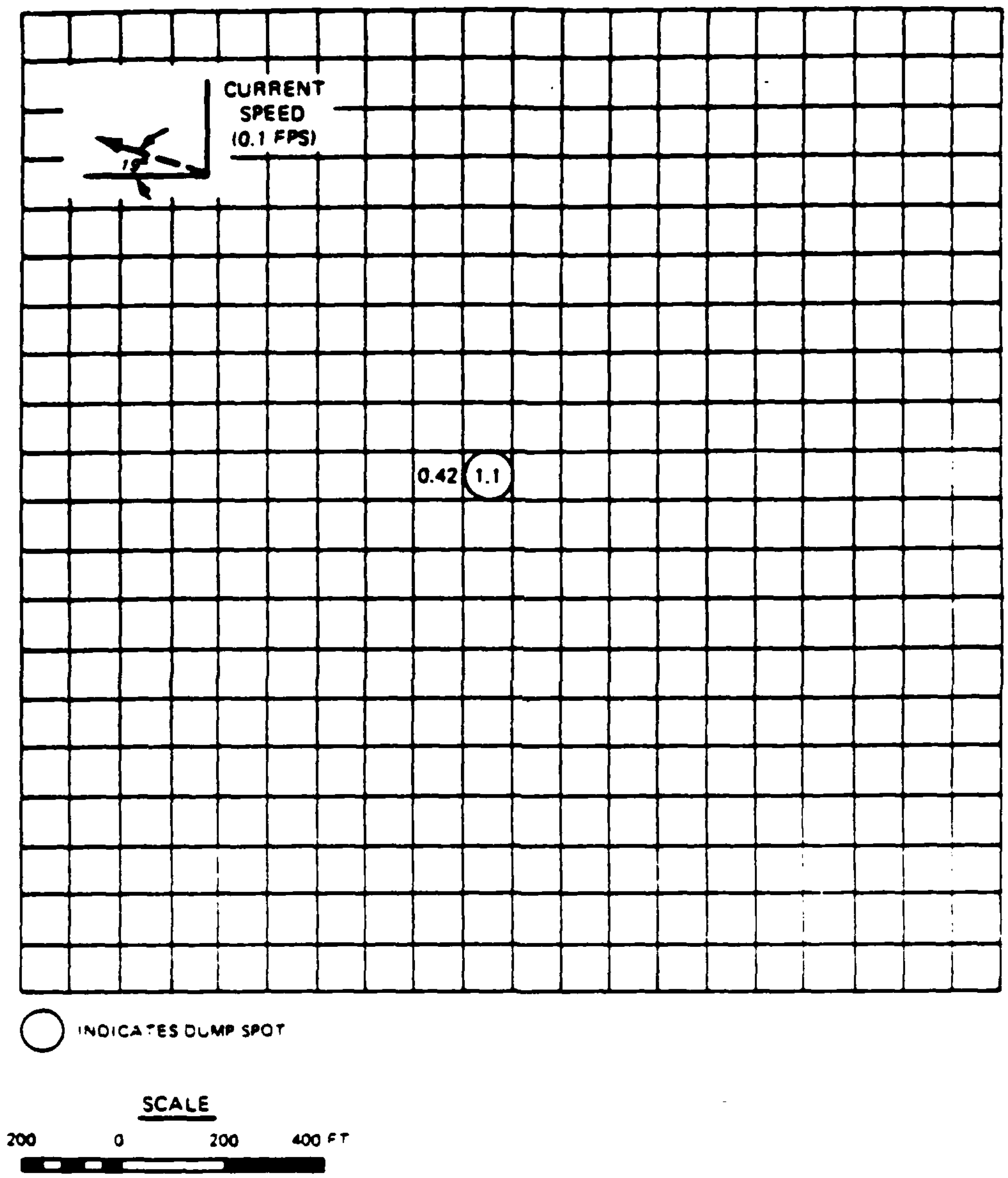


DEPOSITION PATTERN
(IN FEET)

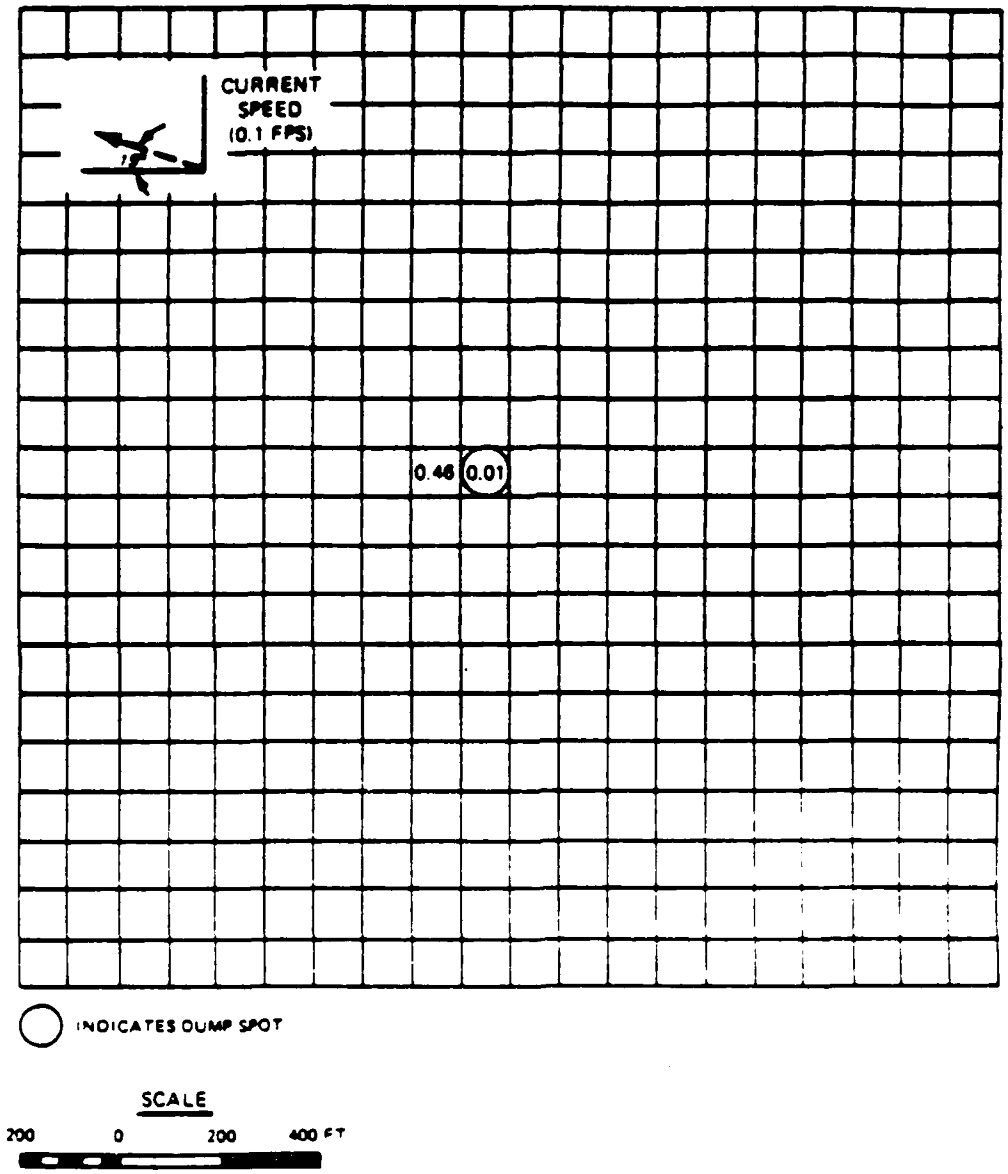


CURRENT
SPEED
(0.1 FPS)
19°
0.02
2.0
INDICATES DUMP SPOT
SCALE
200
0
200
400 FT
DEPOSITION PATTERN
(IN FEET)

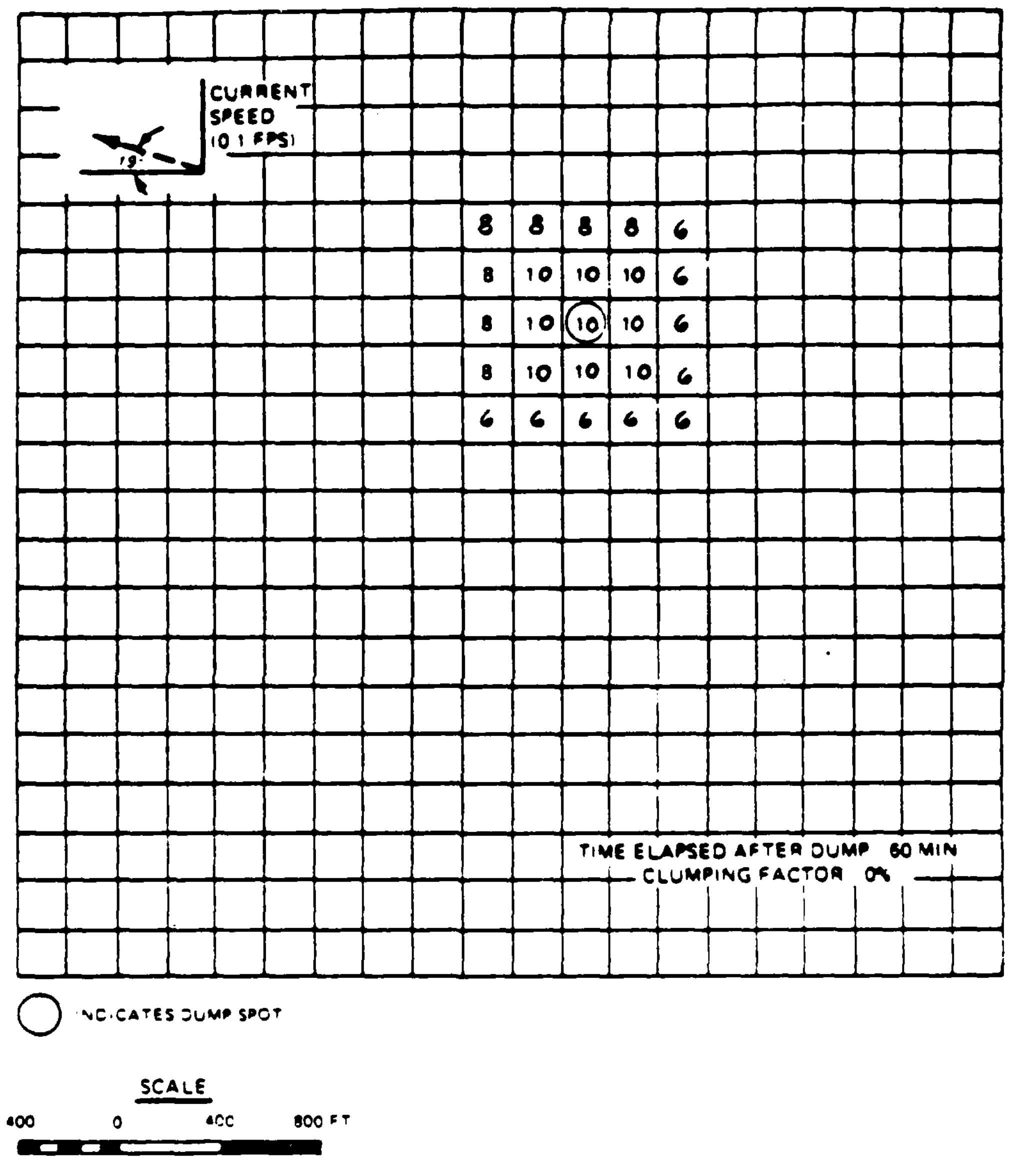
PLATE 18



DEPOSITION PATTERN
(IN FEET)



DEPOSITION PATTERN
(IN FEET)



DEPOSITION PATTERN
(IN HUNDREDTHS OF A FOOT)

APPENDIX C

U.S. NAVY HOMEPORT DISPOSAL SITE INVESTIGATIONS

SUMMER CRUISE REPORT

by

Paul Dinnel, David Armstrong, Bruce Miller and Robert Donnelly
School of Fisheries and Fisheries Research Institute
University of Washington, Seattle

29 August 1986

for

U. S. ARMY
Seattle, Washington

Introduction

The East Waterway within the Port Gardner region of Puget Sound has tentatively been selected as a new homeport by the U.S. Navy. Construction of the facility will require dredging of the East Waterway and the possible disposal of dredged materials at a deep-water site in Port Gardner.

The U.S. Navy in conjunction with the U.S. Army Corps of Engineers (COE) has provided funds to the University of Washington School of Fisheries to conduct trawling studies of the proposed disposal site with special emphasis on Dungeness crabs, *Cancer magister*, commercial shrimp and bottomfish resources.

This report summarizes the preliminary findings of the third set of trawl cruises conducted in Port Gardner during June, 1986 and compares these data to that collected during the February and April, 1986 cruises.

Methods

The methods, trawl gear and sample stations were described in detail in the winter and spring cruise reports (Dinnel et al. 1986a, b) and remain the same except for the following two additions: 1) four additional beam trawl stations (A, B, C, D; Figure 1) were added just west of the proposed Navy Disposal Site to increase the sampling coverage in this region; and 2) three trawls were made along the 60 m contour north of Port Gardner and offshore of the Snohomish River delta, Mission Beach and just north of Tulalip Bay (see Fig. 6 in the Results section for station locations) to help define the northward range of the female Dungeness crab concentrations observed in Port Gardner.

Briefly, crab and shrimp were sampled at 59 stations in Port Gardner with a 3-m beam trawl (Figure 2, top). A subset of 18 of the beam trawl stations

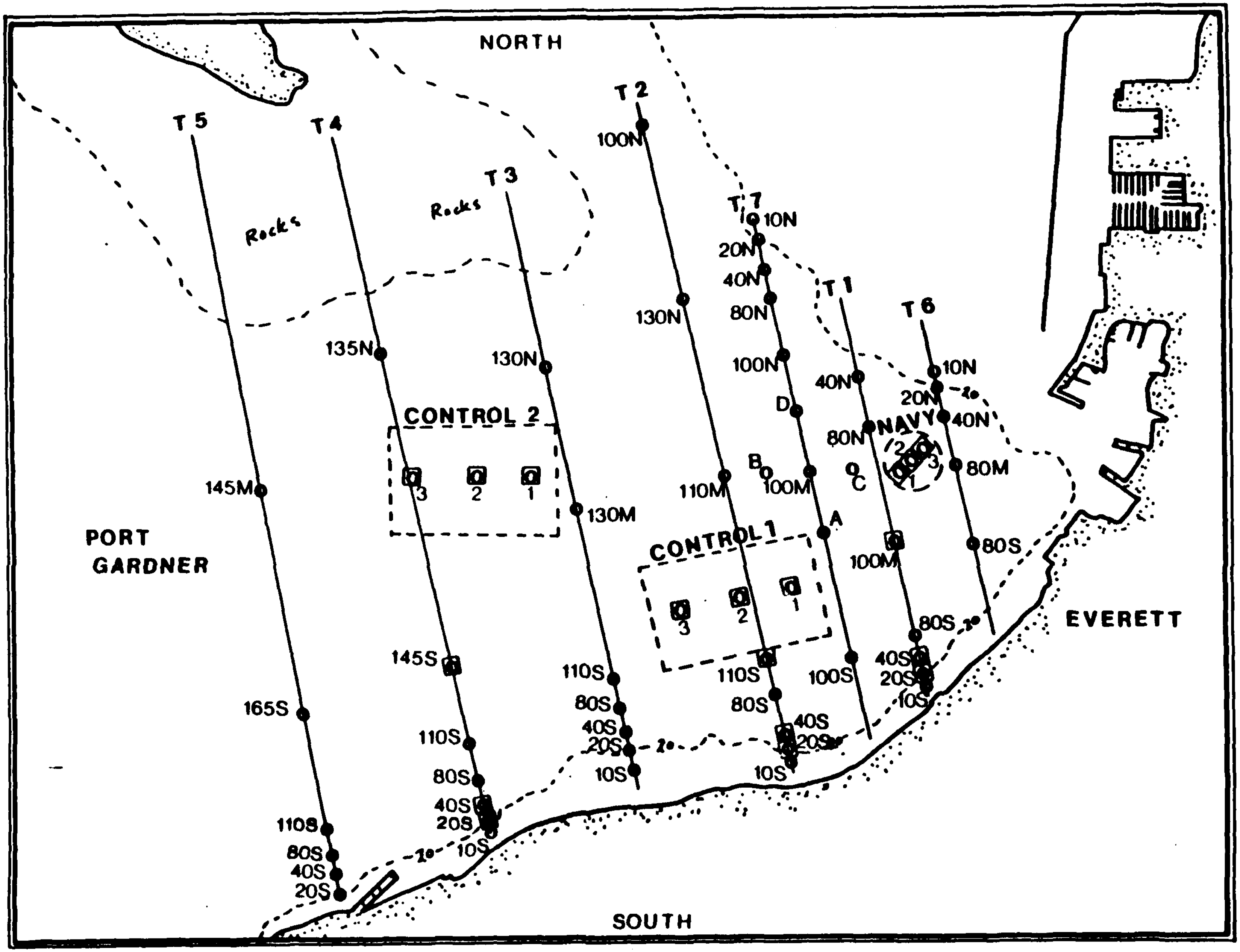
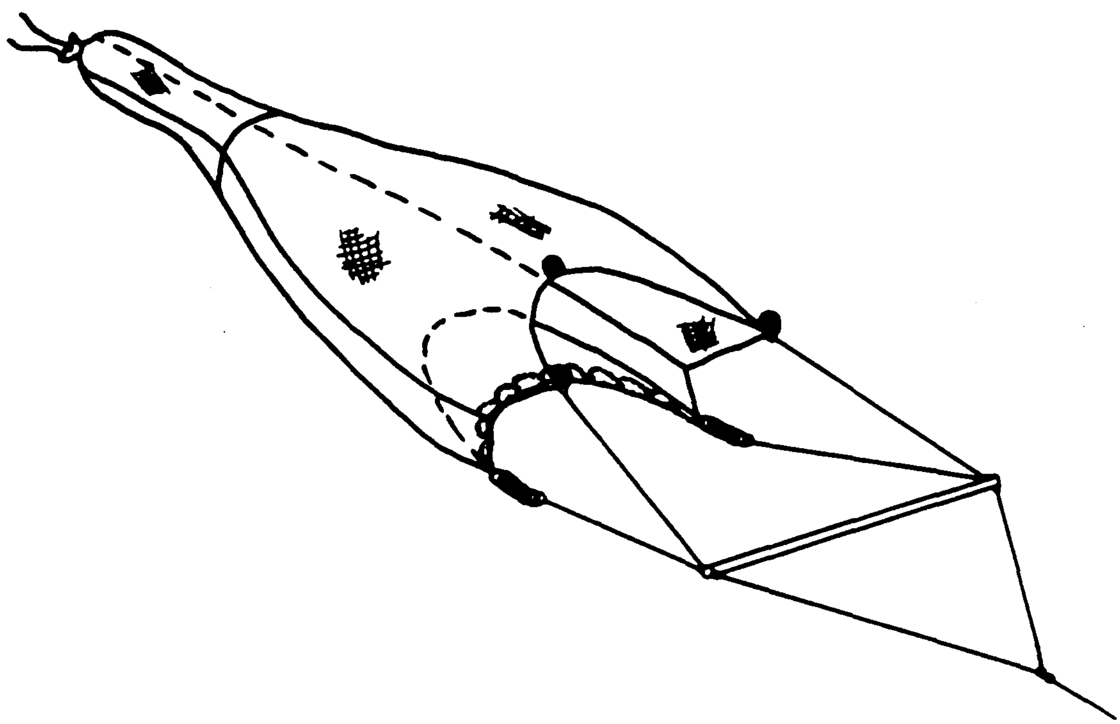


Figure 1. Beam trawl (O) and otter trawl (□) sample stations in Port Gardner. Depths in meters. N = north, M = middle, S = south.



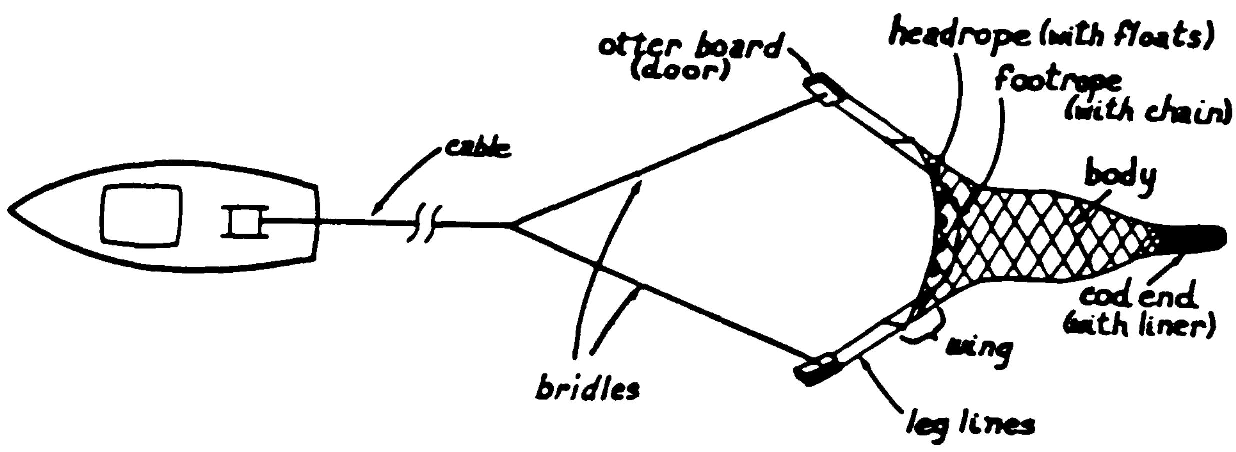


Figure 2. Diagrams of the beam trawl (top) and otter trawl (bottom) used in this study.

(Figure 1) were also sampled for bottomfish with a 7.6 m otter trawl (Figure 2, bottom).

Results

Dungeness Crab

The average density of Dungeness crab calculated from all (excluding the new stations) beam trawls in Port Gardner during June was 114 crabs/ha, a value intermediate to the February (126 crabs/ha) and April (85 crabs/ha) average densities. Individual station densities ranged from 0 to 918 crabs/ha (Appendix Table 1). Average crab densities (crabs/ha $\pm$ 1 standard deviation; n = 3 in each case) at the Navy and control sites in Port Gardner in June were:

Navy Disposal Site	=	502 $\pm$ 103
Control Site 1	=	0 $\pm$ 0
Control Site 2	=	0 $\pm$ 0

The highest crab densities occurred in and near the Navy Disposal Site (Navy Site + Transects 1 and 6) and to the northwest of the Navy Site (north end of Transect 7) (Figures 3 and 4). Both the spatial and depth distributions of Dungeness crab in June were similar to the patterns observed in February and April except that the males tended to be slightly deeper on the average. Generally, both male and female crabs were caught along the nearshore slope from Mukilteo to the Snohomish River delta (Figures 3 and 4) and continued to be rare in deeper areas (i.e. >100 m depth) of outer Port Gardner. Depthwise, the highest densities of female crab were in the 20 m to 100 m range with peak densities at 80 m (Figure 5). The depth distribution of males was fairly uniform between depths of 10 m to 100 m, a change from the two previous seasons where males were rarely caught below 40 m. Again, males were

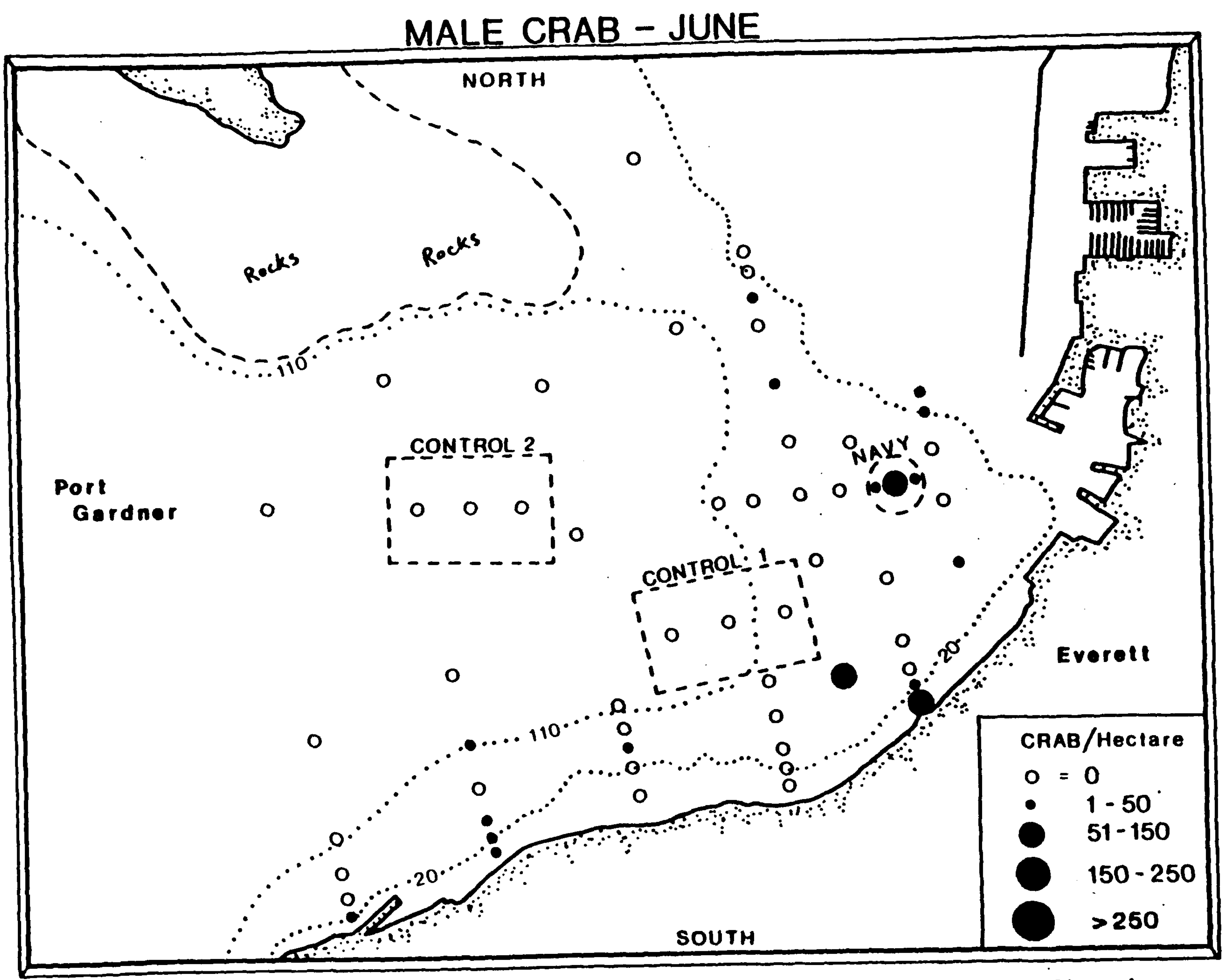


Figure 3. Map of Port Gardner showing distribution of male Dungeness crab during June, 1986 at the beam trawl stations. Depths in meters.

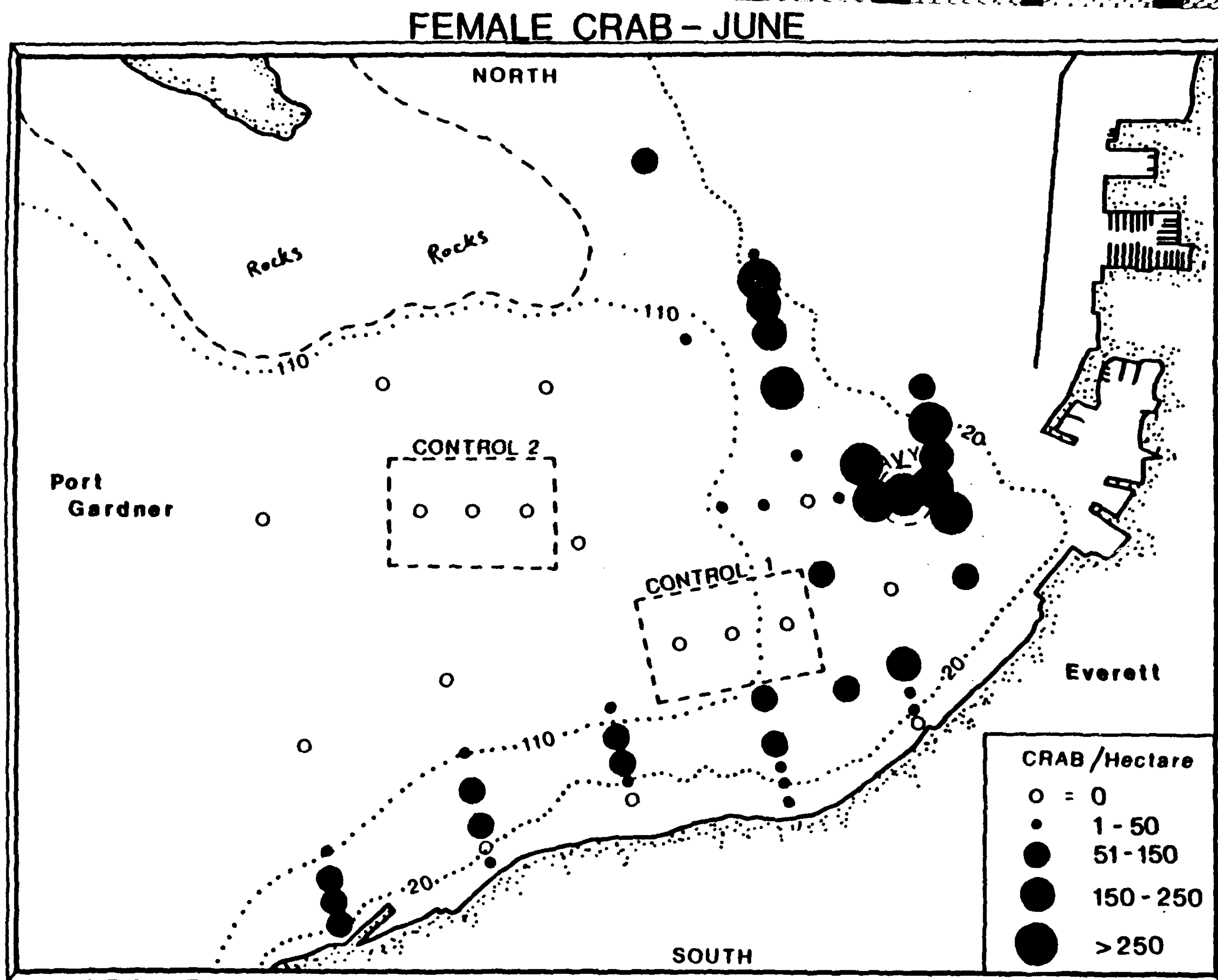


Figure 4. Map of Port Gardner showing distribution of female Dungeness crab during June, 1986 at the beam trawl stations. Depths in meters.

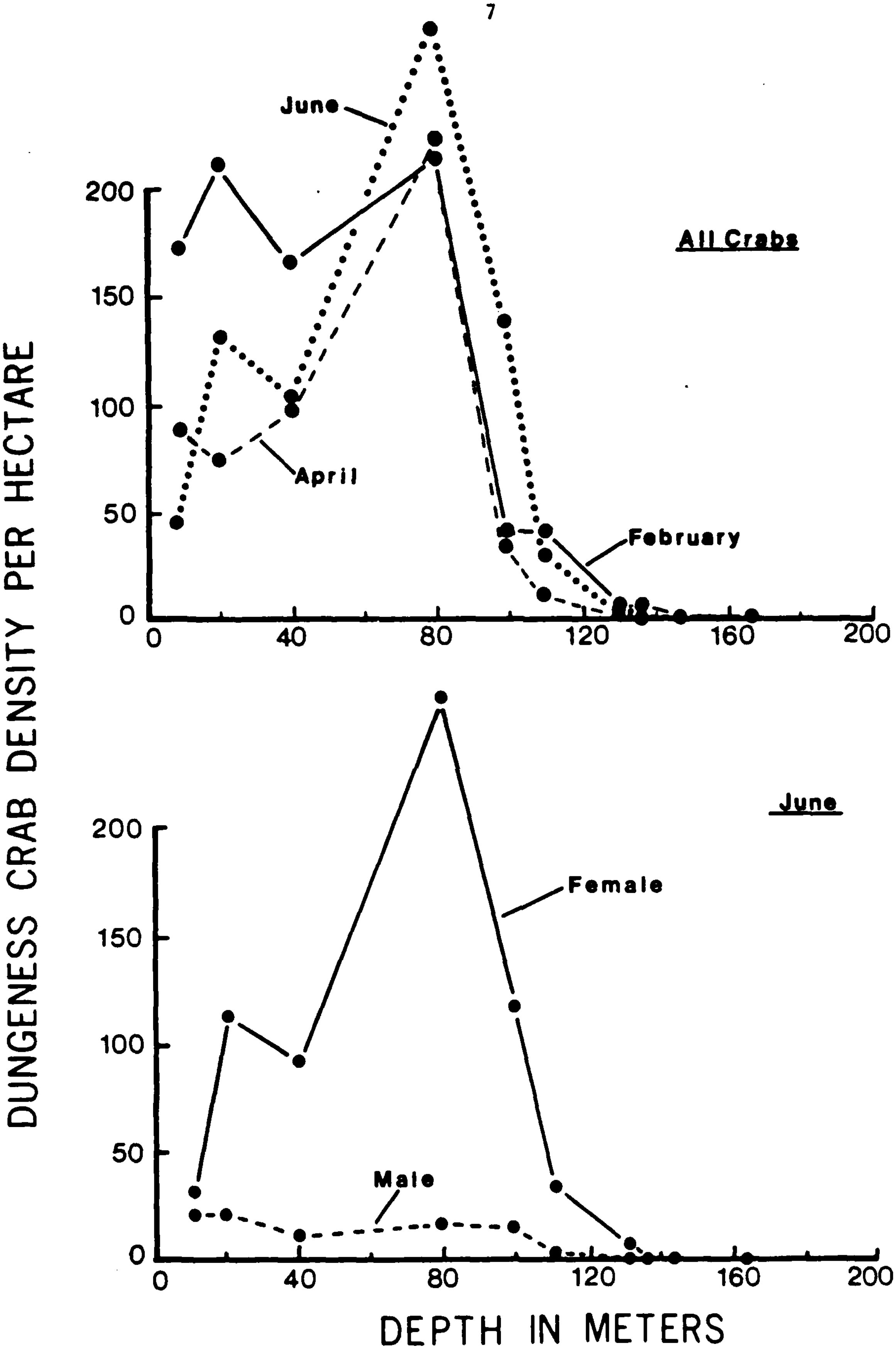


Figure 5. Average density/ha by depth for all Dungeness crab in Port Gardner during February, April and June (top) and average density of males and females by depth during June (bottom).

relatively scarce compared to the females which comprised 91% of the Dungeness crab catch. Less than 1% of the females were gravid and approximately 4% of both male and female crabs had shells that were either soft or very soft which is indicative of recent molting.

The average density of Dungeness crab at the four new stations (A, B, C, D; Figure 1) established just west of the Navy Disposal Site at depths of 90 m to 110 m was 42 crab/ha (all females; Appendix Table 2). This average density is substantially lower than the average density of 502 crab/ha within the Navy Disposal Site at a depth of 80 m.

Three additional trawls at the 60 m contour north of Port Gardner indicated declining numbers as stations occurred northward, decreasing from 243 crab/ha off the Snohomish River delta to 19 crab/ha north of Tulalip Bay (Figure 6; Appendix Table 2).

The otter trawl used for bottomfish also caught Dungeness crab but, as in the past, was again much less efficient at catching crabs than the beam trawl. The average density of crabs calculated from the 18 otter trawl stations was 4 crabs/ha versus 102 crabs/ha for the beam trawl at these same locations; an efficiency factor of 25.5 times less for the otter trawl in June. The densities of crab as determined by each type of trawl gear for the Navy and control sites are shown for each season in Figure 7. Crab densities calculated from otter trawl catches are itemized for each of the 18 stations trawled in June in Appendix Table 3.

Shrimp

Shrimp were caught at only 19 of the 55 regular beam trawl stations in Port Gardner during June, down from 38 and 26 stations in February and April, respectively. The average density of shrimp for the 55 beam trawl stations in

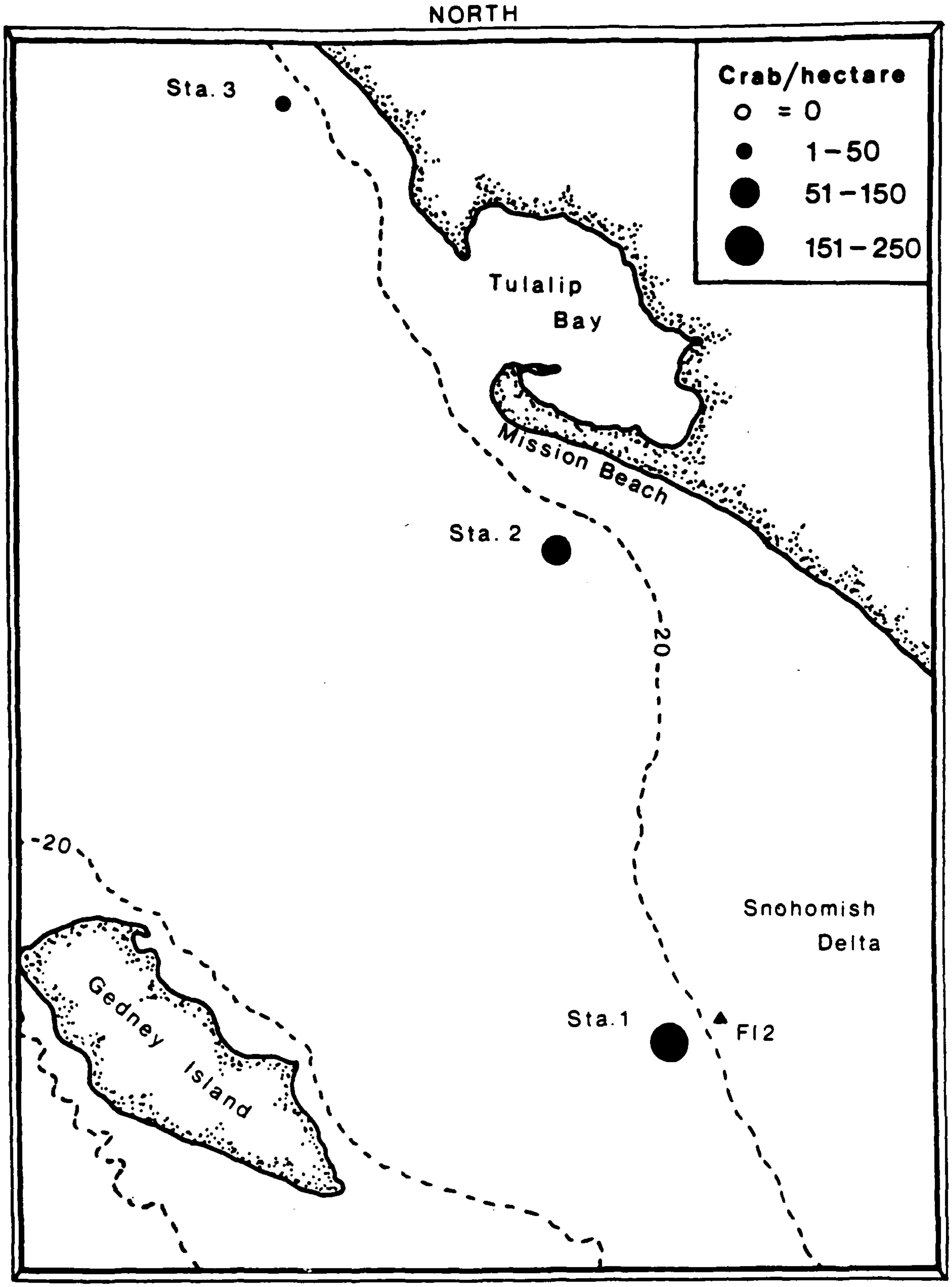


Figure 6. Density of Dungeness crab (all females) from single trawls at three stations north of Port Gardner along the 60 m depth contour.

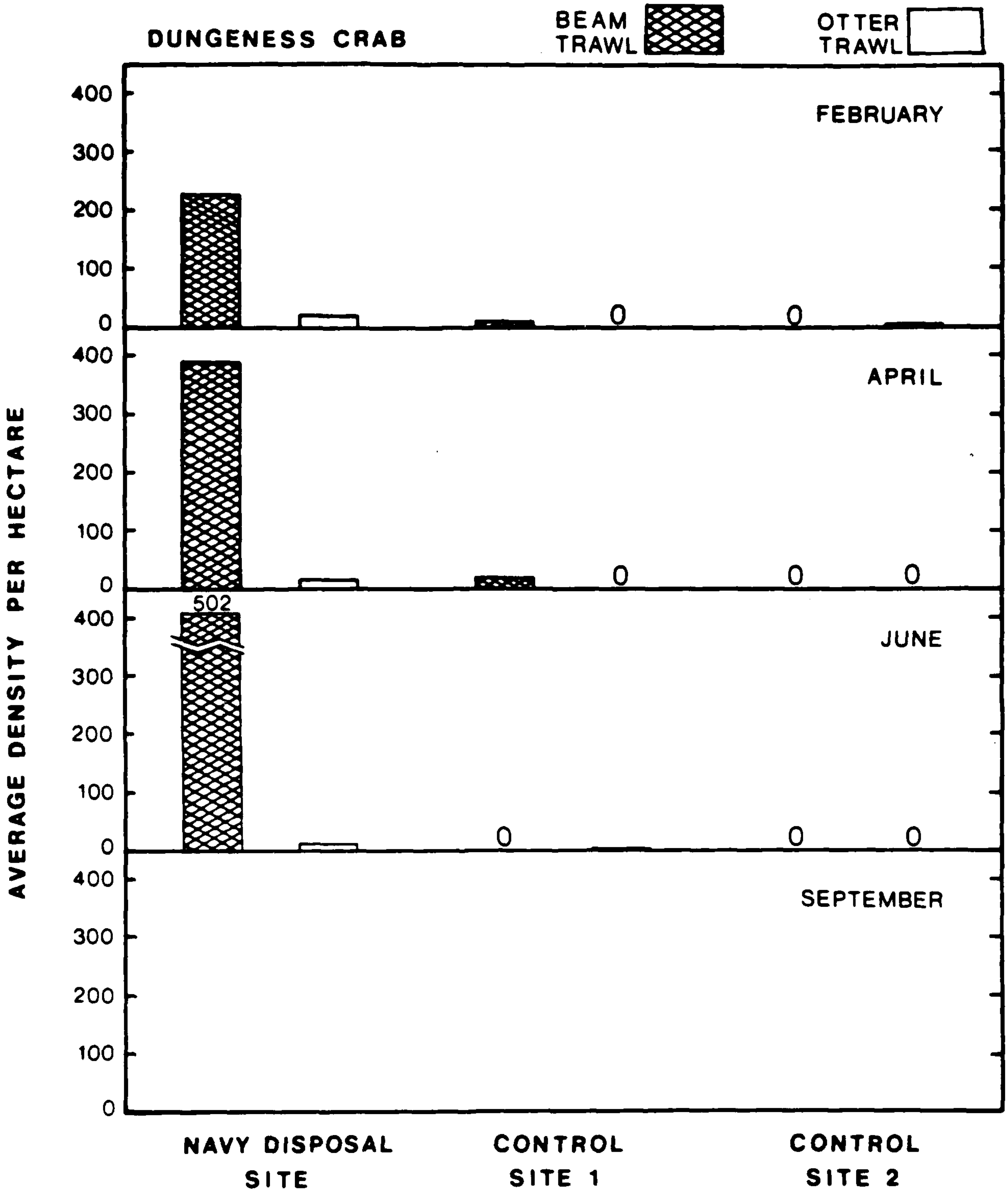


Figure 7. Comparative average densities of Dungeness crab at the three proposed disposal sites in Port Gardner by season and by trawl type.

June was 30 shrimp/ha as compared to 123 and 19 shrimp/ha in February and April (Appendix Table 4). Shrimp sampled by the beam trawl were most abundant at 40 m to 80 m off Mukilteo and were primarily spot prawns (Pandalus platyceros), followed by side-stripe (Pandalopsis dispar) and pink (Pandalus spp.) shrimp offshore of the East Waterway (Figure 8). As a function of depth, shrimp were most abundant at the 40 m stations, a change from both February and April when shrimp were most abundant at 80 m and 100 m, respectively (Figure 9).

Relative shrimp densities in June at the three proposed disposal sites again depended on type of gear. Both beam trawl and otter trawl catches of shrimp were very low at the Navy Disposal Site but varied by gear type at the two control sites (Figure 10). The beam trawl caught very few shrimp at either of the control sites while the otter trawl catches generated estimates of 117 and 80 shrimp/ha for Control Sites 1 and 2, respectively (Appendix Table 4). The relative efficiency of the otter trawl for shrimp was approximately 4.4 times greater than the beam trawl for the 18 stations sampled by both types of gear (average of 10.6 vs. 46.3 shrimp/ha for beam and otter trawls, respectively). However, similar comparisons from the February and April cruises have not found any clearcut superiority of either type of gear for catching shrimp.

Shrimp densities at the extra stations trawled in June (beam trawl only) were low (42 shrimp/ha) at stations A, B, C and D west of the Navy Disposal Site, zero at Tulalip station A and moderate (169 and 300 shrimp/ha) at Tulalip stations B and C, respectively (Appendix Table 5).

Bottomfish

The average number of bottomfish caught at the Navy Disposal Site and the

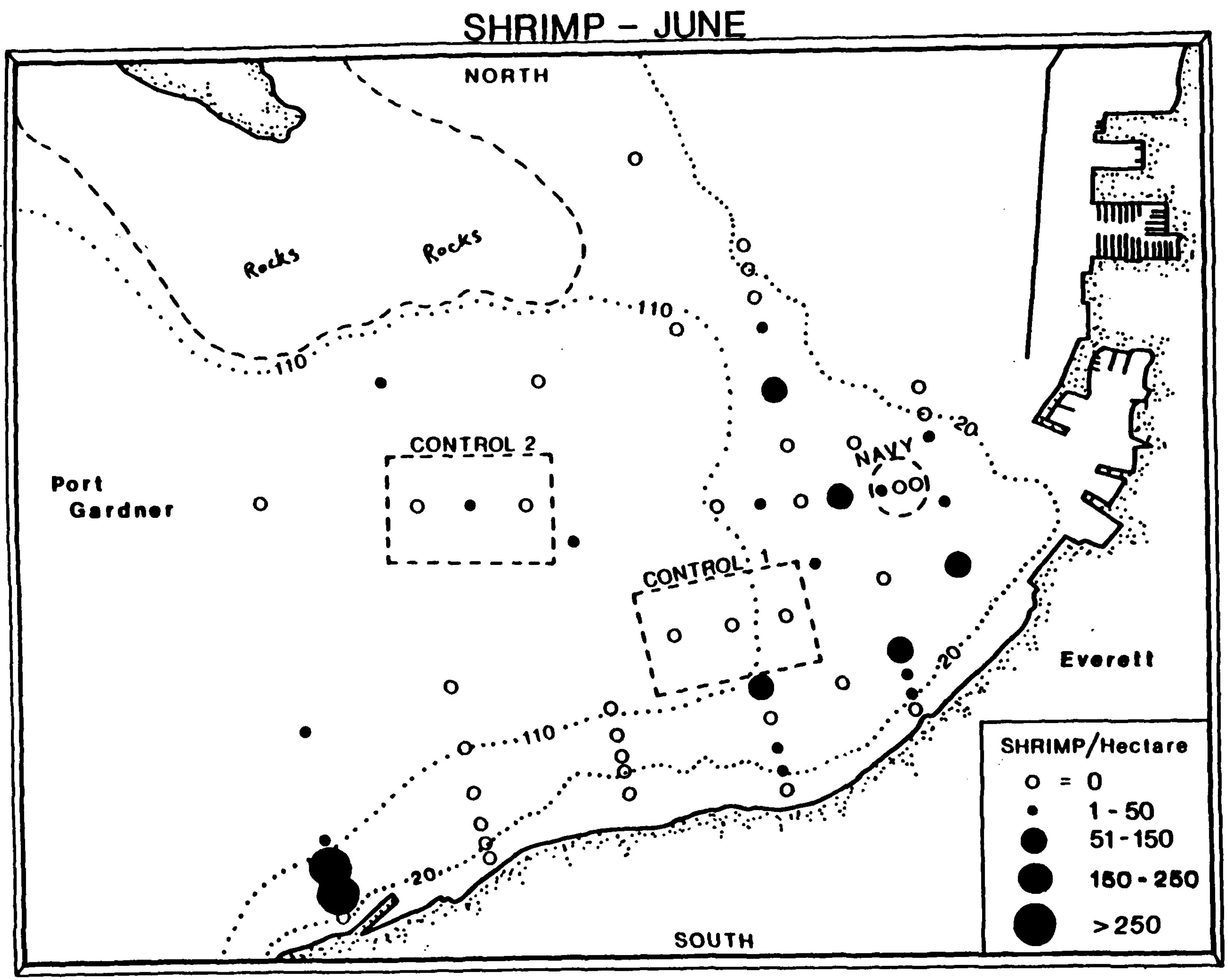


Figure 8. Commercial shrimp densities at the beam trawl stations in Port Gardner during June, 1986. Depths in meters.

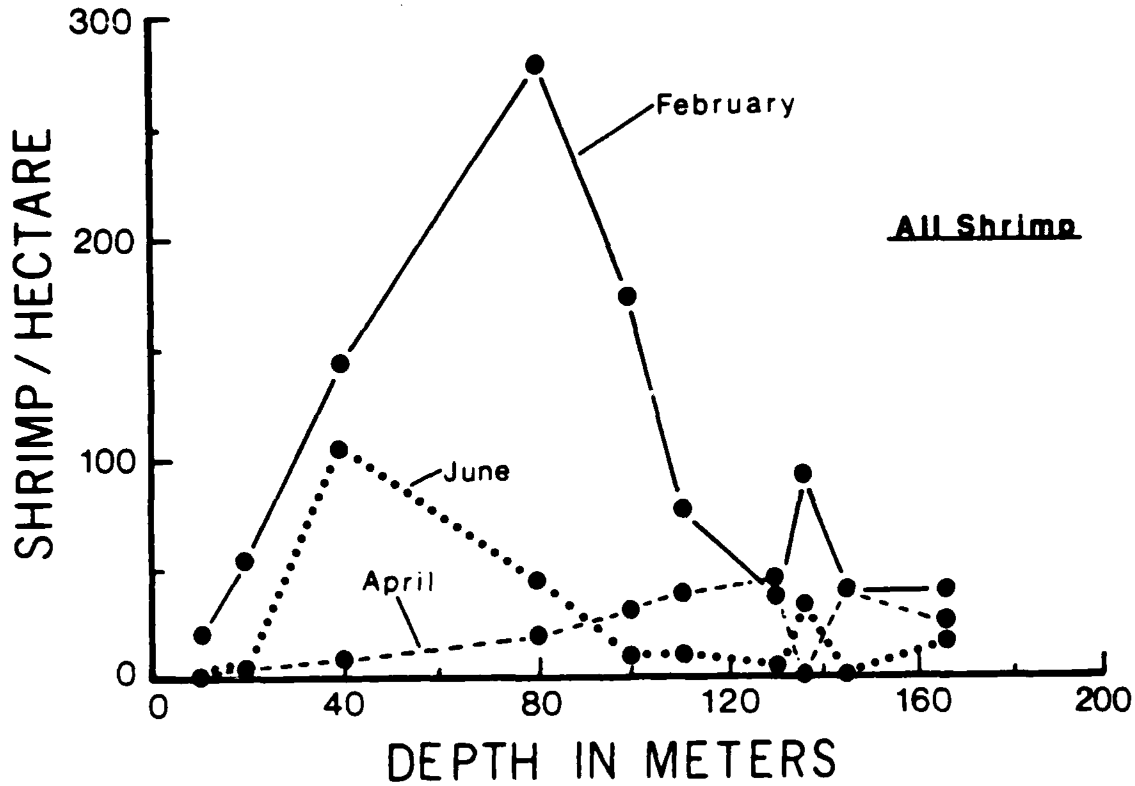


Figure 9. Average commercial shrimp densities/ha by depth and by season in Port Gardner.

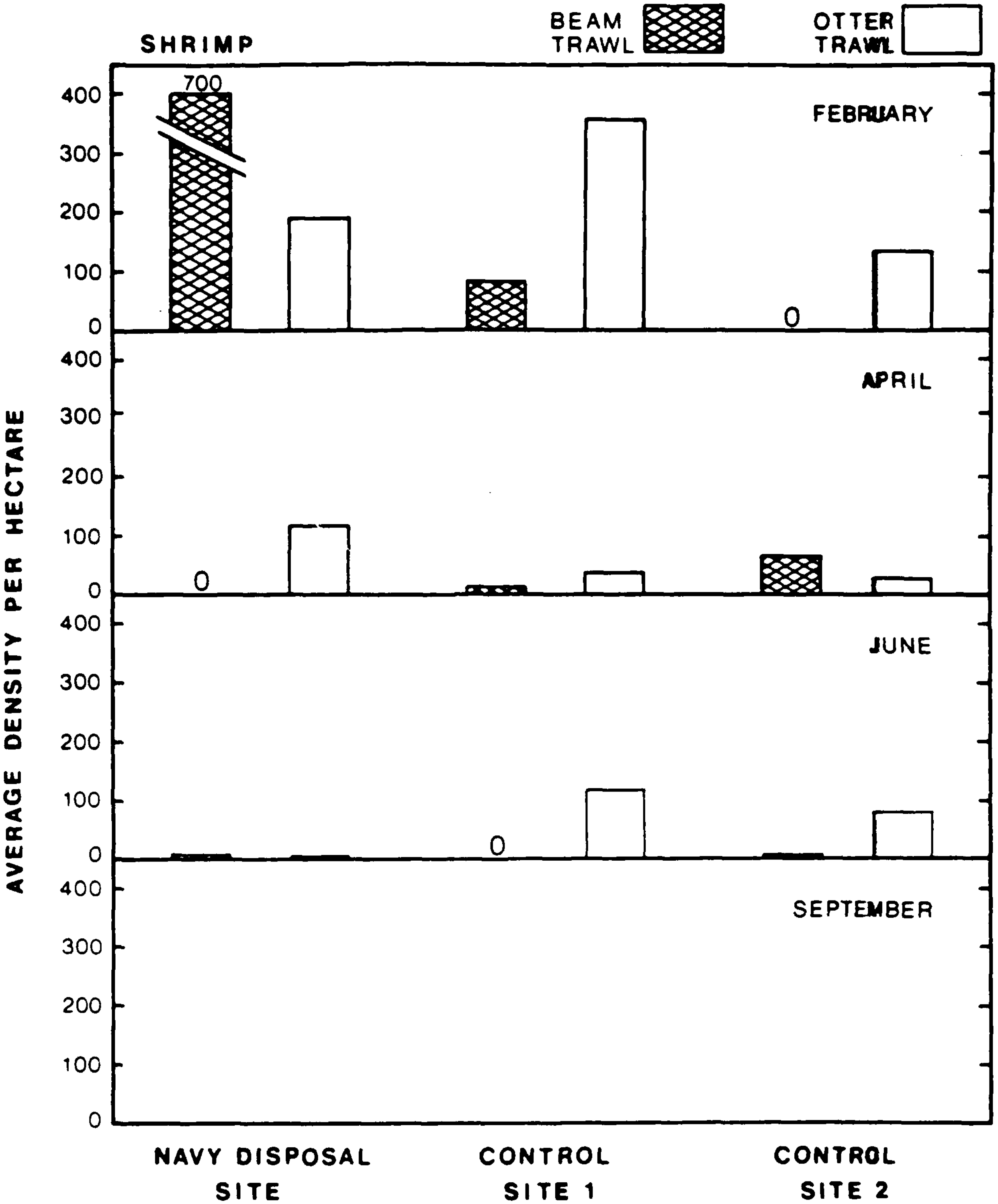


Figure 10. Average commercial shrimp densities/ha in the three proposed Port Gardner disposal sites by season and by trawl gear type.

two control sites in July was 170 fish/ha, down from 202 fish/ha in April and 773 fish/ha in February. The average biomass shows a different pattern with 28 kg/ha in June and 22 kg/ha in April, each down from 101 kg/ha in February. The Navy Disposal Site had the largest number of fish caught (295 fish/ha, down from 1514 and 434 fish/ha in February and April, respectively) as compared with the two control sites (Fig. 11). A comparison of February, April and June sampling showed that Control Site 1 had 401, 102 and 156 fish/ha, while Control Site 2 had 403, 68 and 60 fish/ha, respectively (Fig. 11; Appendix Table 6). The number of species caught at the Navy Disposal Site declined from 14 for both February and April to 10 in June; however, Control Sites 1 and 2, which showed marked reductions from February to April (11 and 16 in February, down to 7 and 7 in April), remained similar with 6 for each site.

Biomass generally followed the same pattern as abundances. The Navy Disposal Site was highest (51 kg/ha) followed by Control Site 1 (23 kg/ha) and Control Site 2 (11 kg/ha; Fig. 11). This was the same pattern exhibited in February and April except that absolute biomass fell from February to April and rose in June.

Comparison sampling with the otter trawl and beam trawl indicated that the otter trawl was a much better sampler of bottomfish than the beam trawl as measured by species diversity, abundance, biomass and size categories sampled.

Internal and external examination of flatfishes for fin erosion, tumors, parasites and liver abnormalities showed the fish to be in good health.

Discussion

Dungeness Crab

The general distribution and densities of Dungeness crab in Port Gardner

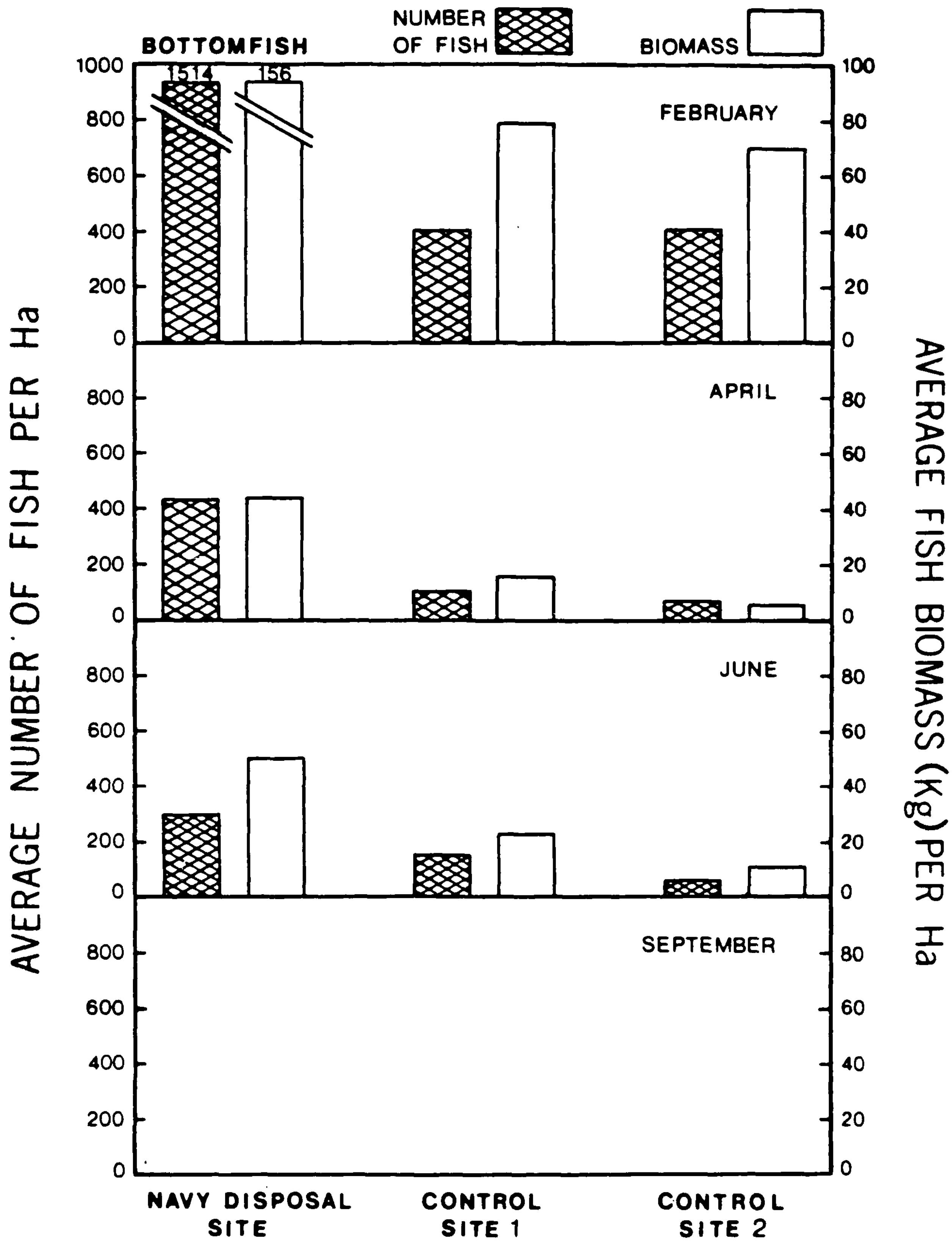


Figure 11. Average bottomfish abundance and biomass at the three disposal sites by season.

remained essentially unchanged from the two earlier sampling periods except that a few more males were caught in deep water; i.e., average male density at the 80 m Navy Disposal Site in June was 53 crab/ha versus 6 crab/ha in February and April. Female crab densities continued to be highest in the 20 m to 100 m range with the highest average densities at 80 m (Figure 5). Trawls at four new stations just west of the Navy Disposal Site (stations A, B, C, D; Figure 1) helped to confirm the pattern of sharply decreasing crab densities in the 90 m to 110 m depth zone. Trawls at three new stations north of Port Gardner in the area of Mission Beach and Tulalip Bay suggest that female crab densities gradually decrease with distance northward from Port Gardner (Figure 6).

Shrimp

Average shrimp densities in Port Gardner remained depressed (30 shrimp/ha) as compared to the February densities of 123 shrimp/ha but slightly increased from the 19 shrimp/ha observed in April. The highest shrimp densities in June were again off Mukilteo (spot prawns) between 40 m to 80 m depths.

Unpublished data have recently been obtained from Dr. Kenneth Chew of the U.W. School of Fisheries which detail the results of shrimp trawls in a variety of areas of Hood Canal and Puget Sound (including Port Susan just north of Port Gardner) during the 1960's and 1970's. These data are presently being analyzed to provide some perspective on the relative importance of shrimp in Port Gardner.

Bottomfish

Bottomfish were most abundant at the Navy Disposal Site, moderately abundant at Control Site 1, and least abundant at Control Site 2. The same pattern was true of biomass. These patterns were similar to the February and April sampling period except biomass rose slightly in June. The continued dominance of the Navy Disposal Site and the higher number of species with the concurrent reduced measures at the Control Sites was not unexpected. The Navy Disposal Site is the shallowest of the three sites and previous studies have shown similar results (Dinnel et al. 1986a, b; Donnelly et al. 1984).

The most abundant fishes (English sole, Parophrys vetulus; Dover sole, Microstomus pacificus; slender sole, Lyopsetta exilis; Pacific hake, Merluccius productus; and ratfish, Hydrolagus colliei) remained the same during all three sampling periods; however, abundances fell from February to April and rose in some cases in June (Appendix Table 4). English sole dominated all sampling periods at the Navy Disposal Site. The relative abundance of Pacific hake was high for all three sample periods, but the biomass declined markedly from February to April and rose only slightly in June. Thus, only smaller (possibly young-of-the-year) individuals were present during April and June. This lends support to the supposition that Pacific hake may be using the Navy Disposal Site as a nursery ground. A nearby area (Port Susan) is known to be a spawning ground and supports a commercial Pacific hake fishery.

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Appendix Table 1. Dungeness crab densities per hectare calculated from beam trawl catches in Port Gardner during June, 1986.

Station[1]	Density/Hectare Females	Males	All crabs	Substrate comments
Navy Disposal Site (80m)				
Station 1	375	47	421	40 gal. wood, cans, crabs, debris
Station 2	543	75	618	50 gal. wood, cans, crabs
Station 3	431	37	468	10 gal. wood, crabs, debris
Average	450 ± 86[2]	53 ± 20	502 ± 103	
Cont. ol Site 1 (110m)				
Station 1	0	0	0	1 gal. wood, detritus
Station 2	0	0	0	1 gal. worm tubes, wood
Station 3	0	0	0	1 gal. wood, detritus
Average	0	0	0	
Control Site 2 (130m)				
Station 1	0	0	0	2 gal. worm tubes, detrital kelp
Station 2	0	0	0	1 gal. worm tubes
Station 3	0	0	0	2 gal. worm tubes
Average	0	0	0	

Appendix Table 1. (Continued)

	Females	Males	All Crabs	Comments
Transect #1				
10-S	0	56	56	3 gal. Ulva, wood
20-S	19	37	56	20 gal. Ulva
40-S	19	0	19	10 gal. wood, Ulva
80-S	169	0	169	6 gal. wood, Ulva
100-M	0	0	0	2 gal. detritus
80-N	918	0	918	8 gal. detritus
40-N	N.S.[3]	N.S.	N.S.	
Average	188 ± 364	16 ± 25	203 ± 355	
Transect #2				
10-S	19	0	19	15 gal. Ulva, wood
20-S	19	0	19	20 gal. Ulva, wood
40-S	19	0	19	5 gal. wood, shell, Ulva
80-S	94	0	94	20 gal. wood, gravel
110-S	112	0	112	10 gal. pea gravel, wood
110-M	19	0	19	2 gal. Ulva, wood, worm tubes
130-N	37	0	37	2 gal. wood chips, worm tubes
100-N	56	0	56	1 gal. wood chips, detritus
Average	47 ± 37	0	47 ± 37	

Appendix Table 1. (Continued)

	Females	Males	All crabs	Comments
Transect #3				
10-S	0	0	0	3 gal. wood, Ulva, shell
20-S	37	0	37	25 gal. wood chips, Ulva
40-S	56	19	75	15 gal. wood chips
80-S	56	0	56	5 gal. wood chips, cans, bottles
110-S	37	0	37	8 gal. clay balls
130-M	0	0	0	1 gal. wood, worm tubes
130-N	0	0	0	2 gal. wood, worm tubes, kelp
Average	27 $\pm$ 26	3 $\pm$ 7	29 $\pm$ 30	
Transect #4				
10-S	19	37	56	3 gal. Ulva, detritus
20-S	0	37	37	15 gal. wood, Ulva, shell
40-S	56	19	75	30 gal. wood, bottles
80-S	75	0	75	4 gal. wood, cans
110-S	37	19	56	2 gal. pea gravel, wood
145-S	0	0	0	2 gal. worm tubes, wood
135-N	0	0	0	1 gal. worm tubes, heart urchins
Average	27 $\pm$ 30	16 $\pm$ 17	43 $\pm$ 32	

Appendix Table 1. (Continued)

	Females	Males	All crabs	Comments
Transect #5				
20-S	94	37	131	20 gal. pea gravel, Ulva
40-S	75	0	75	40 gal. wood, bottles, gravel, debris
80-S	56	0	56	25 gal. wood, bottles, gravel
110-S	19	0	19	3 gal. worm tubes, wood, pea gravel
165-S	0	0	0	2 gal. worm tubes, wood, heart urchins
145-M	0	0	0	2 gal. worm tubes, heart urchins
Average	41 ± 40	6 ± 15	47 ± 51	
Transect #6				
80-S	56	19	75	50 gal. wood
80-M	262	0	262	15 gal. wood, cans
40-N	206	0	206	20 gal. wood
20-N	281	19	300	4 gal. wood chips
10-N	112	19	131	3 gal. bottles, wood
Average	183 ± 97	11 ± 10	195 ± 92	

Appendix Table 1. (Continued)

Transect #7				
100-S	104	52	156	10 gal. wood, cans
100-M	0	0	0	2 gal. worm tubes, wood chips
100-N	449	19	468	4 gal. detritus
80-N	206	0	206	2 gal. wood chips, cans
40-N	225	19	244	10 gal. wood chips
20-N	337	0	337	7 gal. wood
10-N	19	0	19	1/2 gal. detritus
Average	191 ± 165	13 ± 19	204 ± 167	
GRAND AVERAGE	104 ± 171	10 ± 18	114 ± 178	

1 Station numbers for the transects indicate depth in meters plus location where N = north, M = middle, and S = south.

2 Mean ± 1 standard deviation.

3 N.S. = not sampled.

Appendix Table 2. Dungeness crab densities per hectare calculated from beam trawl catches at extra stations in Port Gardner during June 1986.

Station	Density/Hectare			Comments
	Females	Males	All crabs	
West of Navy Site				
Station A (105m)	75	0	75	70 gal. wood
Station B (110m)	37	0	37	1 gal. worm tubes, wood chips
Station C (90m)	37	0	37	1 gal. worm tubes, wood chips
Station D (105m)	19	0	19	1 gal. worm tubes, wood chips
Average	42 ± 24[1]	0	42 ± 24	
Tulalip (60m)				
Station A	243	0	243	3 gal. wood, debris
Station B	56	0	56	2 gal. wood, cans
Station C	19	0	19	1 gal. fish, detritus
Average	106 ± 120	0	106 ± 120	

[1] Mean ± 1 standard deviation.

Appendix Table 3. Dungeness crab densities per hectare calculated from otter trawl catches in Port Gardner in June and early July, 1986.

Station[1]	Density/Hectare Females	Males	All crabs
Navy Site (80m)			
Station 1	9	0	9
Station 2	14	4	18
Station 3	0	0	0
Average	7 ± 7[2]	1 ± 2	9 ± 9
Control Site 1 (110m)			
Station 1	4	0	4
Station 2	0	0	0
Station 3	0	0	0
Average	1 ± 2	0	1 ± 2
Control Site 2 (130m)			
Station 1	0	0	0
Station 2	0	0	0
Station 3	0	0	0
Average	0	0	0
Transect #1			
20-S	0	0	0
40-S	0	4	4
100-M	18	4	22
Average	6 ± 10	3 ± 2	9 ± 12
Transect #2			
20-S	0	0	0
40-S	4	0	4
110-S	14	0	14
Average	6 ± 7	0	6 ± 7

Appendix Table 3. (Continued)

Station	Females	Males	All crabs
Transect #4			
20-S	0	0	0
40-S	0	0	0
145-S	0	0	0
Average	0	0	0
Grand Average	4 ± 6	1 ± 2	4 ± 7

[1] Station numbers for the transects indicate depth in meters plus locations where S = south and M = middle.

[2] Mean ± 1 standard deviation.

Appendix Table 4. Commercial shrimp densities per hectare calculated from beam and otter trawls in Port Gardner in June and early July, 1986.

Station[1]	Density/Hectare	
	Beam trawl	Otter trawl
Navy Disposal Site (80m)		
Station 1	19	9
Station 2	0	0
Station 3	0	4
Average	6 ± 11[2]	4 ± 5
Control Site 1 (110m)		
Station 1	0	228
Station 2	0	41
Station 3	0	23
Average	0	117 ± 148
Control Site 2 (130m)		
Station 1	0	131
Station 2	19	59
Station 3	0	50
Average	6 ± 11	80 ± 44
Transect #1		
10-S	0	N.S.
20-S	19	0
40-S	19	0
80-S	75	N.S.
100-M	0	221
80-N	0	N.S.
40-N	N.S.[3]	N.S.
Average	19 ± 29	74 ± 128

Appendix Table 4. (Continued)

Station	Beam trawl	Otter trawl
Transect #2		
10-S	0	N.S.
20-S	19	0
40-S	19	0
80-S	0	N.S.
110-S	75	27
110-M	0	N.S.
130-M	0	N.S.
100-N	0	N.S.
Average	14 ± 26	9 ± 16
Transect #3		
10-S	0	N.S.
20-S	0	N.S.
40-S	0	N.S.
80-S	0	N.S.
110-S	0	N.S.
130-M	19	N.S.
130-N	0	N.S.
Average	3 ± 7	--
Transect #4		
10-S	0	N.S.
20-S	0	0
40-S	0	4
80-S	0	N.S.
110-S	0	N.S.

Appendix Table 4. (Continued)

Station	Beam trawl	Otter trawl
Transect #4 - Continued		
145-S	0	36
135-N	37	N.S.
Average	5 ± 14	13 ± 20
Transect #5		
20-S	0	N.S.
40-S	787	N.S.
80-S	281	N.S.
110-S	19	N.S.
165-S	19	N.S.
145-M	0	N.S.
Average	184 ± 315	--
Transect #6		
80-S	112	N.S.
80-M	19	N.S.
40-N	19	N.S.
20-N	0	N.S.
10-N	0	N.S.
Average	30 ± 47	--
Transect #7		
100-S	0	N.S.
100-M	0	N.S.
100-N	56	N.S.
80-N	19	N.S.
40-N	0	N.S.

Appendix Table 4. (Continued)

Station	Beam trawl	Otter trawl
Transect #7 - Continued		
20-N	0	N.S.
10-N	0	N.S.
Average	11 ± 21	--
Grand Average	30 ± 112	50 ± 82

[1] Station numbers for the transects indicate depth in meters plus locations where N = north, M = middle, and S = south.

[2] Mean ± standard deviation.

[3] N.S. = not sampled.

Appendix Table 5. Commercial shrimp densities per hectare calculated from beam trawl catches at extra stations in Port Gardner during June, 1986.

Station	Shrimp/Hectare
West of Navy Site	
Station A (105m)	19
Station B (110m)	19
Station C (90m)	131
Station D (105m)	0
Average	42 ± 60[1]
Tulalip (60m)	
Station A	0
Station B	300
Station C	169
Average	156 ± 150

[1] Mean ± 1 standard deviation.

Appendix Table 6. Otter trawl average bottomfish catch density (number of individuals per hectare) at each of the proposed disposal sites in Port Gardner during July 1986.

	Number of Fish Per Hectare		
Species	Navy Site	Control Site 1	Control Site 2
English Sole	131	54	13
Dover Sole	4	31	22
Slender Sole	22	9	13
Rex Sole			
Rock Sole			
Flathead Sole	9		
Arrowtooth Flounder			
Quillback Rockfish	9		4
Ratfish	40	54	4
Blacktip Poacher	4		
Sablefish			
Pacific Hake	31	4	
Blackbelly Eelpout	27		
Cod			
Tom Cod			
Snake Prickleback			
Midshipman			
Shiner Perch			
Dogfish	18		
Spinyhead Sculpin			
Lamprey			
Blackfin Poacher			4
Blackfin Eelpout		4	
Number of Species	10	6	6

Appendix Table 7. Otter trawl average bottomfish catch biomass per hectare at each of the proposed disposal sites in Port Gardner during July 1986.

	Average Fish Biomass (Kilograms/Hectare)		
Species	Navy Site	Control Site 1	Control Site 2
English Sole	24.08	11.20	3.12
Dover Sole	0.81	7.92	5.18
Slender Sole	1.42	0.44	0.50
Rex Sole			
Rock Sole			
Flathead Sole	1.79		
Arrowtooth Flounder			
Quillback Rockfish	2.16		0.96
Ratfish	10.57	2.70	1.44
Blacktip Poacher	0.01		
Sablefish			
Pacific Hake	4.01	0.75	
Blackbelly Eelpout	1.00		
Cod			
Tom Cod			
Snake Prickleback			
Midshipman			
Shiner Perch			
Dogfish	4.92		
Spinyhead Sculpin			
Lamprey			
Blackfin Poacher			0.09
Blackfin Eelpout		0.04	
Total Biomass	50.77	23.05	11.29

APPENDIX D

September 30, 1986

APPENDIX D

U.S. NAVY HOMEPORT DISPOSAL SITE INVESTIGATIONS AUTUMN TRAWL:

DUNGENESS CRAB DATA

This appendix displays data results of beam trawl catches of Dungeness crab made in Port Gardner during September, 1986 as part of disposal site investigations being conducted by the University of Washington, School of Fisheries. No interpretation of these data, with comparison to previous trawls for Port Gardner, has been made. Catch data for shrimp and bottomfish collected by beam trawl and otter trawl have not been worked up at this time. The progress report for this season's trawls is scheduled to be provided to the Seattle District in October.

Appendix Table 1. Dungeness crab densities per hectare calculated from beam trawl catches in Port Gardner during September, 1986. Station numbers for the transects indicate depth in meters plus location where N=North, M=Middle, and S=South. The averages are mean ± 1 standard deviation.

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Navy Disposal Site (80m)				
Station 1	95	0	95	20 gal. wood, debris
Station 2	115	0	115	10 gal. wood, debris
Station 3	19	0	19	15 gal. wood, debris
Average	76±51	0	76±51	
Control Site (110m)				
Station 1	19	0	19	15 gal. wood
Station 2	19	0	19	1 gal. worm tubes wood chips
Station 3	0	0	0	2 gal. wood, shell
Average	13±11	0	13±11	
Control Site 2 (130m)				
Station 1	0	0	0	1 gal. worm tubes, shell
Station 2	57	0	57	1 gal. worm tubes, shell
Station 3	19	0	19	0.5 gal. worm tubes, wood
Average	25 ± 29	0	25 ± 29	
Transect #1				
10-S	19	38	57	3 gal. algae, wood, detritus
20-S	57	19	76	
40-S	191	0	191	30 gal. algae, wood
80-S	248	19	267	15 gal. wood, algae
100-M	95	0	95	20 gal. wood, debris
80-N	0	0	0	5 gal. wood, debris
40-N	-	not sampled	-	
Average	102±99	13±16	114±97	

Appendix Table 1 (continued)

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Transect #2				
10-S	19	19	38	1 gal. algae, detritus
20-S	210	19	249*	15 gal. algae, shell
40-S	153	0	153	15 gal. algae, wood
80-S	305	0	305	25 gal. wood, algae, clay balls
110-S	0	0	0	3 gal. detritus, algae wood
110-M	38	0	38	1 gal. worm tubes, wood chips
130-N	38	0	38	1 gal. detritus, shell
100-N	0	0	0	2 gal. wood chips
Average	95±114	5±9	103±119	
Transect #3				
10-S	0	19	19	6 gal. algae, shell
20-S	38	0	38	50 gal. wood, algae
40-S	553	19	572	30 gal. bark
80-S	95	0	95	8 gal. rock, algae, detritus
110-S	57	0	57	3 gal. wood, algae
130-M	76	0	76	1 gal. worm tubes, wood, shell
130-N	19	0	19	1 gal. worm tubes
Average	120±194	5±9	125±199	
Transect #4				
10-S	19	0	19	1 gal. algae, shell
20-S	38	38	76	6 gal. algae, wood, shell
40-S	172	38	210	30 gal. wood chips, bottles
80-S	115	0	115	4 gal. wood, algae, cans
110-S	153	0	153	4 gal. detritus, wood, gravel
145-S	38	19	57	2 gal. algae, worm tubes
135-N	0	0	0	1 gal. worm tubes, wood chips
Average	76±69	14±18	90±75	

Appendix Table 1 (continued)

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Transect #5				
20-S	76	57	133	20 gal. algae, gravel, wood, shell
40-S	496	57	553	30 gal. wood, rock, algae
80-S	95	19	114	40 gal. wood, algae, rock, debris
110-S	153	0	153	3 gal. wood, detritus
165-S	0	0	0	1 gal. worm tubes
145-M	0	0	0	1 gal. worm tubes
Average	137±186	22±28	159±204	
Transect #6				
80-S	76	19	95	50 gal. algae, wood, cans
80-M	191	0	191	20 gal. wood, debris, cans
40-N	76	0	76	10 gal. wood, debris
20-N	19	0	19	2 gal. wood, detritus
10-N	38	0	38	1 gal. detritus, wood
Average	80±67	4±8	84±67	

Appendix Table 1 (continued)

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Transect #7				
100-S	76	0	76	40 gal. wood chips, bottles, cans
100-M	38	0	38	2 gal. wood chips
100-N	0	0	0	2 gal. wood, detritus
80-N	210	19	229	3 gal. wood, cans
40-N	229	0	229	1 gal. wood, detritus, shell
20-N	95	0	95	4 gal. wood, shell
10-N	76	0	76	0.5 gal. detritus, shell
Average	103±85	3 ~~1~~±7	106±89	
GRAND AVERAGE	92±113	8±15	100±119	

*Includes 1 young-of-the-year (unsexed) crab, 9.0mm carapace width.

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Appendix Table 2. Dungeness ~~Crab~~ crab densities per hectare calculated from beam trawl catches at extra stations in Port Gardner during September, 1986. The averages are means ± 1 standard deviation.

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
West of Navy Site				
Station A (105m)	19	0	~~76~~ 19	8 gal. wood chips
Station B (110m)	0	0	0	1 gal. worm tubes, wood
Station C (90m)	38	0	38	1 gal. detritus, wood chips
Station D (105m)	38	0	38	1 gal. detritus, wood chips
Station E (115m)	0	0	0	1 gal. worm tubes, wood
Station F (110m)	38	0	38	7 gal. wood, debris
Average	22±19	0	22±19	
East of Control Site 2				
Station G (130m)	19	0	19	3 gal. wood, shell
Station H (130m)	0	0	0	4 gal. wood, shell
Between Mukilteo and Picnic Point				
Station 1 - 40m	19	0	19	3 gal. wood, detritus
Station 2 - 40m	0	0	0	5 gal. wood, algae
Station 3 - 40m	0	0	0	5 gal. wood, algae, bottles
Station 4 - 10m	0	0	0	10 gal. sand, algae
Station ~~5~~ 4 - 20m	38	0	38	3 gal. algae
Station ~~6~~ 4 - 40m	0	0	0	5 gal. clay balls, algae
Station ~~7~~ 4 - 80m	0	0	0	20 gal. clay balls, algae
Average	6±15	0	8±15	

End of Table

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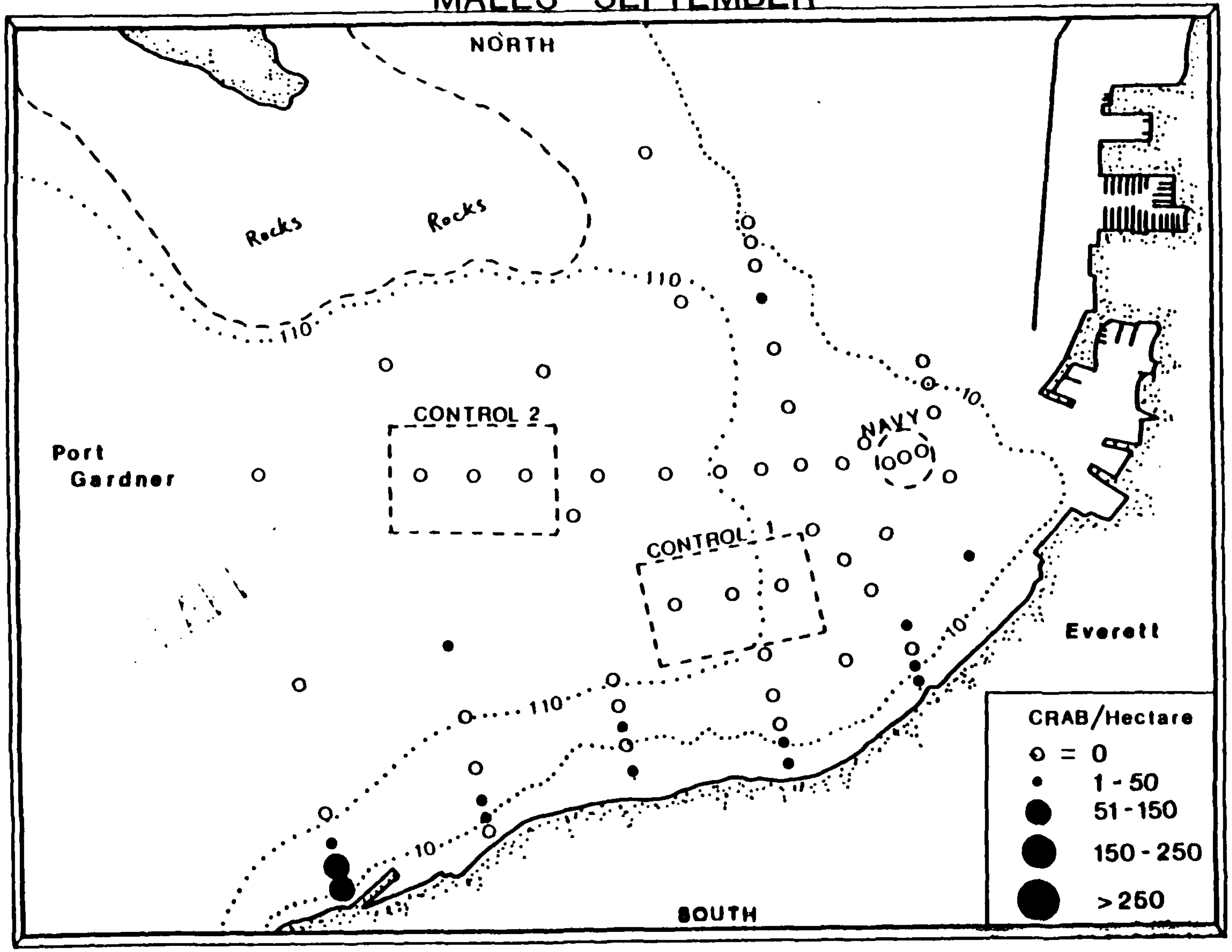
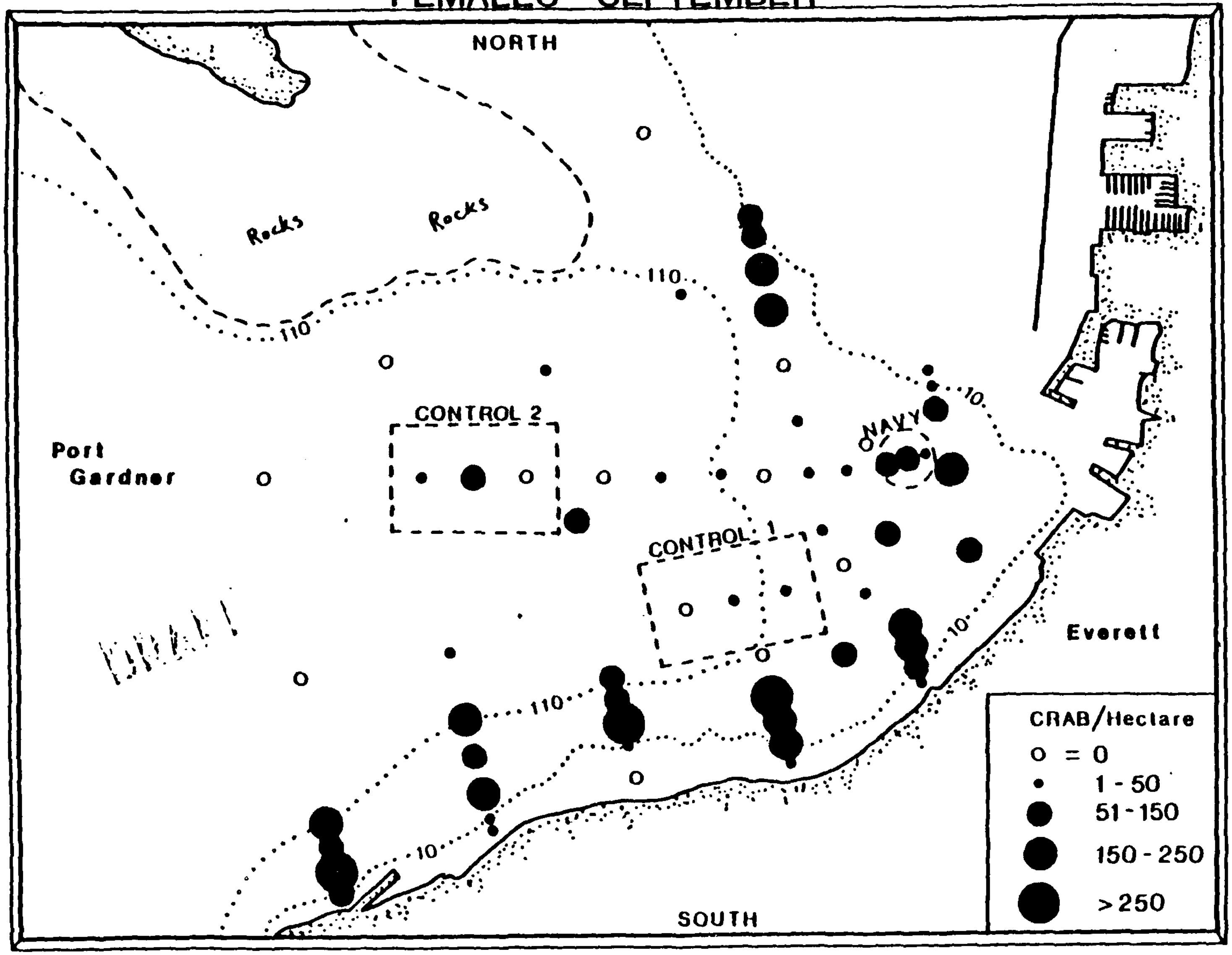
MALES - SEPTEMBER



FEMALES – SEPTEMBER



APPENDIX E

Battelle
Pacific Northwest Division
Marine Research Laboratory
439 West Sequim Bay Road
Sequim, Washington 98382
(206) 683-4151

September 19, 1986

Mr. John Malek
U.S. Army Corps of Engineers
Federal Center South
4735 East Marginal Way South
Seattle, WA 98134

Dear John,

RE: U.S. NAVY HOMEPORT - SEA SURFACE MICROLAYER ANALYSES

The quantity of substances (e.g., pollutants, organics, particles, etc.) that are released to the sea-surface during dredging and disposal of marine sediments are currently unknown. Therefore, the U.S. Army Corps of Engineers (COE) requested that Battelle Marine Research Laboratories perform preliminary laboratory tests that would begin to provide answers to some of these unknowns.

METHODS AND MATERIALS

Basically, the experiments were designed to determine the percentage of each sediment bound contaminant that upon disturbance would be released from sediments into the water column and which would shortly arrive at the sea-surface. The experiments were not designed to provide estimations of surfacing based upon long-term releases after dredge material settled to the bottom of the container.

In order to accomplish these tasks a laboratory experiment was conducted using potential dredged materials to produce sea-surface samples consisting of floatable particles, floatable oils and water. The four treatments were as follows:

1. Sequim Bay bulkwater (filtered, laboratory sea water) without sediment = Blank.

2. Sequim Bay sediment collected at a water depth of 80' near the center portion of Sequim Bay on 7 August 1986.

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3. Everett Harbor East Waterway contaminated composite sample which had been archived by Battelle.

4. Everett Harbor sediments collected by Hart-Crowser and provided to Battelle at the COE request in May 1986.

The experiments were conducted in 3.8 L glass jars that were washed in hot, soapy water, rinsed in deionized water, solvent rinsed with 50-100ml of methylene chloride, soaked in 1:1 nitric acid for 24 hours and rinsed again in deionized water prior to air drying. The following procedures were performed on ten jars per treatment:

1. Approximately 500-575 wet grams of sediment were weighed and transferred to the previously cleaned 3.8 L jars.

2. 2.5 L of filtered sea-water were added to each jar.

3. The sediment was then thoroughly mixed using a Teflon® coated magnetic stirrer for ten minutes. Care was taken to maintain mixing without the introduction of air.

4. These containers were then transferred to a controlled water bath at 14°C and incubated for 48 hours.

5. A single microlayer composite sample was obtained from each treatment by aspiration of the surface of each sample at 1, 24, and 48 hours. Approximately, 1 L of composited surfaced material and water were thus obtained for each treatment.

Each of the surface samples were analyzed for the following parameters:

Total organic carbon.
Extractable materials.
Arochlor 1254 and 16 priority pollutant pesticides.
Saturate hydrocarbons.
Low molecular weight polynuclear aromatic hydrocarbons (LPAH).
High molecular weight polynuclear aromatic hydrocarbons (HPAH).
Total polynuclear aromatic hydrocarbons (TPAH).
Metals:
Copper, Zinc, Lead, Arsenic, Mercury, Cadmium.
Suspended Solids.

Each of the composite sediment samples had previously been or were analyzed for the following parameters:

Grain size.
Total organic carbon.
Extractable materials.
Arochlor 1254 and pesticides.

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Saturate hydrocarbons.
Low molecular weight polynuclear aromatic hydrocarbons (LPAH).
High molecular weight polynuclear aromatic hydrocarbons (HPAH).
Total polynuclear aromatic hydrocarbons (TPAH).
Metals:
Copper, Zinc, Lead, Arsenic, Mercury, Cadmium.
Percent Water.
Percent Volatile solids.
Sulfides.

The aspiration apparatus was a 500 ml acid rinsed Erlenmyer flask connected to a vacuum pump. Teflon® tubes provide the connections to the pump and to the surface of the water samples. Aspiration occurred by placing the tip of the Teflon® tube near the air-water interface. The suction caused the surface of the water to rise to and into the tube. (Surfaced materials were observed to be drawn towards the suction tube.) The volume of samples obtained were measured immediately frozen. After 4 days of frozen storage, the samples were thawed, thoroughly mixed, aliquoted and dispensed for analyses.

Data were provided in concentrations based upon dry weight determinations or upon concentrations measured in the volume of microlayer. These concentrations were extrapolated to the total quantities contained within the sediment in the experimental containers or the total quantity contained in the volume of water aspirated from the containers. The percentage of available contaminant that surfaced was determined by the following:

$$\text{Percent Contaminant Surfaced} = \frac{\text{Total Surfaced Contaminant}}{\text{Total Sediment bound Contaminant}}$$

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RESULTS

The following measurements were made on the materials contained within the sediment composites:

Measurement	Units	Sequim Sediment	Everett Composite	Hart/Crowser Composite
Grain Size:				
Gravel	Percent	0.5	6.0	0.8
Sand	Percent	11.0	27.0	32.9
Silt	Percent	62.3	42.0	42.9
Clay	Percent	25.7	25.0	23.4
Total Organic Carbon	Percent(dry)	2.5	8.75	5.13
Metals:	μg/g (dry)			
Cu		48.0	100.0	24.9
Zn		88.0	216.0	576.0
Pb		9.0	61.0	93.0
As		7.3	11.0	51.5
Hg		0.07	0.67	0.161
Cd		0.90	0.73	3.77
Polynuclear Aromatic Hydrocarbons	μg/kg (dry)			
Total		812.	170,546.0	32,930.88
LPAH		213.0	32,844.0	1,566.49
HPAH		<50.0	125,501.0	14,900.43
Saturate hydrocarbons (C_9-C_{34})	μg/kg (dry)	[ ]	[ ]	4,952.66
Arochlor	μg/kg (dry)	<20.0	299.0	221.0
Pesticides (16 priority pollutant)	μg/kg (dry)	ND	ND	ND
Sulfides	μg/g (dry)	490.0	1,100.0	280.0
Percent Water	percent	53.6	63.0	77.0
Percent Volatile Solids	percent	6.1	22.0	19.9
Extractable Materials	μg/g (dry)	22.3	5,710.0	8,871.0
Total Mass of Sediment (Exp)	g (wet)	5,414.0	5,326.0	5,137.0
Total Mass of Sediment (Exp)	g (dry)	2,512.0	1,971.0	1,182.0

ND = Not detected

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The following measurements were made on the materials contained within the aspirated water sample:

Measurement	Units	Sequim SeaWater	Sequim Bay Sediment	Everett Composite	Hart/Crowser Sediment
Total organic carbon	mg/l	2.66	7.53	24.23	16.61
Metals:	µg/l				
Cu		12.3	9.6	59.5	22.3
Zn		3.22	22.2	88.8	33.3
Pb		<0.6	1.78	67.8	12.2
As		0.98	40.8	9.3	25.8
Hg		<0.01	0.011	0.171	<0.01
Cd		1.62	1.00	1.62	0.81
Polynuclear Hydrocarbons	µg/l				
Total		42.71	28.03	48.65	52.63
LPAH		ND	ND	ND	ND
HPAH		6.9	ND	6.9	1.91
Saturate Hydrocarbons (C_9-C_{34})		0.93	0.87	1.19	0.71
Arochlor 1254		ND	ND	ND	ND
Pesticides (16 priority pollutants)		ND	ND	ND	ND
Sulfide		ND	ND	ND	ND
Extractable Materials	µg/ml	ND	ND	43.0	4.0
Suspended Solids	mg/ml	0.15	0.31	0.45	0.35
Total Volume Aspirated	ml	950.0	1000.0	1025.0	1575.0

ND = Not Detected

Total quantity of materials contained in sediments and the total quantity of that material that reached the surface are contained in the following table:

Material	Units	Sequim Test µlayer	Sequim Test Sediment	Everett Composite µlayer	Everett Composite Sediment	Hart/Crowser µlayer	Hart/Crowser Sediment
Organic Carbon	(mg)	7.53	62,800	24.84	172,463	26.16	60,636.6
Cu	(µg)	9.6	120,576	60.98	197,100	35.12	29,431.8
Zn	"	22.2	221,056	91.02	425,736	52.45	680,832.0
Pb	"	1.78	22,608	69.50	120,231	19.22	109,926.0
As	"	40.8	18,338	9.53	21,681	40.64	60,873.0
Hg	"	0.011	175.84	0.175	1,320.6	< 0.02	190.30
Cd	"	1.0	2,260.80	1.66	1,438.8	1.28	4,456.14
Total PAH	"	28.0	[ ]	49.87		82.89	51,866.14
LPAH	"	ND	535.06	ND	64,735.5	ND	1,851.59
HPAH	"	ND	<125.6	7.07	247,362.5	3.008	17,612.31
Saturate Hydrocarbon	"	0.87	[ ]	1.22	[ ]	1.12	5,854.04
Arochlor 1254	"	ND	<50.24	ND	589.33	ND	261.22
Pesticides	"	ND	ND	ND	ND	ND	ND
Sulfides	"	ND	1,230,880.0	ND	2,168,100.0	ND	330,960.0
Extractable Materials	"	ND	56,017.6	44.08	11,254,410.0	6.3	10,485,522
Suspended Solids	(mg)	0.31	NA	0.46	NA	0.55	NA

Percentage of each material contained in Sediments that also rose to the surface was:

Material	Sequim	Everett Composite	Hart/Crowser
Organic Carbon	1.2×10^{-2}	1.4×10^{-2}	4.3×10^{-2}
Cu	8×10^{-3}	3.1×10^{-2}	1×10^{-1}
Zn	1×10^{-2}	2.1×10^{-2}	7.7×10^{-3}
Pb	7.8×10^{-3}	1×10^{-1}	1.7×10^{-2}
As	2×10^{-1}	4.4×10^{-2}	1×10^{-1}
Hg	6.3×10^{-3}	1.3×10^{-2}	$< 1 \times 10^{-2}$
Cd	4.4×10^{-2}	1×10^{-1}	2.9×10^{-2}
Total PAH			2.0×10^{-1}
High PAH		2.9×10^{-3}	1.7×10^{-2}
Saturate Hydrocarbons			1.9×10^{-2}
Arochlor 1254	------	------	------
Extractable materials		3.9×10^{-4}	6.0×10^{-5}

ND = Not detected
NA = Not Applicable

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APPENDIX F

APPENDIX F

DISPOSAL ALTERNATIVES ANALYSIS

Introduction. This analysis presents the relative advantages and disadvantages of the alternative disposal options that have been considered for disposal of East Waterway sediments. A comparison of alternatives is presented, noting the important issues and tradeoffs associated with each disposal option. Three basic types of disposal are typically considered for contaminated dredged material: contained aquatic (CAD), nearshore (intertidal), and upland. Though nearshore sites were identified and evaluated for the Navy Homeport project, nearshore disposal can be generally described as possessing some of the advantages and disadvantages of CAD and upland. Therefore, discussion will focus on these two disposal options. To further clarify the analysis, dredging methods for each of these alternatives will be constant: mechanical dredging with CAD option and hydraulic dredging with upland disposal. Pertinent contaminant pathways are addressed in the context of comparing disposal method, identifying the key pathways and effects. Control and treatment options available for each disposal method are summarized, along with remedial action techniques.

Identification of Contaminant Pathways. The processes involved with the release or immobilization of most sediment-associated contaminants are regulated to a large extent by the physicochemical nature of the disposal environment. Where the physicochemical nature of a contaminated sediment is altered by disposal, chemical and biological processes important in determining environmental consequences of potentially toxic materials may be affected.

Physicochemical (oxidation-reduction, pH, and salinity) conditions of dredged material at a disposal site influence the mobility and bioavailability of most contaminants. Typical marine dredged sediments are anoxic (reduced) and near neutral in pH. Depending on the disposal methods selected and the properties of the dredged material, changes in the physicochemical conditions at the disposal site may result in substantial mobilization of certain contaminants. Understanding the interaction between contaminants, dredged material properties, and physical, chemical and biological conditions at a proposed disposal site will aid in selection of disposal methods that will minimize potential contaminant release in many cases. Disposed into an aquatic environment, dredged material remains water-saturated, anoxic, reduced and near neutral in pH. In contrast, when sediment is taken out of the water and allowed to dry in an upland site, it becomes oxic and the pH may drop. Nearshore disposal sites have a combination of anoxic, reduced conditions below tidal elevation and oxic conditions in the dredged material placed above the tidal elevation.

There are several physical, chemical and biological processes that can result in transport of contaminants through a sediment/water environment. These mechanisms include:

- o diffusion of dissolved chemicals down a concentration gradient

- o convection and dispersion of dissolved chemicals due to water flow through the sediment (groundwater, precipitation, runoff, tidal action) and sediment consolidation

- o bioturbation of the sediment

- o scour and suspension of surface sediment particles by water and air currents

- o gas generation and ebullition within and through the sediment.

All of these mechanisms can be active in some disposal options, while only one or two may be active in others. Though some active transport mechanisms will be operative in all disposal options, and none of the options will provide a permanent, complete isolation of the contaminants from the environment, environmentally sound disposal of contaminated dredged material can be achieved using any of the major alternatives if appropriate management practices and technologies are employed.

The potential contaminant effects and pathways are quite different for each of these options. For CAD, mechanical dredge resuspension, barge transport leakage, sea surface microlayer releases, water column stripping, nepheloid layer (near bottom) losses and the animal effects and uptake that might be associated with the exposed mound of deposited sediment on the bottom (prior to capping), must all be considered. For upland, hydraulic dredge resuspension, volatilization, effluent releases, sea surface microlayer releases, runoff, leachate and animal/plant effects and uptake from the deposited sediment (prior to covering) must be considered.

CAD Pathways. Mechanical dredging generally results in greater resuspension of sediment at the dredging site than does hydraulic dredging. The action of the mechanical bucket through the water column results in resuspension estimated to be about twice the amount expected with hydraulic dredging (2 percent versus 1 percent resuspension). When compared to turbidity resulting from shipping activities and natural storms, and given the generally disturbed nature of many waterways where dredging occurs, resuspension at the dredging end is less important than potential effects elsewhere in the dredging and disposal process. Elutriate testing provides an assessment of the resuspended contaminants that might result at the dredging site.

Barge transport leakage is not considered a major contamination pathway. Fine-grained sediments usually hold their moisture content; consolidation of the material in the barge will usually push water to the surface of the barge, not to the bottom. Improper operation of the barge equipment (e.g., not ensuring a complete closure of the barge before loading) must be avoided.

The sea surface microlayer (SSM), consisting of the top 100 microns (um) (0.002 in.) of the sea surface, has been shown to contain increased numbers of bacteria, phytoplankton, and animal eggs and larvae. In addition, the SSM often concentrate materials that are not very soluble, are lighter than water, and/or are adhered to floatable matter and debris. These surface concentrations are a natural event, often comprised of chemicals derived from marine plants and animals. However, the SSM also has been shown to contain increased concentrations of contaminants, from 2 to 125 times higher metal concentrations and 100 to 1,000,000 times higher organics concentrations relative to subsurface waters. Once in the SSM, these contaminants can adversely affect marine eggs and larvae and can be carried to nearby beaches. While solar and bacterial degradation of some of the contaminants occurs over time, wind and surface currents often concentrate rather than disperse surface materials.

Dredging and dredged material disposal represent disturbances of the bottom sediments that result in the release of fine particles and organic matter to the water column. Visible "slicks" and occasional "sheens" have been reported during dredging in the Elliott Bay area. Though most of the dredged material solids will settle to the bottom, dredged material will contain some material that could be released to the surface.

As the discharged dredged material descends through the water column, the sediment mass will entrain water and particles can be "stripped away." These water column losses can contain both dissolved and particulate-associated contaminants, which can be assessed by use of the elutriate testing procedures. The fraction of the sediment contamination that is released into the dissolved state varies between 0.0 and 0.08 percent. Though the fraction loss is low, the actual concentrations associated with the dissolved fraction are evaluated by comparison to water quality criteria and background conditions.

The validity of relying solely on water quality criteria to assess the dredged sediments is questionable. Assessing each contaminant independently does not allow for synergistic effects, and water quality criteria do not necessarily protect against contamination of sediments and bioaccumulation of contaminants by aquatic species. For this reason biological tests (e.g., oyster larvae and bioluminescent bacteria (microtox)) are needed to assess the water column losses. These tests allow animals to "experience" all the contaminants present in the water, whether measured or not. Similar reasoning was behind the need to conduct benthic bioassays and bioaccumulation testing in order to assess direct sediment contamination pathways. While the long-term fate of released contaminants cannot be ascertained, natural mixing and dilution, along with tendency for contaminants to bond again into the sediment, suggest that adverse effects would not persist. This is supported by the fact that historic assessment of dredging projects, which emphasized the water column issues, rarely showed significant adverse effects resulting from dredging projects. The sediment contamination chemically prefers to remain with the sediment particles.

All data from chemical analyses and bioassays using elutriated contamination (in water or suspended form) should be interpreted in light of mixing. This is necessary since biological effects (which are the basis for water quality criteria) are a function of biolorically available contaminant concentration and exposure time of the organism. In the field, both concentration and time of exposure to a particular concentration change continuously. Both factors will influence degree of biological effect. There is ample precedent and substantive reference to dispersion, mixing and dilution in current law. The Clean Water Act specifies the consideration of effects, persistence, concentration, dispersal, rates, volumes, loads, and permanence of contamination and associated consequences in the establishment of standards and criteria (i.e., sections 303, 304, 307, 403). The related Section 404(b)(1) guidelines define a "mixing zone" where standards will not be met initially, providing factors for determining acceptability of a needed zone, and requiring permitting authorities to consider mixing in evluating water column effects. Several of the water quality criteria are based on 96 hour "LC 50's," which require a mixing analysis to determine if a concentration will persist for that period of time. In addition, the State of Washington routinely prescribes dilution zones for dredging activities related to State water quality standards.

Particulate losses in the water column primarily occur near the bottom. These losses are predicted by use of disposal models and past information from other dredging projects. Some of the material released during water column descent will settle out in the disposal site. Some of it will drift off-site. The degree of loss will depend on the relative strength of active transport mechanisms (i.e., wind and wave currents and tidal action) at the disposal site.

Once placed, the disposal mound will contain the majority of material originally dredged. Returning the material to a neutral, anaerobic geochemical environment reduces the potential for contaminant release into the water column. But until capped, the material will still be exposed to animal contact and passive diffusion of surface contamination. Though in a similar state to that present in the waterway prior to dredging, the material would now be located in an area previously less directly exposed to that degree of contamination.

Upland Pathways. As mentioned above, resuspension at the dredging site will be less with the hydraulic dredge than with a mechanical dredge. Since a hydraulic dredge uses water movement to move sediments, the suction forces generated by the pump will entrain much of the suspended material given proper operation of the dredge equipment. However, this efficiency advantage of hydraulic equipment results in the need to address added water and associated mobilized contamination at the disposal end of the process.

Transport of the dredge slurry typically occurs via pipeline. Though leakage at the pipe joints is common on routine operations, design features for transporting contaminated slurries will reduce this potential loss.

The greater degree of agitation provided by the hydraulic dredging process, including the initial discharge into the disposal site, can result in volatilization of certain contaminants to the air. This is only a significant concern if the contamination is relatively volatile, which does not include the major types of contamination present in the Everett Harbor sediments. As the sediments dry out, contaminant losses to the air may increase. Changes in atmospheric pressure can "barometrically pump" air through the sediment mass and facilitate chemical losses. Aerobic degradation of the organic matter matrix that currently binds many of the chemicals will render additional chemicals mobile and subject to air loss. Again, the significance of this potential contaminant pathway is dependent on the type of contamination present.

After most of the solids have settled in the disposal site, the dredge slurry water will be discharged back into the environment. This effluent can be a significant carrier of both dissolved and particulate-bound contamination. Assessment of this potential loss is based on the results of the modified elutriate tests. With upland disposal, determining whether the necessary mixing zone is acceptable can often be more of an issue than with aquatic disposal. This is because effluent discharge will normally occur in a smaller water body, with less dilution potential, and because the discharge is relatively continuous over the dredging project construction period and not discrete like barge disposal. Accordingly, the final determination of mixing zone acceptability will be site-specific. The amount of contamination present in the particulate phase of the effluent will also be site specific because contamination is dependent on the amount of particles left in the effluent and particle settling depends on the site configuration and discharge rate into the site.

Floatable contamination present in the effluent would contribute to the SSM. These losses could be more important than those associated with CAD given the degree of disturbance resulting with hydraulic dredging. Though treatment of the effluent can significantly reduce contaminant losses via the effluent, treatability of SSM contamination in the effluent has been sufficiently researched to determine effectiveness.

Sediment consolidation will extrude interstitial water (mostly to the sediment surface). This water, combined with runon and precipitation water, will result in site runoff, another carrier of contaminants. Site runoff is typically an issue during initial dewatering of the disposal site. Assuming that a cover is eventually placed over the site, and that basic runon controls will be provided, long-term runoff problems can be minimized. As with effluent, contamination in the runoff is both dissolved and particle-bound. Unlike the effluent, longer-term geochemical changes due to oxidation in the upland site can mobilize additional contamination which would be available for transport by ground or surface water.

Related to surface runoff, contaminant effects due to plant and animal uptake can result if the dredged material is left exposed for sufficient period of time. Cover material, placed after initial dewatering is complete, will reduce both runoff and uptake losses.

Upland disposal can also result in leaching of the contaminants to the groundwater or back to surface waters (seeps). The geochemical changes associated with disposal on land typically result in mobilization of a large fraction of some of the contaminants. If the material could be placed under the water table at a given site (usually more of an option for nearshore disposal), this mobilization could be significantly reduced. Experience with dredged material throughout the Nation indicate that mobility of metals and organic contaminants remains low under anaerobic conditions. Under aerobic conditions, metals can be mobilized in large quantities.

Summary of Key Contaminant Pathways for East Waterway Sediment. Summarizing the above discussion and considering the results of the contaminant mobility tests, the key contaminant pathways that require consideration for Everett Harbor sediments are:

- CAD: deposited mound
  near-bottom mass release

- Upland: effluent releases
  leachate releases

Though biological effects are the key to assessing the acceptability of potential contaminant releases, the mass release of contaminants cannot be directly related to effects because the fate of the released materials cannot be ascertained. This is true for both CAD and upland disposal. Dispersion of the particle-associated mass releases will reduce concentrations and thereby reduce potential effects. At best, far-field effects of particle-associated mass releases are not expected to exceed, and will likely be much less than, observed effects in the lab. For the dissolved fractions, released contaminants will be rapidly diluted to levels not associated with adverse effects.

For CAD, current estimates of the mass release for the combined dredging and disposal are around 4.1 percent, split evenly between the dredging and disposal sites. Though estimated mass release for upland depends on the specific site involved, releases for the nearshore sites in the Everett Harbor area were calculated to vary from 4.3 to 5.5 percent. The primary differences between CAD and upland mass releases is the potential for using effluent treatment to reduce contaminant losses. Given the unknown fate of the releases, proper siting of the disposal site and reasonable management practices (including design and performance goals) are the primary tools for addressing mass releases. The fact that the bulk of the contamination still remains with the deposited sediments is also salient.

Control and Treatment Options. Proper siting of a disposal site is the usual key to successful disposal of contaminated sediments. Once acceptable site locations have been found, any type of disposal site can be designed to acceptably confine contaminants. "Acceptability" of a given design for contaminant control is partially independent of the site location; although, the necessary and acceptable design will be greatly influenced by the site location and characteristics. These, in turn, influence cost of disposal and final selection of preferred disposal option.

There are many control and treatment options that could be applied at specific disposal sites. Even though many of the technologies are not demonstrated or do not appear to be demonstratable in the near future, the number of feasible control and treatment alternatives needing evaluation still represent a reasonable number of choices. These major alternatives for restricting contaminant migration are discussed below.

The alternatives are ranked in order of increasing cost and contaminant management effectiveness. These ranks represent the general order in which they may be considered and applied in order to achieve acceptable design at any given site.

The development of schemes that address contaminant resuspension at the dredge must first consider the type of dredging operation (i.e., mechanical or hydraulic). Primary control and treatment alternatives addressing the resuspension at the dredge include:

- Mechanical Dredging

  (1) Operational Controls
  (2) Operational Controls + Water Tight Bucket
  (3) Operational Controls + Water Tight Bucket + Silt Curtains
  (4) Hydraulic dredging

- Hyraulic Dredging

  (1) Operational Controls
  (2) Operational Controls + Dredge Modifications
  (3) Operational Controls + Dredge Modifications + Silt Curtains
  (4) Special Purpose Dredges
  (5) Special Purpose Dredges + Silt Curtains

Primary control and treatment schemes that address the pathways of aquatic disposal include:

(1) Operation Controls
(2) Operational Controls + Downpipe
(3) Operatioinal Controls + Downpipe + Diffuser
(4) Lateral Confinement
(5) Capping
(6) Lateral Confinement + Capping

Development of schemes that address the surface water pathway must consider both short and long term contaminant release. Short term releases result from the discharge of effluents during active dredging operations, particularly hydraulic dredging operations. Long term releases result from direct rainfall runoff, rainfall runon and subsequent runoff, and dredged material dewatering processes. Primary control/treatment schemes that address contaminant migration through the surface water pathway include:

- Effluent (Short Term)

  (1) Collection and Treatment of Effluent
  (2) Mechanical versus Hydraulic Dredging

- Runoff (Long Term)

  (1) Runoff/Runon Control + Cover
  (2) Runoff/Runon Control + Direct Rainfall Collection
  (3) Runoff/Runon Control + Cover + Direct Rainfall Collection

Primary control/treatment schemes which address contaminants released through the leachate/groundwater pathway include:

- o Runoff/Runon Controls
- o Runoff/Runon Controls + Cover
- o Runoff/Runon Controls + Single Liner
- o Runoff/Runon Controls + Cover + Single Liner
- o Runoff/Runon Controls + Double Liner
- o Runoff/Runon Controls + Cover + Double Liner
- o Runoff/Runon Controls + Cover + Single Liner + Leachate Collection
- o Runoff/Runon Controls + Double Liner + Cover + Leachate Collection
- o Solidification/Stabilization of Dredged Materials

Primary control/treatment schemes that address the plant$and animal uptake pathway include:

- o Site security
- o Chemical treatment
- o Covers
- o Site security + Covers

Primary control/treatment schemes that address the direct contact pathway include:

- o Site security
- o Covers
- o Site security + covers

Primary control/treatment schemes that address the air pathway include:

- o Covers
- o Buffer zones
- o Cover + Buffer zone
- o Solidification/Stabilization of Dredged Material

Disposal of contaminated sediments in the upland environment may produce contaminated liquids including effluent produced during active dredging operations, runoff water produced during initial dewatering and rainfall events, and leachate produced during initial dewatering and subsequent rainfall events. Six levels of treatment for site waters can be identified. These are listed in order of increasing cost and complexity:

- o Level I is the removal by sedimentation of suspended solids and particulate-bound contaminants from disposed and site-derived water. This level would remove 99.9 percent of solids, 80-99 percent of heavy metals, and 50-90 percent of organic contaminants.

- o Level II is additional treatment to remove soluble metals. This level would increase heavy metals removal to 99 percent.

- o Level III is treatment to remove soluble organics. This level increases organics removal to 95 percent.

- Level IV is treatment to remove nutrients such as ammonia and phosphorus.

- Level V is treatment to remove dissolved solids. This level would increase organics removal to 99 percent, but is primarily designed to remove nonmetallic, inorganic contaminants (e.g., nutrients and common anions).

- Level VI is disinfection for destruction of pathogenic organisms.

Remedial Action Techniques. There are two types of remedial techniques that can be utilized in the dredging and disposal of contaminated sediments. During the construction phase, contingency plans (short-term remediation) will specify how unexpected events will be addressed to prevent uncontrolled release of contaminants. In the longer term, remedial response is an integral part of the monitoring plan at the disposal site. Monitoring data are used to determine when remedial actions are needed and what they should be.

For CAD, the placement of additional or different capping materials is the primary method for remediation. How more material could fix a problem that the original cap could not handle is best understood by considering an assessment of the possible reasons for failure of the original cap. These reasons include:

- incomplete original capping (or inadequate thickness)
- unexpected animal or human bioturbation
- unexpected physical erosion or geologic disturbance
- through-cap diffusion of chemicals
- ebullition (gas formation) and cap disruption

Of these five possibilities, the first three are more likely possibilities than the latter two. These three are effectively addressed by adding more cap material. Through-cap diffusion is a very slow process. Ditoro estimated PCB movement through sediment caps to be less than 1 cm per year. This diffusion rate can be easily monitored via cap coring and analysis (most caps are self-healing after coring). More cap material continues to effectively prevent release of the contamination. Ebullition can result in gas-transported contaminant loss, but is greatly reduced in anaerobic environments relative to aerobic ones. Any physical cap disruption can be repaired by more cap material. In addition, different cap materials can be brought to the site to improve thickness, provide resistance to erosion, reduce permeability, etc., as needed. Again, the key is an effective monitoring program.

Remedial response at upland sites is much more diverse. Once the site has been filled, typical monitoring includes leachate and runoff quality measurements. Assuming runon controls and surface covers are in place, and gas formation is not a major issue, the emphasis in the long-term is ground water and surface water seeps. Sites can be designed to include second liner systems and leachate collection drains, though these types of designs are usually specified for more dangerous and hazardous waste. With these systems, leachate can be monitored, collected and treated, as necessary. Without these systems, leachate loss into the groundwater is difficult, at best, to remediate and may often be impossible. Rates of ground water movement and frequency of the monitoring measurements are important factors here. Longevity of these underground systems is also dependent on geologic stability of the area.

Disposal Site Tradeoffs. Disposal sites represent chemical gradients from high contamination levels within the site to lower levels outside the site. These gradients naturally tend to drive contamination out of the site. Factors affecting the rate of movement include the solubility of the chemicals (all chemicals are soluble to some degree), the geochemical condition of the sediment matrix (aerobic or anaerobic), and physical forces (such as water and air movement in and around the sediment mass).

Consequently, there is no permanent confinement, no technology that is guaranteed to work in the long term. CAD capping material and upland liners will, over the long term (decades or longer), become saturated with moving chemicals. Even water treatment technologies, such as chemical clarification, do not completely remove contaminants. Additionally, most treatment technologies result in "spent" or concentrated, contaminated materials that must be disposed of elsewhere. Technology for upland disposal sites is much more developed and proven than for CAD sites. On the other hand, chemical mobility and geologic stability favors aquatic sites. In either case, the consequences of technology failure must be weighed, and long term potential releases should be considered. This again emphasizes the importance of proper site selection.

Therefore, the "acceptable" design for a given site is not necessarily dependent on an analysis of several sites with varying design. Given enough money and time, any site can be designed to acceptably contain contaminated sediments. There is no "technically best" option from the perspective of contamination confinement, the keys are usually site availability and costs of design to achieve acceptability. At the heart of this siting decision is the weighing of very different types of resources and conditions present at the different types of sites. Socioeconomic and political considerations play major roles in this weighting.

Consideration of the adverse effects associated with the sediment in place in the waterway (in situ effects) is often useful as a reference in determining acceptability for the design at different sites. The sediments in most harbor waterways typically represent areas impacted by contamination and reduced dissolved oxygen levels. Biological value of such areas is relatively low as a result. Final conditions that would exist in the disposal sites should be considered in relation to pre-project conditions. While the dredging project would relocate and isolate this material to other areas not currently exposed to this degree of contamination, unless "loading" of contaminants is continuing at substantive levels, conditions within the harbor would be expected to improve.

The key considerations involved with disposal method effectiveness are:

- the class of contaminants of concern,
- the similarity of the disposal site condition to in situ conditions,
- the number and magnitude of contaminant transport mechanisms

operating at the disposal site,

- o the degree of control or treatment possible to intercept migrating contaminant fractions, and
- o the risk of significant adverse effects from contaminants released by the disposal method.

Heavy metals often go into solution and become mobile in oxidized, unsaturated sediments. Organic contaminants tend to remain partially soluble regardless of how wet or dry the sediment stays. Therefore, they will have greater mobility where greater exchange of water within the sediments occurs. Nearshore sites have greater water exchange than upland, and upland has greater exchange than open water.

In general, disposing of contaminated sediments in a chemical environment as close as possible to their in situ state favors retention, especially of metals. Geochemical changes associated with air and oxygen in upland and nearshore sites can change sediment pH (mobilizing metals) and alter (dissolve, degrade, or volatilize) sediment organic carbon (mobilizing organics). Based on this, many contaminants would tend to stay bound to sediments better in an open-water, capped site than a nearshore or upland site.

Open-water sites, especially those in deep water, have fewer transport mechanisms (e.g., air is absent) than upland sites. Nearshore sites have the most transport routes available and are located in a very active environment; therefore, nearshore disposal is the least preferred method for long-term confinement of contaminants.

In terms of controlling contaminant release, open-water disposal allows for very few controls of releases other than cap thickness. However, increasing cap thickness is a relatively simple and effective control method. Upland disposal allows for the greatest control through design features, monitoring capabilities, backup contaminant intercept systems, and treatment facilities, but at substantially greater cost.

Mass releases will occur at several phases of the project and at all types of disposal sites. The mechanical/CAD option will have losses at the dredging site, during transport, to the microlayer, during water column stripping, to the nepheloid, and prior to and during capping. The hydraulic/upland option will have releases at the dredging site, from pipeline joints during transport, to the air upon discharge to the site, in the effluent, via the leachate and prior to and during covering operations (runoff), if included. Different controls and treatments can assist in reducing these releases. Since the fate and effects of these released contaminants is unknown, reasonable management practices are needed in direct relation to nearby resources that might be at risk. Thus, mass releases are substantively addressed by proper site location. Additional technology can be utilized as necessary.

The factors that differ between the basic options of CAD, nearshore, and upland are shown in table F-1. The arrows indicate the site type that is favored by the factor.

In the comparison of sites (which is ideally done without specified design alternatives for contaminant confinement), the relative value of resources, the ascribed importance of costs and time relative to risk amelioration, and the favoring of either technology (upland approach) or contaminant immobility (CAD approach), will all require a decision that is not entirely technical, but is social as well.

In summary, assuming that effluent treatment is conducted at the upland site, CAD represents a situation of higher short-term mass releases, but has opportunities for longer-term control due to lower mobility of chemical contamination. Upland disposal relies more heavily on technology, has less short-term mass releases, but greater long-term concerns due to mobilized contamination (and the very steep chemical gradients that result) and the active physical forces that can move contamination. Nearshore, generally a more dynamic environment than either CAD or upland, shares advantages and disadvantages of both the other options.

TABLE F-1

FACTORS OF CONSIDERATION BETWEEN BASIC DISPOSAL OPTIONS
(Arrows indicate option favored)

Factor	Contained Aquatic (CAD)	Nearshore	Upland
Technology	----->	----->	----->
Remediation	----->	----->	----->
Monitoring	----->	----->	----->
Mass Release			
with Treatment	----->	----->	----->
Surface Water Quality	----->	----->	----->
Aquatic Habitat/Life	----->	----->	----->
Groundwater	<-----	<-----	<-----
Terrestrial Habitat/Life	<-----	<-----	<-----
Human Exposure	<-----	<---->	<-----
Geochemistry/Mobility	<-----	<-----	<-----
Volatilization	<-----	<-----	<-----
High Energy Potential	<-----	<---->	<-----
Dilution Buffer	<-----	<-----	<-----
Project Cost			
with Treatment	<-----	<---->	<-----

APPENDIX C

SMITH ISLAND FEASIBILITY DESIGN

DEPARTMENT OF THE NAVY

WESTERN DIVISION

NAVAL FACILITIES ENGINEERING COMMAND

NAVAL STATION PUGET SOUND

EVERETT, WASHINGTON

FEASIBILITY STUDY

UPLAND DISPOSAL ALTERNATIVES

SMITH ISLAND SITE

OCTOBER, 1986

PARAMETRIX, INC.

13020 NORTHUP WAY, SUITE 8

BELLEVUE, WASHINGTON 98005

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B Leachate Control System - Smith Island Upland Disposal Site Feasibility Study. Letter Report. Parametrix, Inc. October 1986

C Water Quality Data Tabulation, Steamboat/ Union Sloughs, Snohomish River Estuary, Smith Island Disposal Site Feasibility Study. Samples Collected October 1, 1986.

D Wetland Determination for the U.S. Navy's Homeport Alternative on Smith Island near the Snohomish River at Everett, WA. September 30, 1986.

I. INTRODUCTION

The U.S. Department of Navy proposes to build a Carrier Battle Group homeporting facility in East Waterway in Port Gardner at Everett, WA. Development of this facility will require dredging and disposal of both contaminated and clean sediments from East Waterway to provide navigation depths for the homeporting vessels. The Navy homeport proposal, including its dredging and disposal activities, has been the subject of extensive data development and evaluation in terms of a major Environmental Impact Statement (FEIS, 1985, and DEISS, 1986).

Smith Island is being considered as an upland site for disposal of contaminated sediments dredged from East Waterway for the proposed homeporting project. This report presents a feasibility study of two basic disposal configurations for upland disposal at Smith Island, as follows:

1. Excavated disposal site. A cell would be excavated below existing groundwater level and subsequently backfilled with contaminated sediments. Sediments would remain saturated and anaerobic over the long term.

2. Elevated disposal site. Contaminated sediments would be placed above existing ground and water table within a constructed perimeter dike. Sediments may eventually dry and become aerobic (oxidized) over the long term with resulting potential need for leachate controls.

II. PHYSICAL CHARACTERISTICS

Smith Island is located in the Snohomish River delta approximately 4 miles upstream from the dredging area in East Waterway (Figure 1). The proposed disposal site is located on the north edge of Smith Island adjacent to Steamboat Slough. Roughly triangular, the site is bounded on the east by Burlington Northern Railroad and on the south by a remnant non-tidal slough forming a boundary with Weyerhaeuser Corp. property. The site is in private ownership parcels and lies entirely within City of Everett city limits.

The proposed disposal site (Figure 2) comprises about 110 acres overall and is the combined area of disposal sites 2 and 4 identified previously in the Navy FEIS (1985). It is primarily an upland area contained within a low dike along Steamboat-Union Sloughs, with an isolated wetland area about one-quarter acre in size within the site boundaries (Wetland Determination, Corps of Engineers, September 30, 1986, see Appendix D). Ground elevations within the site typically range from +2 feet to +5 feet above Mean Sea Level (National Geodetic Vertical Datum) with average elevation of about +3 feet. (NOTE: Add +6.5 feet to msl

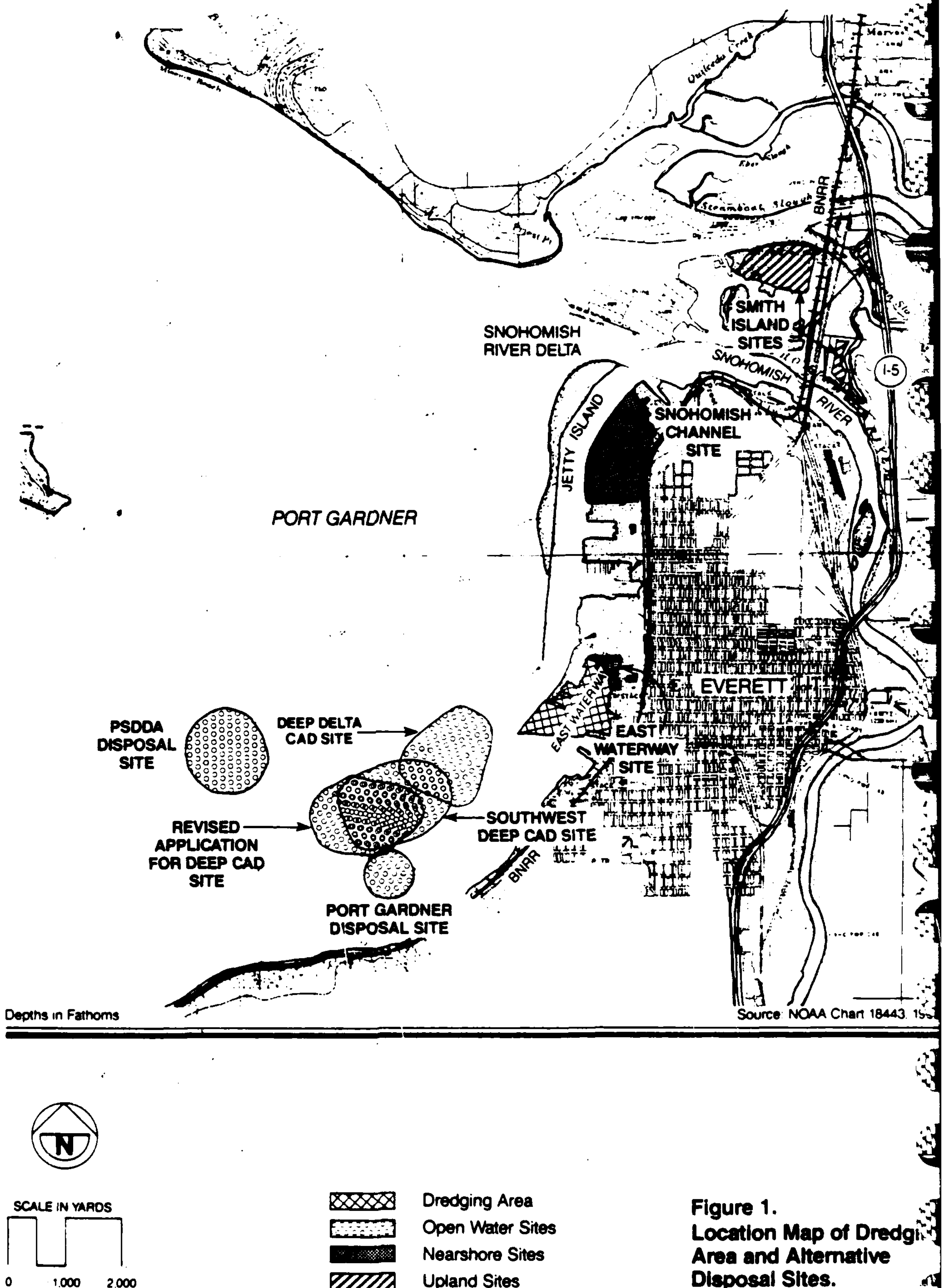


Figure 1.
Location Map of Dredgi
Area and Alternative
Disposal Sites.

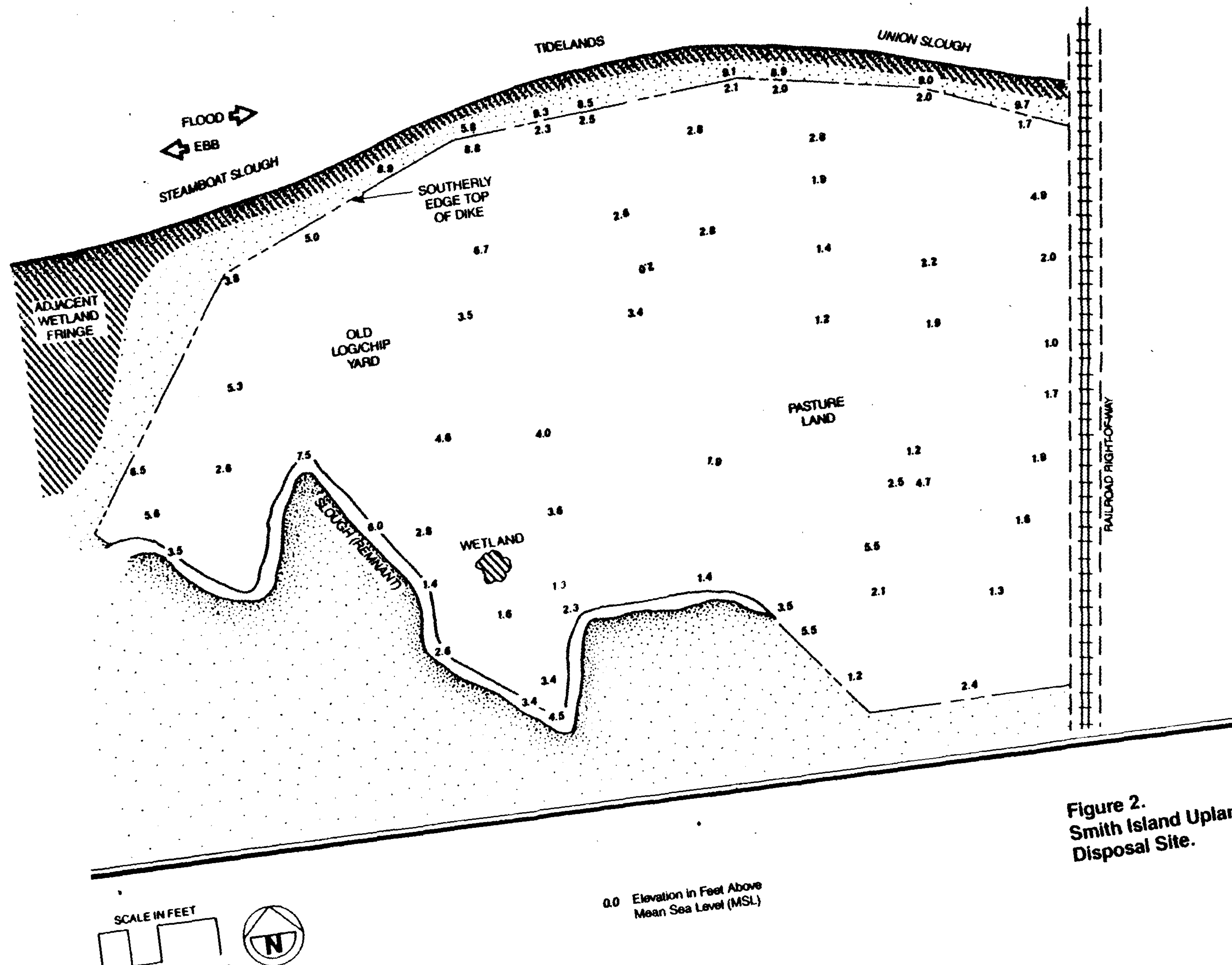
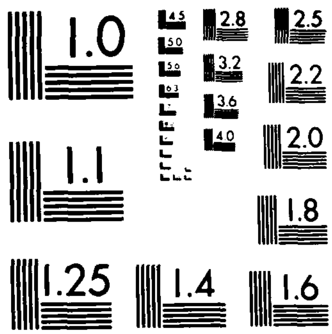


Figure 2.
Smith Island Upland Disposal Site.

AD-A175 114   CARRIER BATTLE GROUP (CVBG) HOMEPORTING IN THE PUGET   5/7
SOUND AREA WASHINGTON STATE TECHNICAL APPENDICES(U)
CORPS OF ENGINEERS SEATTLE WA SEATTLE DISTRICT   NOV 86

UNCLASSIFIED   F/G 6/6   NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

elevations to obtain elevations referred to Mean Lower Low Water (mllw); e.g., 0.0 feet msl is +6.5 feet mllw.) All of the site lies within the 100-year (base) flood plain at elevation of +9 feet of the Snohomish designated in Snohomish County Flood Insurance Study (FEMA, 1984). The westerly portion of the site has been filled with coarse grained sediments for the purpose of log storage and sorting (now abandoned). The easterly area is a pastureland at lower elevation than the west. A fringe wetland area is present outside and adjacent to north and west boundaries of the disposal area.

III. DISPOSAL CONCEPTS

Disposal of East Waterway contaminated sediments to Smith Island site is constrained by the need to minimize potential impacts of leachate generation. Corps of Engineers leachate tests (Appendix B of the Draft EISS) show that sediments maintained in a saturated anaerobic condition generate substantially less concentrations of leachate contaminants than do the same sediments in an aerobic condition. As the contaminated sediment mass dries, it tends to become oxidized, with an associated drop in pH and resulting mobilization of certain contaminants. Corps leachate test results for selected parameters of concern are shown in Table 1 in comparison with Federal/State Safe Drinking Water Standards. Whether and to what extent leachate controls may be required is dependent upon site-specific conditions and may include the need for Regional Authority decision (RAD) concerning resource impacts.

For the purpose of this feasibility study, two upland disposal options for Smith Island are evaluated as satisfying the need to minimize leachate impacts:

1. Excavated Upland. This option will place all contaminated sediments in an excavated cell below existing groundwater level. This requires removal of existing ground, both above and below groundwater level. This option will keep the contaminated mass in its saturated anaerobic condition over the long term and minimize potential for contaminant release. A dredged cap of clean East Waterway sediments would be placed to prevent surface runoff and vegetative intrusion. A low perimeter dike is needed to provide confinement and retention time for hydraulic placement of the dredged cap. Material excavated for the contaminated disposal cell would be disposed to other sites in the vicinity of Smith Island. It should be noted that safe drinking water criteria are moderately exceeded by anaerobic leachate (Table 1); consequently, RAD may be required for this disposal option.

2. Elevated Upland. This option would place all contaminated sediments and cap materials above existing ground level

within constructed perimeter dikes. It is assumed that the contaminant mass would eventually dewater and oxidize, resulting in potentially high leachate concentrations requiring control. The control system considered in this feasibility study includes an impermeable liner under the contaminated cell, a leachate collection and treatment system, and an impermeable liner cap.

Table 1. Contaminant Leachate Concentrations (mg/l) For Flux Analysis

	Drinking Water Standards (mg/l)			
Contaminant	Federal	State	Anaerobic	Aerobic
As	.05	.05	0.039	<0.005
Cd	.01	.01	0.010	0.034
Cr	.05	.05	0.080	2.27
Cu	-	-	0.096	0.023
Ni	-	-	0.052	0.449
Pb	.05	.05	0.058	0.210
Zn	5.0	5.0	0.181	3.5
PCB	-	-	0.00036	0.00176

Note: Table taken from "Technical Supplement to Sediment Testing and Disposal Alternatives Evaluation," Corps of Engineers, Seattle District, September, 1986.

Both of the options are scoped to include all of the "dredge contaminated" sediments from East Waterway (i.e. 928,000 cu. yds. in situ x 1.3 bulking factor = Approx. 1.2 Million cu. yds.). Also, a minimum six-foot cap depth of clean-dredged sediments after consolidation is selected to provide runoff control and protection against vegetative intrusion. Remaining clean sediments dredged from East Waterway and not used for capping at Smith Island would be disposed of at an approved deep water disposal area in Port Gardner.

IV. GEOTECHNICAL CONSIDERATIONS

A review of geotechnical data was made to determine the subsurface soil and groundwater characteristics and to develop a geotechnical basis for feasibility design of the Smith Island upland disposal alternatives (Appendix A).

Subsurface Soil Conditions

An understanding of subsurface soil conditions at this site is based on three drilled explorations accomplished for this study by Hart-Crowser (Appendix A) as well as on soils information obtained by Hart-Crowser for previous studies in the area and by two studies accomplished at the site by others (Earth Consultants, Inc., August 1979, and Geotech Consultants, Inc., 1986).

Subsurface soil conditions as based on the above limited data are summarized below:

- The surficial 2 to 3 feet is composed of medium stiff, organic silt. This layer appears to be capable of supporting light construction access traffic.
- The medium stiff surface layer is underlain by very soft, wet, organic clayey silt with pockets of peat and sand seams to depths below ground ranging from 7 to 10 feet over the western portion and from 10 to 20 feet over the eastern portion of the site.
- The soft, clayey silt is typically underlain by medium dense, silty sand and sand to depths of at least 50 feet.

Groundwater

The general groundwater conditions at the Smith Island site, based on physiographic conditions and the general hydrologic setting, is characterized by shallow groundwater which is influenced by both tidal fluctuations and seasonal variations in precipitation.

Groundwater elevations are expected to vary depending on the tidal stage and season of the year. Precipitation not lost to runoff, used by plants, or evaporated, infiltrates and becomes recharge typically resulting in a mounding of groundwater under the island. General groundwater flow would occur laterally toward the perimeter of the island. Localized variations in permeability of the soils as well as tidal effects may influence the overall radial flow of groundwater to the surrounding surface water. Throughout the majority of the site the groundwater level is anticipated to be near MSL (+6.5 feet MLLW), with minor variations. This is consistent with observed groundwater levels measured in our monitoring wells at the site. More significant variations are likely immediately adjacent to the waterways due to tidal fluctuations.

Groundwater flow velocities are expected to be fairly low, especially in the upper silt layers due to the low permeability of the soils and low hydraulic gradients expected at the site.

Groundwater flow velocities may be higher in the underlying deeper sands due to the higher permeability; however, the hydraulic gradients are also expected to be fairly low in this lower soil unit.

There is currently limited groundwater quality data for the Smith Island site. Monitoring wells were installed and groundwater samples submitted on October 2, 1986 to a laboratory for analysis of dissolved metals, PCB's, TOX, TOC, and hardness. These parameters were identified as a potential concern from the U.S. Army Corps of Engineers, September 1986 report: "Technical Supplement to Sediment Testing and Disposal Alternatives Evaluation" prepared for the Department of the Navy, Western Division, Naval Facilities Engineering Command. Results of the tests were not available for inclusion at the time of this report. The results will be submitted in a separate addendum to this report when the testing is completed. Field test parameters including pH, temperature, and specific conductance were measured on October 1, 1986 in groundwater samples from the three monitoring wells installed at the site. The pH values measured were close to neutral, ranging from 6.61 to 6.86; temperature measurements were within the range of 11C to 12^{o}C; and specific conductance, which is a measure of the dissolved ion concentration, were measured in the range from 8,400 micro mhos/cm3 to 9,000 micro mhos/cm3. These values indicate the presence of brackish water which is consistent with the expected impact of saline intrusion to the Snohomish River estuary. The presence of brackish (salty) groundwater substantially limits its beneficial use.

Geotechnical Feasibility Parameters

Geotechnical feasibility parameters are outlined below for both the excavated upland and elevated upland disposal options. These are based on feasibility level engineering analyses of limited soil and groundwater information (Appendix A) and are not considered sufficient basis for design-level work. Each disposal option is considered separately. The bulked quantity of contaminated materials to be accommodated by either option is assumed to be 1.2 million cy.

Excavated Upland Disposal Site

This disposal option involves excavating existing soil to a sufficient depth to place the contaminated sediments below the groundwater level so that the sediments will remain in a saturated state as discussed elsewhere. This would reduce generation of leachate from the contaminated sediments to a low level. A cap of clean soil would be placed over the contaminated dredge material to reduce exposure of the contamination to the surrounding environment. A typical cross section for this option is illustrated in Figure 3.

Assumptions used for this option include:

- Groundwater level at the site is assumed to be at mean sea level. Average elevation of the existing ground level is approximately +3 feet MSL.

- A perimeter dike constructed to at least +10 feet MSL would be built to contain the cap material, and provide ponding and freeboard for hydraulic placement of the dredged materials.

- The excavation would extend to about elevation -9 feet MSL for placement of the contaminated sediments.

Discussion of this disposal option is divided into six categories: Excavation, Groundwater, Dike Construction, Settlements, Dewatering and Contamination Transport.

Excavation:

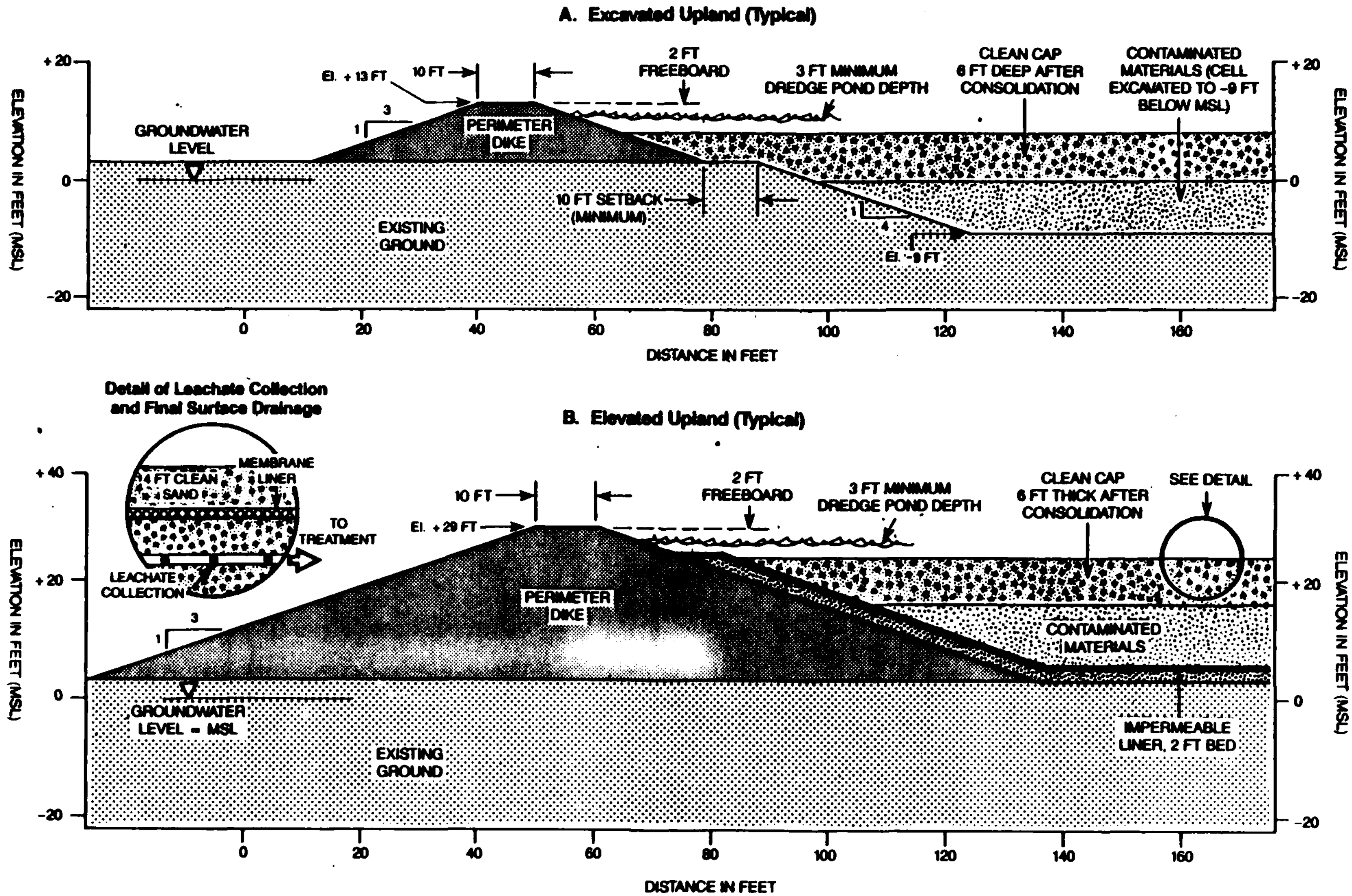
- Material excavated to -9 feet MSL at this site is expected to be predominantly soft, wet, organic silt and clay with varying amounts of peat and sand seams.

- Excavation made below the groundwater level would probably need to be cut at about 4H:1V or flatter to provide stable excavation slopes.

- Stockpiles of excavated soil would not support construction equipment unless an extended period of dry weather was available to allow the soil to dry.

- Future use of the site which receives the excavated soils would be limited due to the soft organic nature of those soils. The site would not be usable for several years without special treatment, allowing for reconsolidation of the excavated soils. Drainage provisions could be used to accelerate the consolidation process. Following that time and placement of a sand and gravel cap, the site might be used for light industrial applications. However, the site could still experience continuing settlement. Structures sensitive to settlement might require pile support. This does not mean that the site cannot be effectively used, but that adequate foundation design must be provided.

- Excavated soil may not be suitable for constructing dikes. Slopes of 4H:1V to 5H:1V or flatter may be required to construct a dike without significant slope failures during



Note: Elevations referenced to mean sea level (MSL)
Add 6 5 feet to MSL elevations to obtain
mean lower low water (MLLW) elevations.

Figure 3.
Smith Island Upland Disposal Concepts.

construction. Even at relatively flat slopes, localized sloughing would be expected. In addition, the wet organic material is expected to be difficult to work with conventional construction equipment.

- The bulking factor of excavated soil is expected to range from about 1.2 to 1.4 of the in-situ volume.

- A setback of 10 feet or more from the edge (top) of excavation to the toe of the perimeter dike should be assumed to reduce potential instability at the toe of the dike slope.

Dike Construction:

- Imported sand or sand and gravel is recommended for use to build the perimeter dike. The granular material would provide better constructability than would in-situ soils, as discussed above. It is possible that a portion of the dike could be constructed of in-situ sand encountered below the organic silt during excavation. (The quantity of in-situ sand between 7 and 13 feet below ground may be sufficient to construct a 6-foot-high perimeter dike around the site).

- Slopes of 3H:1V or flatter would likely be required to reduce potential failure below the dike within the underlying soft, organic silt. Alternatively, steeper slopes might be used in conjunction with staged construction of the dike.

- A setback of 30 to 50 feet between the dike and the Burlington Northern Railroad tracks should be assumed to reduce the effects of construction on the railroad.

Settlement:

- Some limited settlement below the dike may be expected due to consolidation of the underlying soft soils. The amount of anticipated settlement is not considered to be significant.

- Since final grade over the site may be 4 to 6 feet above existing ground level, settlement of one to two feet due to consolidation of the underlying in-situ soil may occur. In addition, significant total and differential settlement is anticipated along the surface of the fill resulting from consolidation of the slurry fill material of 4+ feet.

- A significant portion of settlements due to consolidation is expected to occur within 1 to 3 years following construction. Long-term settlement in excess of a foot may occur over a 20-year period following construction.

- Future development at this site following completion of the disposal project would need to consider the effect of long-term settlements and associated impact on foundations. Light industrial development which is not settlement sensitive may be feasible.

- Future development would likely require the placement of several feet of additional fill (above the cap) to provide sufficient bearing and to raise site grade to above 100 year flood level (approximately +9 feet MSL). This additional fill would result in settlements above those described above.

Dewatering:

If a liner were required by the regulatory agencies for the excavated option, then the site may have to first be dewatered to facilitate liner construction. Dewatering considerations are presented below:

- The soils within the depth of excavation are of relatively low permeability.

- Because of the low permeability, dewatering could probably be accomp'ished by a system of trenches and sumps throughout the base of the excavation supplemented by perimeter dewatering wells.

- A 2 to 4-foot-thick blanket of sand and gravel, in combination with lateral drains would likely be required across the base of the excavation to aid in collection of water reaching the surface.

- Pressure relief wells may also be required at areas producing water in excess of the capacity of the sump system.

- A potential impact of dewatering would be consolidation and settlement of adjacent properties.

Contaminant Transport:

The potential for contaminant transport under the Excavated Upland disposal option was discussed in the U.S. Army Corps of Engineers, Technical Supplement to the Sediment Testing and Disposal Alternatives Evaluation, September 1986. The results of anaerobic batch leaching tests indicate that the identified contaminants are sediment bound as long as the material remains saturated and a chemical environment similar to in-situ conditions is maintained. Alterations in pH, oxidation-reduction potential, salinity, and degree of aeration may influence the mobility of contaminants including metals and organics. The Corps of Engineers study shows that minimal leachate generation would occur under this disposal option.

Groundwater transport of leachate was identified as a major transport mechanism. Leachate generated would travel in the general groundwater flow direction. The leachate generation from the disposal area is expected to be low due to the low permeability of the dredge soils and the small hydraulic gradients typical for this type of hydrologic setting. The degree of groundwater impact from leachate is expected to be minimal due to adsorption of contaminants by soils in the flowpath and dilution resulting from groundwater dispersion.

Potential for leachate migration by groundwater transport may require monitoring and potential implementation of abatement measures. Water quality could be monitored in wells installed around the perimeter of the site.

Elevated Upland Disposal Site

This disposal option involves constructing a dike around the perimeter of the site and filling the diked area with contaminated and clean dredge material above existing site grades. The contaminated soil would be above the groundwater level. A possible cross section for the embankment disposal option is illustrated in Figure 3. Assumptions used for this option include:

- o Groundwater level at the site is assumed to be at mean sea level. The average elevation of the existing ground level is assumed to be +3 feet MSL.
- o A relatively high (e.g. 20 to 25 foot) perimeter dike would need to be constructed to contain the dredged materials and provide ponding and freeboard for hydraulic placement.

Discussion of this disposal option is divided into four categories: Excavation, Dike Construction, Settlements and Contamination Transport.

Excavation:

- o Partial excavation of in-situ soil is not advised in order to reduce the final elevation of the fill. Once the surface crust (1 to 3 feet thick) is removed, underlying soft soil would not be able to support construction equipment. Excavation should be limited to minor grading in preparation of the site for liner placement.

Dike Construction:

- The height of the perimeter dike depends on the depth of excavation, liner thickness, and the net usable area in which to deposit the contaminated dredge spoils. A dike height of 20 to 25 feet above existing ground is considered possible for the proposed development.

- Slopes of 3H:1V or flatter would likely be required to provide adequate stability within the underlying soft soils.

- Dike construction of imported sand or sand and gravel is recommended to provide improved constructability.

- A setback of 30 to 50 feet between the perimeter dike and the Burlington Northern Railroad track should be assumed to reduce the effects of construction on the railroad.

Settlement:

- Significant settlements resulting from consolidation of in-situ soft soils underlying the dike and fill are anticipated due to raising site grade. Such settlement could be on the order of 2 to 4 feet.

- If required, a leachate control liner would have to be designed to withstand the 1 to 4 feet of total settlement, with a differential settlement of 3 feet over a 100 to 200 foot horizontal distance.

- Additional settlements at the fill surface will result from consolidation of the dredge fill material. These settlements could exceed 4 feet.

- A significant portion of settlements due to consolidation is expected to occur over a period of 1 to 3 years. Continued settlement beyond that time, in excess of 1 1/2 feet, is possible.

- Future development at the site would need to consider the effects of settlement on foundations. Other impacts to future development include limitations on use of piling for a lined site, and the need to maintain saturated conditions in the contaminated fill.

Contamination Transport:

The Elevated Upland disposal option poses greater potential for leachate generation and contaminant transport than the Excavated Upland disposal option, because of the potential for the sediments to drain and become aerobic. Physicochemical changes including oxidation-reduction potential, pH, salinity, and temperature are likely to occur under aerated conditions, which may increase the mobility of contaminants in the sediment. Results of aerobic batch leaching tests conducted by the U.S. Army Corps of Engineers as reported in the September 1986 Technical Supplement, indicate an increase of contaminant concentration in the leachate compared to results of the anaerobic tests.

For an unlined Elevated Upland option, leachate generation would occur as rainfall infiltrates through the cap to the eventually dried and aerated contaminated sediments. Leachate would also be generated by pore-water extrusion during consolidation of the soils during the first 1 to 3 years following placement. Migration of leachate may occur both by surface discharge from the sides of the contaminated sediments and by movement into the underlying groundwater. Control measures to limit leachate generation could include a sloped clay or synthetic cap with a vegetative cover. In addition, measures to abate potential leachate migration to groundwater or to surrounding surface waters may include options such as a liner, depending on the findings of detailed site-specific studies.

As considered in this feasibility study, a lined Elevated Upland disposal option would reduce the drying rate of the soils, but not guarantee the sediments would always remain saturated. A liner would tend to eliminate loss of water through the walls and floor of the system, but loss through evaporation is possible. It is anticipated, though, that drying of the contaminated soils (if covered with 5 feet plus of saturated clean dredge spoils) would take several years, if not several decades.

Earthquake Considerations

The Pacific Northwest is a seismically active area, with the Puget Sound area classified as Zone 3 by NAVFAC P-355 and the Unifor Building Code. Earthquake considerations in seismically active areas include: the potential for and intensity of ground shaking; ground rupture due to faulting; and liquefaction.
Ground shaking from a major earthquake could impact the site during the service life of the facility. Peak ground accelerations of 0.15 g have an approximate 80 percent probability of nonexceedence during a 50-year period. Such accelerations would likely develop from earthquakes of magnitude 6.5 or greater.

Ground rupture due to faulting is not a concern for the site. In the Puget Sound region all of the large earthquakes have been deep subcrustal events at depths ranging from 20 to 40 miles below the ground surface.

The liquefaction potential at the site is not considered significantly different than that of other saturated fills in Puget

Sound. For example, the ports of Everett, Seattle, and Tacoma are all founded over areas of hydraulic dredge filling, and sandy delta deposits. Historically the Everett site has been exposed to the two major recent earthquakes of the region, Olympia 1949 and Seattle-Tacoma 1965. During both earthquakes no major damage was noted at the Everett site. The only significant Puget Sound port damage noted during those earthquakes, that we are aware of, involved movement of a bulkhead on Harbor Island, at the Port of Seattle and some ground failure at the Port of Olympia. The damage was not catastrophic, but did require repair. Seattle and Olympia are located much closer to the center of those past earthquakes than Everett, possibly explaining why damage was not observed at Everett.

There is uncertainty associated with predicting earthquake damage in the Puget Sound region and the Everett area. This is primarily due to relatively limited data relating to major earthquakes. Analytical techniques typically predict liquefaction potential at area port facilities, while historic records (50 years) show limited damage due to liquefaction.

In the event of a major earthquake, the site could experience localized liquefaction. This could result in localized loss of foundation support, settlement, or slope distortion. Some repair of the facility might be required. It is possible that some of the contaminated sediment could be exposed by such an event.

The Elevated Upland disposal option is considered to have a greater seismic risk than the Excavated Upland disposal option. This is because in the excavation option the contaminated materials are embedded into the area land mass, having much greater confinement than the elevated option. In the event of loss of foundation support or slope distortion, it is more likely that the contaminated material would be exposed in the elevated configuration.

Geotechnical Conclusions

Both the Elevated and Excavated Upland disposal options appear to be geotechnically feasible at the Smith Island site. Final design of either option will require collection of additional site soil and groundwater data, in addition to laboratory testing and in-depth engineering analyses.

V. LEACHATE CONTROL

The elevated upland disposal option is assumed to require leachate controls to limit potential off-site impacts of higher leachate concentrations associated with ultimate drying (oxidizing) of the contaminant mass. For the purpose of this feasibility study, it is assumed that the leachate control system will consist of an impermeable liner under the contaminated sediment cell, leachate collection at the surface of the contaminated layer, and treatment of the collected leachate for removal of contaminants prior to discharge (see Figure 3b). A feasibility level evaluation of this leachate control system was conducted by Parametrix, Inc., October 1986, and is included as Appendix B. Essential elements of the control system are discussed below.

Liner

The recommended liner includes two separate layers. The first layer would be two feet of recompacted, bentonite-amended soil with a maximum hydraulic conductivity of 10^{-7} centimeters per second. Site preparation would be minimal, requiring only clearing and grubbing and grading the existing ground surface level. The borrow source for the base soil would have to be identified. Preferred soil would be silty or clayey fine sand, sandy silt or sandy, silty clay. Approximately 250,000 cubic yards would be required. The base soil would be admixed with a pre-determined amount of sodium bentonite in a pug-mill and placed and compacted in six inch lifts. The cost for the soil liner is estimated to be $7,500,000, including contingencies, engineering, administration and sales tax.

After the soil liner was constructed, a 100 mil High Density Polyethylene (HDPE) membrane liner would be installed. The HDPE liner would be delivered to the site in pre-cut rolls varying from 6 to 30 feet in width, depending on the manufacturer. The panels would be joined in the field using thermal fusion techniques that vary depending on the manufacturer. All manufacturers warrant field seams to be stronger than the material itself. Quality assurance during construction would be implemented to ensure proper field seaming. The estimated cost of the HDPE liner is $4,400,000. Total liner costs would them be $11,900,000. The cost figures include contingencies, engineering, administration and sales tax, and represent a planning level estimate that should be accurate to within plus 50% or minus 30%.

Leachate Collection

The leachate collection system for the upland elevated (above-groundwater) alternative would be installed within the top four feet of the clean dredge sands that will be placed over the contaminated dredge spoils. This would entrap any leachate collecting or arising over the contaminated sediments while tending to maintain the contaminated cell in its saturated anaerobic state. The collection system would include a network of six inch, perforated, plastic pipe meeting ASTM F-405 (ADS or equal). A filter fabric sock around the pipe would be used to prevent the clogging of the pipe by soil fines. The pipe would be placed at approximately 200 foot centers and sloped at a minimum of 0.2%. The collection pipes would be connected to a non-perforated, collection header pipe within the perimeter dike. The header pipes would converge at the northeast portion of the site for further transfer to the treatment or temporary storage facilities. It is estimated that approximately 16,900 feet of perforated pipe and 4,200 feet of non-perforated pipe is required. Installation of the perforated pipe would require specialized equipment for access and burying the pipe in the unconsolidated dredge spoil material. The total cost, including contingencies, engineering, administration, and sales tax, is $530,000. As with the liner, this is a planning level estimate.

Capping

After the dredge spoils have consolidated, the site would be capped. The objective of the capping would be two-fold: First, it would prevent the entry of oxygen into the contaminated sediment such that the anaerobic conditions tend to be maintained and contaminants remain absorbed to the sediment particles. Second, it would prevent the percolation of precipitation into the sediments with the subsequent need to treat the leachate generated.

Preparation for lining would be limited to grading of the disposal site to minimum grades of 2%. After grading, a 100 mil HDPE liner would be installed. Overlying the liner, a polyethylene drainage net and filter fabric would be installed to provide a flow path to the sides of the site for infiltrated precipitation. The final layer of the cover would be three feet of topsoil. The topsoil would be hydroseeded to control erosion. The cost for this system is estimated at a planning level to be $13,200,000, including contingencies, engineering, administration and sales tax.

Treatment

Because of heavy metal and PCB concentrations in the dredge disposal leachate, some method of treatment will be required prior to disposal in surface waters in the site vicinity. Initial analysis of the dredge spoils was used to predict heavy metal concentrations in the leachate removed from the dredge materials. These concentrations are presented in Table 1. A study by the U.S. Army Corps of Engineers concerning the treatment of dredge spoil leachate (Appendix B of the Draft EISS) listed chemical precipitation as a viable method for removing heavy metals from the leachate. Because heavy metals are the primary concern for treatment, a system consisting of lime addition, settlement, recarbonation and filtration was chosen for this preliminary investigation and cost analysis. The cost for this system, assuming a flowrate of 4,000 gal/day, would be about $275,000 over a five year project life. Approximately 50 percent of this cost, or $137,000, would be for initial capital expenditures, with the remaining required for operation and maintenance of the facility. Because of the relatively low flow from the site, an alternative method of treatment would be to haul the leachate to a local wastewater treatment plant. The cost of this alternative, assuming the leachate is hauled via a 3,500 gallon tanker truck to the Everett Wastewater Treatment Plant, would be about $231,000 over a five year project life. The initial capital cost expenditure for this alternative would be approximately $100,000 for tanker truck acquisition and on-site storage and transfer facilities. The transportation costs could probably be reduced if this task was contracted to a public or private hauler. In short, it is recommended that the leachate be disposed of at the Everett treatment facility if the leachate meets the guidelines for disposal at the treatment facility.

VI. DREDGE AND DISPOSAL PLANS

Construction of the Navy homeporting facility requires dredging the East Waterway at Port Gardner. The total amount of material to be removed by dredging consists of 3,305,000 cubic yards. This material is distributed to Project Nos. P-111, P-905 and P-112 as indicated in Table 2. Not included in the volume figures identified above but shown in the table is a quantity of debris which will be removed as a part of the dredging process.

Table 2. Dredge Quantities from East Waterway.

Project No.	Debris (tons)	Dredged as Contaminated[1] (cu yd)	Uncontaminated[1] (cu yd)	Total (cu yd)
P-111	10,500	97,000	739,000	836,000
P-905	18,000	224,500	1,140,000	1,364,500
P-112	23,500	552,000	498,000	1,050,000
		54,500[2]		54,500[2]
TOTALS	52,000	928,000	2,377,000	3,305,000

1 Overdepth quantities included in Dredge Contaminated
2 Contaminated sediment below project depth

The purpose of this section of the feasibility report is to identify practical methods of dredging and disposal for both the Excavated and Elevated option of disposal at Smith Island. It should be noted that the main emphasis of this study is on the engineering and construction feasibility. Environmental assessment, impact, and mitigation of impacts are not within the scope of this study.

Dredging Equipment

The location of the disposal site in relationship to the project area allows two dredging methods be considered. Prior to dredging start the initiation of the debris removal would commence, and would continue during the dredging of the surface sediments. Debris would be removed by mechanical dredge and barged to an offloading site for rehandling and eventual disposal at an approved upland site.

The first dredging method considered viable is use of a large hydraulic pipeline dredge to remove and transport the sediments by pipeline slurry to be deposited at the site. The proximity of the railroad to both the dredging and disposal areas suggest the use of this level right of way for the discharge pipeline. The discharge pipeline would then cross the Snohomish River near the Weyerhaeuser treatment lagoons and terminate at the proposed site. Assuming use of rail right of way for the pipeline, approximately 25,000 feet of discharge line would be required. This pipeline length is within the capacity of modern hydraulic dredges assisted by a booster pump.

The second dredging method would be the use of clamshell and haul barges. Under this method, the barges move up Steamboat Slough at high tide and discharge into the site either by a second clamshell unloading material to trucks or by a small shore based hydraulic pumping system to pump the barge load into the disposal area. This option requires the construction of a landing for the barges in the disposal site bankline which has value as a wetland. Care in construction of access would be necessary to minimize the habitat loss.

The production rate for the pipeline dredge assumes the use of a suitable booster pump in line. Production rate for a 26 inch hydraulic pipeline dredge will approach 16,000 cubic yards per day for contaminated and 20,000 cubic yards per day for uncontaminated. Production rates for a clamshell dredge with haul barges will approach 6500 cubic yards per day. This is based on a 10 cubic yard clamshell dredging at the East Waterway and another offloading at the Smith Island site.

The pipeline alternative is the preferred option for the dredging method based on dredge production rates, estimated cost and reduced the environmental impact at the dredging area.

Disposal Plans

Smith Island is being considered as a disposal site for contaminated sediments dredged from East Waterway. Two basic disposal configurations are evaluated. These configurations are identified by the positioning of the contaminated sediments above or below the groundwater elevation.

- o <u>Excavated</u> disposal site. A cell would be excavated below existing groundwater level and subsequently backfilled with contaminated sediments.

- o <u>Elevated</u> disposal site. contaminated sediments would be placed above existing ground and water table within a constructed perimeter dike. A liner and leachate treatment system would also be constructed.

Both alternatives would require a containment dike structure and other extensive site preparation prior to start of the dredging and disposal operations.

Excavated Disposal Site

Corps leachate test results show that saturated anaerobic sediments generate substantially less leachate concentrations then sediments that are allowed to dry and oxidize. Placement of the contaminated sediments below the ground water level at Smith Island has been selected to maintain the saturated condition.

The ground water level has been determined to be at approximate mean sea level elevation (+6.5 feet MLLW). The existing ground surface at the disposal site averages +3 feet msl elevation. The plan for placement of the contaminated sediments is to excavate the disposal area for burial of the contaminated sediments only below the ground water level. A clean material cap would then be deposited over the contaminated sediments. This cap deposit would be above the ground water level. A minimum six foot thick cap of clean sediments has been recommended to cover the contaminated sediments (Phillips et al., 1985). This cap thickness is considered necessary to prevent sediment erosion concerns and limit vegetation entrusion with the contaminated sediment layer.

Containment Dike Construction

The existing ground surface elevation at the site ranges from approximately 9 feet MSL to 1 foot MSl. These existing elevations require construction of a low dike structure to contain the capping sediments. To assure a clean cap thickness of 6 feet after long term settlement, the initial disposal volume pumped in by pipeline dredge must be 8 feet thick. Placement of this material above the ground water elevation would require a containment dike elevation of 13 feet MSL (8 feet sediment + 3 feet ponding + 2 feet freeboard); See Figure 3. Dike construction volume would require 160,000 cubic yards of offsite sediments. This volume is based on a 3 on 1 side slope and a 10 foot wide top width for 9610 lineal feet of earth dike structure.

The sediments for dike construction could be obtained from the existing State Department of Natural Resources (DNR) site that now exists immediately south of the proposed Smith Island site. The DNR site has been used in the recent past by the U.S. Army Corps of Engineers for disposal of maintenance dredging of the Snohomish River channel. These sediments are Snohomish River silty sands and sand materials that would be structurally suitable for the dike construction. The borrowing of the sediments would also prolong the use of the DNR site for receiving future maintenance dredging sediments from the Corps. It is estimated that approximately 1,000,000 cubic yards of dredged sandy sediments are available from this site.

The dike construction would occur prior to excavation of the site for dredge disposal of contaminated sediments. This is necessary to assure access of large earth moving equipment to the site periphery over the existing ground cover. The thin layer of sediments above the water table provide limited strength for occasional passage of equipment to the dike construction alignment. Removal of this existing ground and construction of an open pit below groundwater prior to dike construction would create impossible access and construction limitations for the containment dike.

Protection of containment dikes from erosion by revetment will be required. The sandy sediments will be subject to erosion during higher flood stages. A 100-year flood stage for the Smith Island area is 9 feet msl. Design for flood stage, wind and wave run up is approximately 13 feet msl. Flood stage design velocity will be 6 feet per second, based on calculated maximum flood velocities of 4 fps in the main channel. Revetment will be constructed using 150 lb. stone maximum or less, two feet thick revetment layer with an additional 6" gravel filter sublayer. The revetment will be tied into the top of the existing bankline and extended up to 13 feet msl. Existing bankline is considered to be stable, and fringe wetlands will not be disturbed by revetment construction. Future localized bankline erosion may endanger the revetment integrity and require some future site specific revetment at the erosion site.

<u>Disposal Site Excavation</u>

The remaining surface area for disposal of East Waterway dredging would be approximately 90 acres after completion of the containment dike to an elevation of 13 feet MSL; see Figures 4 and 5. In this remaining area the surface sediments typically 3 foot

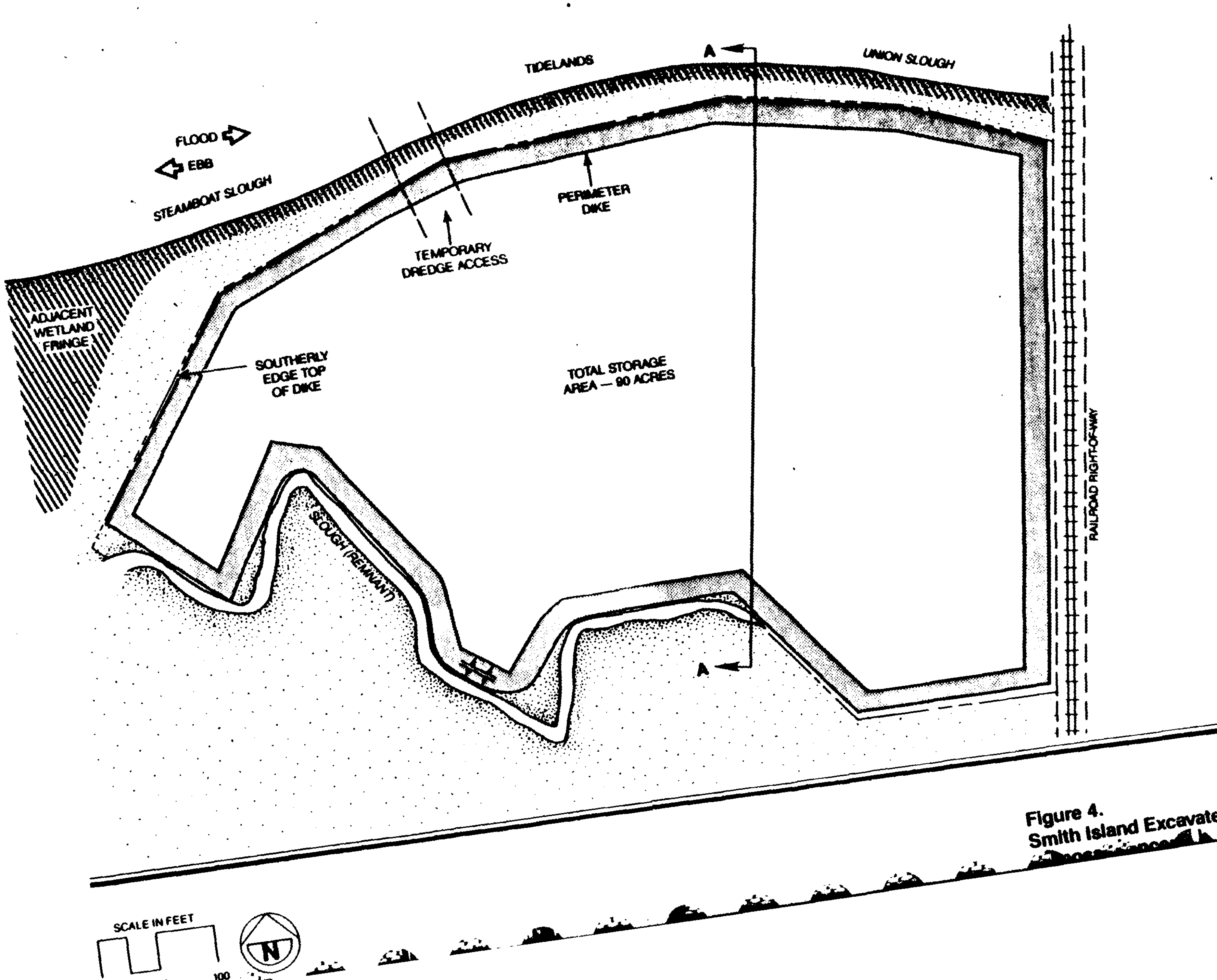
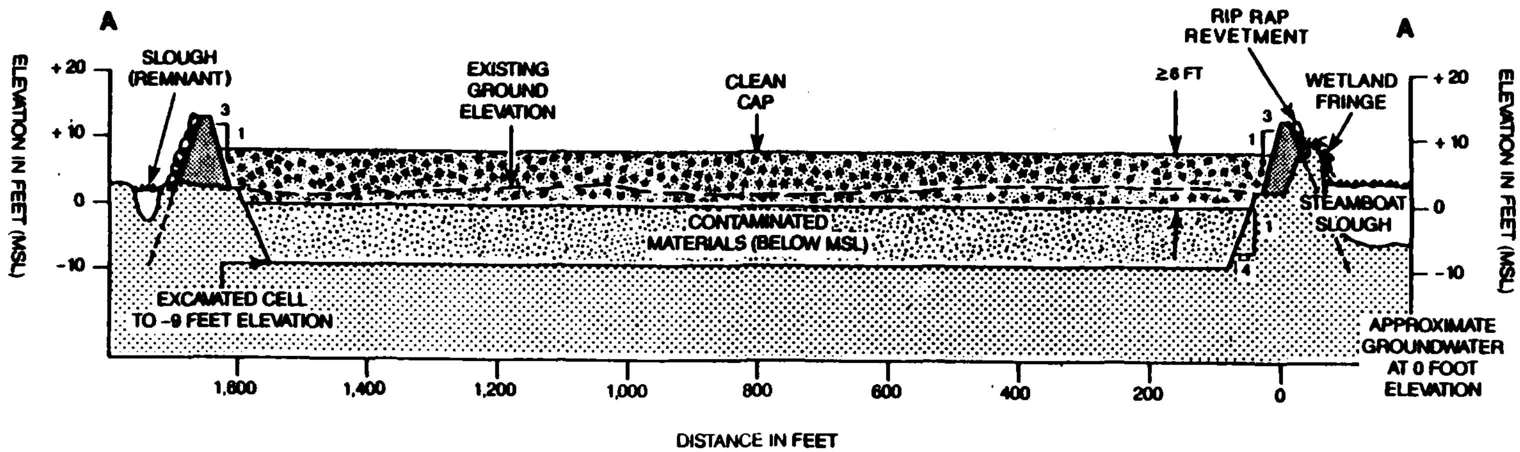


Figure 4.
Smith Island Excavated



Note: Elevations referenced to mean sea level (MSL)
Add 6.5 feet to MSL elevations to obtain
mean lower low water (MLLW) elevations.

Figure 5.
Smith Island Excavated Upland Disposal Concept (Cross Section A-A).

thick above the ground water level and the subsurface sediments below the ground water level down to an elevation of -9 feet msl would be excavated. These sediments would be removed and transported to an acceptable disposal site. Potential disposal sites for this excavation include the following locations (City of Everett, Department of Public Works, 1986).

- o Weyerhaeuser property on Smith Island. Two parcels of open land approximately 21 and 36 acres in area.
- o DNR disposal site. Presently used for disposal of Corps maintenance dredging.
- o Dagmars Landing. Open area of approximately 15 acres adjacent the existing boat storage site.
- o Biringer Property. Approximately 30 acres on the east side of Union Slough.
- o Weyerhaeuser Plant. Approximately 100 acres on the south bank of the Snohomish river, upstream of the Smith island site. This site does have existing structures that must be removed prior to use as a disposal site.

The Tulalip landfill site was considered for disposal of the excavated sediments. This site includes approximately 150 acres. It was determined to not be viable because of the existing requirements for acceptable filling. Those requirements include site conditions that limit fill next to 4 feet or less, and a cap conductivity requirement of 10^{-7} centimeters per second. The entire site has been classified as a wetland by recent Corps of Engineers assessment survey, and the environmental impacts would be significant. Another site considered was the Simpson Timber Co. disposal area 4 miles upstream along the Snohomish River near the town of Lowell. This site was considered less feasible because of the long haul/pumping distance.

Surface sediments to be excavated from the Smith Island site that is above the ground water could be removed by earth moving equipment. This sediment could be truck hauled to the nearest sites (the Weyerhaeuser sites) for disposal. A total of 436,000 cubic yards of predominantly organic silts would be removed. This would create a fill of approximately 7.5 feet over a 36 acre area. The removal of these surface sediments would be difficult due to the limited strength of the surface layer to support the earth moving equipment. Haul roads and a specific excavation and traffic plan must be developed to complete this excavation.

After the completion of the surface sediment removal, the exposed sediments remaining would be typically at MSL (groundwater level. The wet conditions of the sediments would require the use of dragline, clamshell or hydraulic dredge to remove the sediments.

The locations for potential disposal sites as given above suggest the use of a pipeline dredge for overland transport to the sites. This equipment approach would avoid the construction time necessary for stockpiling and dewatering the sediments prior to truck haul overland. The pipeline dredge alternative requires a breach in the containment dike from Steamboat Slough to allow access of the dredge and to obtain dredge slurry feed waters during the wet sediment excavation.

A total of 1,330,000 cubic yards of wet sediments must be excavated, including the breach into the site from Steamboat Slough. The disposal site for these sediments must be diked prior to receiving the dredge discharge slurry. The slurry condition of the sediments would mean that a 100 acre site must have a 16 foot high dike constructed prior to disposal of sediments. The eventual fill height of the sediments after settlement and dewatering would approach 8 to 9 feet for that same 100 acre area.

After completion of pit excavation dredging for disposal site, the breach would be closed and an overflow weir for subsequent disposal operations would be constructed. A minimum time for settlement must be allowed for the breach fill prior to site use for the disposal of P-111 contaminated sediments.

East Waterway Dredging

The P-111 contaminated sediments would be dredged first and placed into the site. Ponding depth and area would be adequate to allow a minimum retention time for the first year dredging. The remaining clean sediments in P-111 would be dredged and disposed at the RAD CAD site. Relocation of the discharge pipe to this site from the Smith Island site would require approximately two weeks time.

The FY 1988 dredging would include disposal of all contaminated sediments from the P-905 and P-112 projects into the Smith Island site. After placement of the P-112 and P-905 contaminated sediments, a total volume of 1,253,000 cubic yards of in situ clean sediments would be discharged into the site. It is assumed that this would provide a predominantly clean sediment cap of 6 feet over the contaminated after dewatering and settlement. An interface mixing of the contaminated slurry and the clean sediment slurry is probable and should be considered in any final design.

Based on modified elutriate testing the Corps of Engineers (U.S. Army, 1986) has specified retention pond requirements, volumetric storage, minimum surface area and effluent suspended solids concentrations for various size pipeline dredges. During the final stages of contaminated sediment disposal the retention pond level can be maintained at increased depths sufficient to assure conformance to Corps retention time requirements prior to overflow return to the waterway. Total surface area available under this option at approximately 90 acres is adequate for effective settling.

The remaining clean sediments to be dredged in FY 1988, approximately 385,000 cubic yards, would be dredged by pipeline dredge and disposed into the proposed RAD CAD site. The placement of 1,124,000 cubic yards at the CAD site over a two year period would cover approximately 120 acres total. Disposal would be accomplished in approximately 350 feet water depth in Port Gardner.

Elevated Disposal Site

Corps leachate test results (Appendix C, FEIS) were characterized by large metal losses for aerobic sediment conditions. This indicated the potential for contaminant release is higher in a confined disposal plan that allows the dredged material to become oxidized than for a plan that maintains anaerobic leaching conditions. Typically the partially oxidized sediments will constitute a relatively thin surface crust making up a small part of the total sediment mass. Even though the contaminant release from the crust may be significantly higher than from underlying materials, contaminant flux through foundation soils or through dikes probably will not be affected unless the significant portion of the containment site reaches a partially oxidized state. Placement of the contaminated sediments above the ground water level at Smith island utilizing a containment dike and a combination clay and membrane liner has been selected to assure the minimization of total site oxidization and contaminant release.

Containment Dike Construction

A high dike structure must be constructed to contain the contaminated sediments and a minimum clean cap. Total dike height required is 26 feet, or a typical top elevation at the Smith Island site of 29 feet msl. See Figure 3. Dike construction volume would require 720,000 cubic yards of offsite sediments. This volume is based on 3 on 1 slopes, a top width of 10 feet and 9110 lineal feet of earth dike structure.

The sediments for dike construction could be obtained from the existing DNR site that now exists immediately south of the proposed Smith Island site. The DNR site has been used for disposal of U.S. Army Corps of Engineers maintenance dredging disposal from the Snohomish River channel. These sediments are Snohomish River silty sands and sand sediments that would be structurally suitable for dike construction. Borrow from the site would also prolong the use of the site for receiving future maintenance dredging sediments from the Corps program. It is estimated that approximately 1,000,000 cubic yards of river sand sediments are available from this site.

After completion of the dike construction to an elevation of 29 feet msl, the remaining surface area for disposal of East Waterway dredging would be approximately 73 acres. See Figures 6 and 7. Installation of a two layer liner would then be accomplished.

Protection of containment dikes from erosion by revetment will be required. The sandy sediments will be subject to erosion during higher flood stages. A 100-year flood stage for the Smith Island area is 9 feet msl. Design for flood stage, wind and wave run up is approximately 13 feet msl. Flood stage design velocity will be 6 feet per second, based on calculated maximum flood velocities of 4 fps in the main channel. Revetment will be constructed using 150 lb. stone maximum or less, two feet thick revetment layer with an additional 6" gravel filter sublayer. The revetment will be tied into the top of the existing bankline and extended up to 13 feet msl. Existing bankline is considered to be stable, and fringe wetlands will not be disturbed by revetment construction. Future localized bankline erosion may endanger the revetment integrity and require some future site specific revetment at the erosion site.

Bottom Liner Construction

The recommended liner includes two separate layers (Appendix B). The first layer would be two feet minimum of recompacted bentonite-amended soils with a maximum hydraulic conductivity of 10^{-7} centimeters per second. Site preparation would be minimized to clearing and grading of the existing ground surface level. Base soil of 250,000 cubic yards would be obtained from the remaining sediments at the DNR site. This material would be admixed with a pre-determined amount of sodium bentonite in a pug-mill and placed in four separate compacted lifts of six inches over the site.

After the soil liner was constructed, a 100 mil High Density Polyethylene (HDPE) membrane liner would be installed. The HDPE liner would be delivered to the site in pre-cut roll varying from 6 to 30 feet in width, manufacturer dependent. Seams would be joined in the field using thermal fusion techniques.

East Waterway Dredging

The P-111 contaminated sediments would be pumped into the site following the bottom liner construction. Ponding depth and area would be adequate to allow a minimum retention time for the first year dredging. The remaining clean sediments in P-111 would be dredged and disposed at the RAD CAD site. Relocation of the

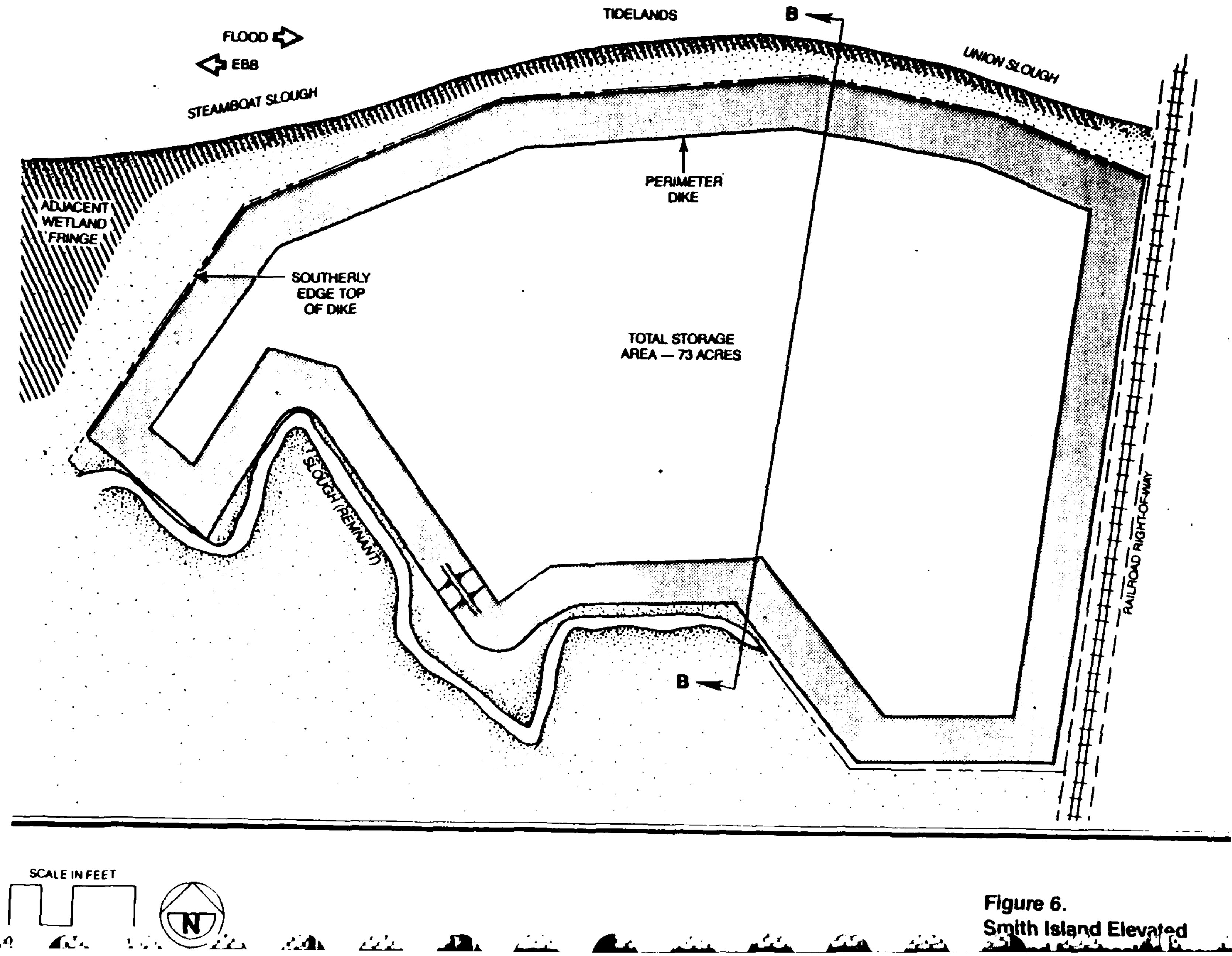
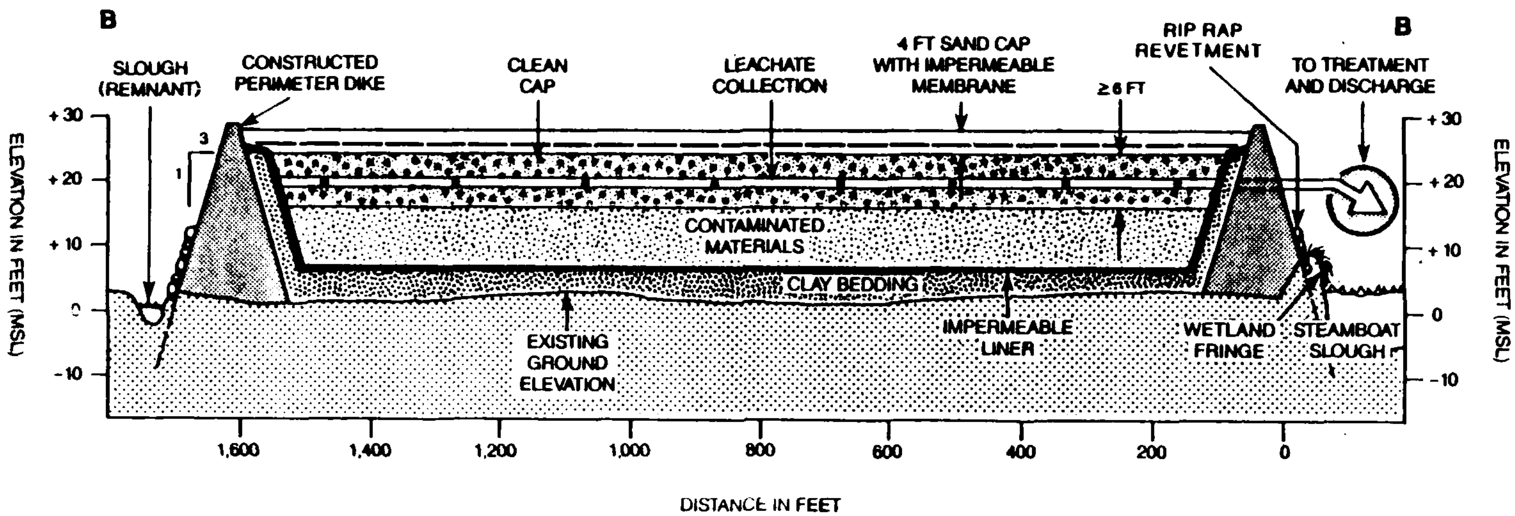


Figure 6.
Smith Island Elevated



Note: Elevations referenced to mean sea level (MSL). MSL is approximately + 6.5 feet above mean lower low water (MLLW) tidal datum.

Figure 7.
Smith Island Elevated Upland Disposal Concept With Leachate Liner, Collection and Treatment (Cross Section B-B).

discharge pipe to this site from the Smith Island site would require approximately two weeks time.

The FY 1988 dredging would include disposal of all contaminated sediments from the P-905 and P-112 projects plus approximately 1,075,000 cubic yards of clean sediment disposal for the cap. Based on modified elutriate testing the Corps of Engineers (Appendix B, DEISS) has specified retention pond requirements for various size pipeline dredges. During the final stages of contaminated sediment disposal the retention pond level will be maintained at increased depths sufficient to assure conformance to Corps retention time requirements prior to overflow return to the waterway. The total area available under this option is less than required at approximately 80 acres. Continuous monitoring will be required to identify effluent return suspended solids. The dredging activity may have to be limited to partial days pumping to allow adequate settling of dredged sediments.

After placement of the P-112 and P-905 contaminated sediments, a total volume of 1,075,000 cubic yards of in situ clean sediments would be discharged into the site. It is assumed that this would provide a predominantly clean sediment cap of 6 feet over the contaminated after dewatering and settlement. An interface mixing of the contaminated slurry and the clean sediment slurry is probable and should be considered in any final design.

The remaining clean sediments to be dredged in FY 1988, approximately 563,000 cubic yards, would be dredged by pipeline dredge and disposed into the proposed RAD CAD site. The placement of a total 1,302,000 cubic yards of clean material over two disposal events would cover approximately 140 acres total bottom area at the RAD CAD site. Disposal would be accomplished in approximately 350 feet of water in Port Gardner.

Leachate Collection & Surface Liner Construction

Following disposal of the clean sediments the site would be allowed to dewater and settle for a minimum period until a shallow surface crust is formed. This time allowance will vary depending on the rainfall conditions experienced immediately after disposal operations. It is estimated that a 1 year period of natural dewatering and decanting of the site must take place along with application of the continuous trenching method to remove surface waters from natural precipitation.

Following the one year dewatering of the dredged sediments, a four foot layer of dredged sands would be placed over the site, or 470,000 cubic yards of sand cap. This material may be available from the DNR site if Corps dredging has occurred since removal of the existing stockpiled sediments for the dike and bottom liner construction.

Prior to placement of the four foot cover of dredged sands, a leachate collection system would be installed within the surface crust of dredged sediments. The collection system would include a network of six inch, perforated, plastic pipe. A filter sock around the pipe would be used to prevent the immediate clogging of the pipe by soil fines. These collection pipes would be connected to a non-perforated, collection pipe within the perimeter dike. The header pipe would converge at the northeast corner of the disposal site for further transport to a constructed treatment or temporary storage facilities.

The leachate collection system would then be covered with a minimum one foot of the dredged sand cover materials. A 100 mil HDPE liner would be installed on the one foot cover. Overlying the liner, a polyethylene drainage net and filter fabric would be installed to provide a flow path to the sides of the site for infiltrated precipitation. The final layer of the cover would be the remaining three feet of dredged sand sediments with one additional foot of organic silt materials worked into the surface of the sand fill, hydroseeded and fertilized to provide vegetation for erosion control.

Construction Schedule

Start of dredging under the Smith Island disposal site option would be delayed until the disposal site preparation is completed. Time to complete disposal site preparation is dependent on the final disposal alternative selected for the site. The two alternatives considered viable for site use are Smith Island Excavated and Smith Island Elevated. The construction schedule estimated for either Smith Island disposal alternative is dependent on availability of the required land.

In order to assure the long term integrity of the disposal site, it is assumed that ownership of upland disposal area be retained by a responsible public agency. Consequently, prior to construction start, the properties necessary for Smith Island Disposal option must be purchased by the ultimate long term owner and caretaker of the site. If the Navy is to be the site owner, the acquisition must be made through U.S. Department of the Navy real estate offices. Typical time required to complete real estate negotiations of this type vary depending upon the ownership questions, property zoning and other legal aspects. Based on recommendations from the Department of the Navy, a minimum lead time of up to 9 months should be allowed for property acquisition and easement procurement. This action is subject to congressional approval and it is unlikely that appropriation can be completed in time to allow for 1987 funding. Consequently, under the Navy purchase option, disposal site construction start would be delayed to February 15, 1988 when it is anticipated that Congressional authorization and appropriation would be completed. An alternative allowing disposal construction to proceed in 1987 is possible if another public agency can acquire the parcels in a more timely manner for use by the Navy. The schedule alternatives for the excavated and elevated disposal options are reflected in Tables 3 and 4, respectively.

VII. CONSTRUCTION COSTS

Costs for dike construction, dredging and debris disposal were developed commensurate to costs provided in previous feasibility studies for other alternative disposal options (ABAM, 1986). Dredging costs are based on a hydraulic dredge removing all of the sediments from the East Waterway, both contaminated and clean. Disposal of all contaminated sediments are at Smith Island. The clean sediments are disposed at both Smith Island and the proposed RAD CAD site. Debris is disposed upland.

Cost estimate for the Smith Island Excavated total \$33,357,000 and is itemized as follows:

Mobilization/Demobilization	
Disposal site preparation	\$ 700,000
Dikes (Smith Island) 9610 lf @ \$240/lf	2,306,400
Dikes (off-site) 8350 lf @ \$530/lf	4,426,000
Dry Excavation 435,000 cy @ \$3.50/cy	1,523,000
Dike breach & weir install job	90,000
Revetment 9610 lf @ \$18.75/lf	180,000
Debris, dredging and disposal	
Debris removal 52,000 ton @ \$44/ton	2,288,000
Contaminated 928,000 cy @ \$4.17/cy	3,870,000
Clean Cap 1,253,000 cy @ \$3.45/cy	4,323,000
Clean to CAD 1,124,000 cy @ \$2.65/cy	2,979,000
Pipeline Relocation - 2 times	60,000
Sand cap 580,000 cy @ \$3.50/cy	2,030,000
Real Estate	
Smith Island 110 acres @ \$0.90/ft^2	4,312,000
TOTAL	\$33,357,000

Added costs of \$500,000 for chemical flocculation of contaminated sediments dredging return flow and \$10,000,000 for dewatering site and placing a synthetic liner may be incurred if localized long term and short term impacts must be avoided.

Cost estimate for Smith Island Elevated total \$54,750,000 and is itemized as follows:

Mobilization/Demobilization	
Disposal Site Preparation	\$ 700,000
Dike Construction 9110 lf @ \$1110/lf	10,112,000

Table 3. Construction Schedule for Smith Island Excavated Disposal Option. All contaminated sediments placed below groundwater level.

Activity	Navy Purchase Date	Non-Navy Purchase Date
Start Dike Construction	February 1988	February 1987
Complete Dike	April 1988	April 1987
Complete excavation top layer	June 1988	June 1987
Complete excavation wet sediments	August 1988	August 1987
Close dike breach	August 1988	August 1987
Complete contaminated dredging	Sept. 1988	Sept. 1987
Complete dredging	October 1988	October 1987
Start Dredging	June 15, 1989	June 15, 1988
Complete contaminated dredging	August 1989	August 1988
Complete Smith Island cap	October 1989	October 1988
Complete dredging	November 1989	November 1988

Table 4. Construction Schedule for Smith Island Elevated Disposal Option. All contaminated sediments placed above the groundwater level with a liner in place.

Activity	Navy Purchase Date	Non-Navy Purchase Date
Start Dike Construction	February 1988	February 1987
Complete Dike	May 1988	May 1987
Complete liner installation	August 1988	August 1987
Complete contaminated dredging	Sept. 1988	Sept. 1987
Complete dredging	October 1988	October 1987
Start Dredging	June 15, 1989	June 15, 1988
Complete contaminated dredging	August 1989	August 1988
Complete Smith Island cap	October 1989	October 1988
Complete dredging	November 1989	November 1988
Install Collection System	August 1990	August 1989
Complete surface liner/cap	November 1990	November 1989

Weir - 1 job	10,000
Revetment 9110 lf @ 18.75/lf	171,000
Debris, dredging and disposal	
Debris removal 52,000 ton @ $44/ton	2,288,000
Contaminated 928,000 cy @ $4.17/cy	3,870,000
Clean cap 1,075,000 cy @ $3.45/cy	3,709,000
Clean to CAD 1,302,000 cy @ $2.65/cy	3,450,000
Pipeline Relocation - 2 times	60,000

(Land costs should reflect fair market value of at least $0.75/sf)

Real Estate Acquisition	
Smith Island 110 acres @ $0.90/ft^2	4,313,000
Treatment Facility 4 ac @ 0.90/ft^2	157,000
Sediment Treatment	
Bottom liner	11,900,000
Leachate Collection	530,000
Sand Cap with Liner	13,200,000
Treatment	280,000
TOTAL	$54,750,000

This cost estimate includes acquisition of Smith Island site (110 acres) and property adjacent the site for treatment facilities (4 acres). The treatment costs reflect a five year effort. An additional cost of $500,000 for chemical flocculation of contaminated sediment dredging return flow may be incurred if minor short term impacts are to be avoided.

VIII. REGULATORY FRAMEWORK

Federal

Under Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers has regulatory authority over the discharge of dredged or fill material into waters of the United States or on their adjacent wetlands. Runoff or overflow from a contained land or water disposal area is considered to be a discharge regulated under Section 404.

State and Local

In addition to federal requirements, disposal of contaminated sediments to the Smith Island upland site may be subject to either or both the State Water Quality Standards (Ch. 173-201 WAC) and the Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC). The solid waste rules apply only if the dredged materials are not regulated by Section 404 of the Federal Clean Water Act (PL 95-217). Under the Solid Waste Minimum Functional Standards (MFS), disposal to the Smith Island upland site of contaminated dredged sediments not regulated by Section 404 would require a permit from Snohomish County Health Department, unless the site was in federal government ownership.

The preferred method of dredging and disposal to Smith Island upland site is by hydraulic pipeline dredge with effluent return to adjacent surface waters. This disposal is subject to Section 404 of the Clean Water Act (CWA) and is, therefore, exempted from requirements of state/local solid waste MFS. In the event that an upland disposal method is selected which is not subject to Section 404, e.g. no return flow to public waters, a local permit will be required for the activity unless the U.S. Navy acquires prior ownership of the site.

A state water quality (WQ) certification or waiver (Section 401, CWA) from Washington State Department of Ecology is prerequisite to final issuance of the federal Section 404 permit for upland disposal to Smith Island. The state WQ certification is issued within the framework of its water quality protection rules and policies, including compliance with water quality criteria and the Antidegradation Policy. The Antidegradation Policy (WAC 173-201-035) essentially requires that existing beneficial uses (of water) will be maintained and not degraded, and that existing high water quality may not be degraded except where 1) it is clear that overriding considerations of the public interest will be served, and 2) all waste/discharges are provided with all known, available and reasonable methods of treatment and control prior to discharge. The state may allow reduced requirements for certain short-term activities and/or a "mixing zone" wherein water quality criteria can be exceeded. Within this framework, the state WQ certification may be conditioned to assure compliance with surface and groundwater criteria and maintenance of existing beneficial uses.

Specific detailed requirements will be formulated by the regulatory agencies based on final site-specific factors and dredging/disposal methods. For the purpose of this evaluation it is assumed that as a minimum: 1) surface water quality criteria in the estuary will be met beyond a suitable mixing zone for dredge return flows, and at the soil/water interface for potential leachate migration by groundwater; and 2) existing beneficial uses of both surface and ground waters must be maintained. The two basic disposal options evaluated are:

1. Excavated upland, where contaminated sediments are maintained in a long-term saturated anaerobic condition to minimize potential leachate generation/migration; and

2. Elevated upland where leachate migration is precluded by an impermeable liner with leachate collection and treatment.

A detailed site-specific evaluation of potential leachate migration in groundwater may be required as a basis for final agency decisions. Such evaluation is not within the scope of this study but would be conducted as appropriate prior to final site design.

Regional Authority Decisions

It is noted earlier that a Regional Authority Decision (RAD) process may be required prior to final permitting, design and construction of a Smith Island upland disposal alternative. As contemplated here, the RAD process would include necessary federal, state and local decision-making to provide final regulatory specifics with regard to such issues as groundwater protection, surface water quality-related mixing zones, and flood plain development. Both the excavated and elevated upland alternatives considered in this report were selected on the basis of minimizing potential leachate impacts. It is recognized that RAD could provide a site-specific basis for selecting or modifying either of the identified alternatives.

Factors and conditions which may be considered in the RAD process include:

Contaminant Concentrations:

Leachate values given in Table 1 are for a composite sediment sample representing the 486,900 cy of contaminated sediments overlying cleaner native materials in East Waterway. However, due to equipment limitations, a total of 928,000 cy of contaminated and underlying clean sediments will be removed by overdredging. The entire 928,000 cy mix of contaminated and cleaner sediments will be disposed of as contaminated sediments only. Therefore, due to sediment dilution, the resulting slurry mass disposed to the Smith Island upland site will have bulk average contaminant concentrations less than that tested by the Corps. Since leachate generation tends to be somewhat concentration-dependent, i.e., higher contamination tends to release higher leachate values, the actual leachate generated from contaminated sediments disposed to Smith Island may be less than those values reported in Table 1.

Groundwater Protection:

Appendix A, herein, presents groundwater quality data collected for this study which shows that brackish (saline) groundwater underlies the Smith Island disposal site. This probably limits or precludes its beneficial use as drinking water.

The disposal site is within the City of Everett City limits, and is candidate for city water service, thus limiting expected use of groundwater.

Nearby municipal and industrial wastewater treatment ponds situated within the groundwater prism on Smith Island may already reflect prior RAD's concerning groundwater uses.

Surface Water Protection:

Surface water quality data was collected from Steamboat Slough and Union Slough under this study and is included as Appendix C herein to provide a reference point for water quality-related determinations. This data shows that salinity excursion adjacent to the disposal site varies between fresh water and salt water. This indicates a widely varying biologic habitat which may not harbor either the very sensitive marine or fresh water species, but rather a more hardy diversity capable of living under such conditions.

In-depth evaluation of a similar contaminated disposal site at Port of Seattle Pier 91 (Hart-Crowser, 1984) showed that leachate migration through a granular perimeter dike under tidal influence was very slow, and was governed by tightness of the disposed soils rather than porosity of the exiting seepage pathway. Because of similar dredged soil characteristics (silt/clay), leachate migration from East Waterway contaminated sediments is likely to be similarly slow and of low volume. Consequently, tidal fluctuations and associated dilution at the adjacent estuary soil/water interface may reduce offsite migration of leachate to biologically acceptable levels in the immediate vicinity of the interface.

The Pier 91 study also showed that the porous dike (leachate pathway) provided an effective tidal dilution buffer prior to leachate reaching the estuary interface. Such a porous (gravel) cover could be installed along the Steamboat/Union Slough bankline if long-term monitoring identified an emerging leachate-related water quality problem.

Flood Plain Development:

Filling of the Smith Island disposal site above the 100 year base flood elevation of +9 feet MSL may require a locally approved Shoreline Development permit.

Conclusion:

Because of the relatively high cost of strictly limiting the potential for offsite migration of leachate, it is important that an objective Regional Authority Decision process for any Smith

Island upland disposal alternative be concluded before final design is initiated.

APPENDIX A

DREDGE SEDIMENTS DISPOSAL
SITE FEASIBILITY STUDY - SMITH ISLAND

HARTCROWSER

Earth and Environmental Technologies

Dredge Sediments Disposal
Site Feasibility Study - Smith Island
Geotechnical and
Hydrogeologic Considerations
NAVSTA - Puget Sound
Everett, Washington

Prepared for
The Department of the Navy
Naval Facilities Engineering Command
Western Division
and
Parametrix

October 3, 1986
J-1827

J-1827

CONTENTS

J-1827

DREDGE SEDIMENTS DISPOSAL SITE FEASIBILITY STUDY - SMITH ISLAND
GEOTECHNICAL AND HYDROGEOLOGIC CONSIDERATIONS
NAVSTA - PUGET SOUND
EVERETT, WASHINGTON

INTRODUCTION

This report presents the results and conclusions of our geotechnical and hydrogeologic feasibility study for the disposal of potentially contaminated dredged sediments at Smith Island. This work is part of ongoing geotechnical studies for the proposed Navy homeporting facility in Everett, Washington. This study addressed only the geotechnical and hydrogeologic considerations associated with the Smith Island disposal site. Other disposal site alternatives were assessed for geotechnical feasibility in a previous report by Hart Crowser, Inc. (Report No. J-1418-13, revised May 13, 1986). A vicinity map of the Smith Island site is presented on Figure 1.

The purpose of this study was to provide geotechnical input and support for the overall feasibility study. The work is not of sufficient detail to be considered adequate for preliminary design. The scope included review of existing data, drilling three shallow borings and installing three groundwater monitoring wells, conducting limited engineering analyses, and developing opinions regarding geotechnical and hydrogeologic feasibility of the site as a disposal area. A description of the exploration program together with boring logs is presented in Appendix A along with a description of groundwater well installation and results.

This work has been accomplished in general accordance with guidelines established at a meeting with Parametrix and the Navy on September 29, 1986. This report has been prepared for the exclusive use of Western Division, Naval Facilities Engineering Command, Parametrix, Inc., and their consultants for specific application to the disposal site discussed. This study has been performed in accordance with generally accepted geotechnical engineering and hydrogeologic practices. No other warranty, expressed or implied, is made.

SITE CONDITIONS

General Site Description

The Smith Island site, as shown on Figure 1 is located in the northwest section of Smith Island, a distance of about 3 to 4 miles north of the homeporting site. The proposed disposal site is bordered by Old Highway 99 on the east, Steamboat Slough on the north and west, and a small waterway on the south.

A dike, the top of which appears to vary from less than one foot to about 8 feet above surrounding ground, is located along Union Slough on the north. The topography of Smith Island is relatively flat and typically varies from about +2 to +5 feet, mean sea level (MSL). This site is virtually undeveloped except for some areas which are used as farmland.

Subsurface Soil Conditions

Our understanding of subsurface soil conditions at this site is based on three explorations accomplished for this study (Appendix A) as well as soils information obtained by Hart Crowser for previous studies in the area and by two studies accomplished at the site by others (Earth Consultants, Inc., August 1979, and Geotech Consultants, Inc., 1986). The soils reports from Earth Consultants, Inc. and Geotech Consultants were provided to us by the Navy. Previous explorations were located within the eastern third of the site (i.e., within approximately 1,000 feet of the Burlington Northern Railroad).

The subsurface soil conditions as disclosed by the limited soil data described above are summarized below:

- The surficial 2 to 3 feet is composed of medium stiff, organic silt. This layer appears to be capable of supporting light construction access traffic. Haul roads would likely be required for moderate to heavy construction traffic.

- The medium stiff surface layer is underlain by very soft, wet, organic clayey silt with pockets of peat and sand seams to depths below ground ranging from 7 to 10 feet over the western portion and from 10 to 20 feet over the eastern portion of the site.

- The soft, clayey silt is typically underlain by medium dense, silty sand and sand to depths of at least 50 feet.

General Groundwater Conditions

The general groundwater conditions at the Smith Island site, based on physiographic conditions and the general hydrologic setting is characterized by shallow groundwater which is influenced by both tidal fluctuations and seasonal variations in precipitation.

Groundwater elevations are expected to vary depending on the tidal stage and season of the year. Precipitation not lost to runoff, used by plants, or evaporated, infiltrates and becomes recharge typically resulting in a mounding of groundwater under the island. General groundwater flow would occur laterally toward the perimeter of the island. Localized variations in permeability of the soils as well as tidal effects may influence the overall radial flow of groundwater to the surrounding surface water. Throughout the majority of the site the groundwater level is anticipated to be near MSL, with minor variations. This is consistent with observed groundwater levels measured in our monitoring wells at the site. More significant variations, are likely immediately adjacent to the waterways due to tidal fluctuations.

Groundwater flow velocities are expected to be fairly low, especially in the upper silt layers due to the low permeability of the soils and low hydraulic gradients expected at the site. Groundwater flow velocities may be higher in the underlying deeper sands due to the higher permeability; however, the hydraulic gradients are also expected to be fairly low in this lower soil unit.

There is currently limited groundwater quality data for the Smith Island site. Monitoring wells have been installed and groundwater samples submitted on October 2, 1986 to a laboratory for analysis of dissolved metals, PCB's, TOX, TOC, and hardness. These parameters were identified as a potential concern from the U.S. Army Corps of Engineers, September 1986 report: "Technical Supplement to Sediment Testing and Disposal Alternatives Evaluation" prepared for the Department of the Navy, Western Division, Naval Facilities Engineering Command. Results of the tests were not available for inclusion at the time of this report. The results will be submitted in a separate addendum to this report when the testing is completed. Field test parameters including pH, temperature, and specific conductance were measured on October 1, 1986 in groundwater samples from the three monitoring wells installed at the site. The pH values measured were close to neutral, ranging from 6.61 to 6.86; temperature measurements were within the range of 11°C to 12°C; and specific conductance, which is a measure of the dissolved ion concentration, were measured in the range from 8,400 micro mhos/cm^3 to 9,000 micro mhos/cm^3. These values indicate the presence of brackish water. (The specific conductance for monitoring wells B-2 and B-3 were measured in the laboratory from samples obtained in the field.)

PROPOSED DISPOSAL OPTIONS

Two options to dispose contaminated dredged soil at Smith Island were considered for this study and are categorized as 1) Excavated Upland and 2) Elevated Upland. For this report "upland" is defined as a site which is higher in elevation than wetlands, as determined by the U.S. Corps of Engineers. At this time, it is our understanding that all of the site except an isolated ½-acre pond would be classified as "upland" by the Corps of Engineers. Each option is considered separately in the following paragraphs. The bulked quantity of dredge material that will be placed at the site is assumed to be about 1.2 million cubic yards.

Excavated Upland Disposal Site

This disposal option involves excavating existing soil to a sufficient depth to place the contaminated sediments below the groundwater level so that the sediments will remain in a saturated state. This would reduce generation of leachate from the contaminated sediments to a small level, as discussed in subsequent sections. A cap of clean soil would be placed over the contaminated dredge material to reduce exposure of the contamination to the surrounding environment. An illustration of a typical cross section for this option is presented on Figure 2a.

Assumptions used for this option include:

- o Groundwater level at the site is assumed to be at mean sea level. Average elevation of the existing ground level is assumed to be +3 feet MSL.
- o A perimeter dike constructed to at least +10 feet MSL would be built to contain the cap material, and provide ponding and freeboard for hydraulic placement of the dredged materials.
- o The excavation would extend to about elevation -10 feet MSL for placement of the contaminated sediments.

Elevated Upland Disposal Site

This disposal option involves constructing a dike around the perimeter of the site and filling the diked area with contaminated and clean dredge material above existing site grades. The contaminated soil would be above the groundwater level. An illustration of a possible cross section for the embankment disposal option is presented on Figure 2b.

Assumptions used for this option include:

- Groundwater level at the site is assumed to be at mean sea level. The average elevation of the existing ground level is assumed to be +3 feet MSL.

- A relatively high (e.g. 20- to 25-foot) perimeter dike would need to be constructed to contain the dredged materials and provide ponding and freeboard for hydraulic placement.

GEOTECHNICAL FEASIBILITY CONSIDERATIONS

The opinions presented in this section are based on limited soil and groundwater information and on feasibility level engineering analyses. The information presented herein is intended to be used only in the evaluation of the feasibility of the site as a dredge material disposal area and is not considered sufficient for design level work.

Excavated Upland Disposal Site

Discussion of this disposal option is divided into five categories: Excavation, Dike Construction, Settlement, Dewatering, and Contamination Transport.

Excavation

- Material excavated to -10 feet MSL at this site is expected to be predominantly soft, wet, organic silt and clay with varying amounts of peat and sand seams.

- Excavation made below the groundwater level would probably need to be cut at about 4H:1V or flatter to provide stable excavation slopes.

- Stockpiles of excavated soil would not support construction equipment unless an extended period of dry weather was available to allow the soil to dry.

- Future use of the site which receives the excavated soils would be limited due to the soft organic nature of those soils. The site would not be usable for several years without special treatment, allowing for reconsolidation of the excavated soils. Drainage provisions could be used to accelerate the consolidation process. Following that time and placement of a sand and gravel cap, the site might be used for light industrial applications. However, the site could still experience continuing settlement. Settlement sensitive structures might require pile support.

- Excavated soil may not be suitable for constructing dikes. Slopes of 4H:1V to 5H:1V or flatter may be required to construct a dike without significant slope failures during construction. Even at relatively flat slopes, localized sloughing would be expected. In addition, the wet organic material is expected to be difficult to work with conventional construction equipment.

- The bulking factor of excavated soil is expected to range from about 1.2 to 1.4 of the in-situ volume.

- A set back on the order of 10 feet or more from the edge (top) of excavation to the toe of the perimeter dike should be assumed to reduce potential instability at the toe of the dike slope.

Dike Construction

- We recommend that imported sand or sand and gravel be used to build the perimeter dike. The granular material would provide better constructability than would in-situ soils, as discussed above. It is possible that a portion of the dike could be constructed of in-situ sand encountered below the organic silt during excavation. The quantity of in-situ sand between 7 and 13 feet below ground may be sufficient to construct a 6-foot-high perimeter dike around the site.

- Slopes on the order of 3H:1V or flatter would likely be required to reduce potential failure below the dike within the underlying soft, organic silt. Alternatively, steeper slopes might be used in conjunction with staged construction of the dike.

- A setback on the order of 30 to 50 feet between the dike and the Burlington Northern Railroad tracks should be assumed to reduce the effects of construction on the railroad.

Settlements

- Some limited settlement below the dike may be expected due to consolidation of the underlying soft soils. The amount of anticipated settlement is not considered to be significant.

- Since final grade over the site may be 4 to 6 feet above existing ground level, settlement of one to two feet due to consolidation of the underlying in-situ soil may occur. In addition, significant total and differential settlement along the surface of the fill resulting from consolidation of the slurry fill material is anticipated on the order of 4 feet plus.

- A significant portion of settlements due to consolidation is expected to occur over a period of time on the order of 1 to 3 years following construction. Long-term settlement in excess of a foot may occur over a 20-year period following construction.

- Future development at this site following completion of the disposal project would need to consider the effect of long-term settlements and associated impact on foundations. Light industrial development which is not settlement sensitive may be feasible.

- o Future development would likely require the placement of several feet of additional fill (above the cap) to provide sufficient bearing and to raise site grade to above flood level (assumed to be approximately +10 feet MSL). This additional fill would result in settlements above those described above.

Dewatering

If a liner were required by the regulatory agencies for the excavated option, then the site may have to first be dewatered to facilitate liner construction. Dewatering considerations are presented below:

- o The soils within the depth of excavation are of relatively low permeability.

- o Because of the low permeability, dewatering could probably be accomplished by a system of trenches and sumps throughout the base of the excavation supplemented by perimeter dewatering wells.

- o A 2- to 4-foot-thick blanket of sand and gravel, in combination with lateral drains would likely be required across the base of the excavation to aid in collection of water reaching the surface.

- o Pressure relief wells may also be required at areas producing water in excess of the capacity of the sump system.

- o A potential impact of dewatering would be consolidation and settlement of adjacent properties.

Contamination Transport

The potential for contaminant transport under the Excavated Upland disposal option was discussed in the U.S. Army Corps of Engineers, Technical Supplement to the Sediment Testing and Disposal Alternatives Evaluation, September 1986. The results of anaerobic batch leaching tests indicate that the identified contaminants are sediment bound as long as the material remains saturated and a chemical environment similar to in-situ conditions is maintained. Alterations in pH, oxidation-reduction potential, salinity, and degree of aeration may influence the mobility of contaminants including metals and organics. The Corps of Engineers study shows that minimal leachate generation would occur under this disposal option.

Groundwater transport of leachate was identified as a major transport mechanism. Leachate generated would travel in the general groundwater flow direction. The leachate generation from the disposal area is expected to be low due to the low permeability of the dredge soils and the small hydraulic gradients typical for this type of hydrologic setting. The degree of groundwater impact from leachate is expected to be minimal due to adsorption of contaminants by soils in the flowpath and dilution resulting from groundwater dispersion.

Potential for leachate migration by groundwater transport may require monitoring and potential implementation of abatement measures. Water quality could be monitored in wells installed around the perimeter of the site.

Elevated Upland Disposal Site

Discussion of this disposal option is divided into four categories: Excavation, Dike Construction, Settlement, and Contamination Transport.

Excavation

- Partial excavation of in-situ soil is not advised in order to reduce the final elevation of the fill. Once the surface crust (1 to 3 feet thick) is removed, underlying soft soil would not be able to support construction equipment. Excavation should be limited to minor grading in preparation of the site for liner placement.

Dike Construction

- o The height of the perimeter dike depends on the depth of excavation, liner thickness, and the net usable area in which to deposit the contaminated dredge spoils. A dike height of 20 to 25 feet is considered possible for the proposed development.

- o Slopes on the order of 3H:1V or flatter would likely be required to provide adequate stability within the underlying soft soils.

- o We recommend the dike be constructed of imported sand or sand and gravel to provide improved constructability.

- o A setback on the order of 30 to 50 feet between the perimeter dike and the Burlington Northern Railroad track should be assumed to reduce the effects of construction on the railroad.

Settlement

- o Significant settlements resulting from consolidation of in-situ soft soils underlying the dike and fill are anticipated due to raising site grade. Such settlement could be on the order of 2 to 4 feet.

- o A leachate control liner would have to be designed to withstand the 1 to 4 feet of total settlement, with a differential settlement of 3 feet over a 100- to 200-foot horizontal distance.

- o Additional settlements at the fill surface will result from consolidation of the dredge fill material. These settlements could be on the order of 4 feet plus.

- o A significant portion of settlements due to consolidation is expected to occur over a period of 1 to 3 years. Continued settlement beyond that time, in excess of 1½ feet, is possible.

o Future development at the site would need to consider the effects of settlement on foundations. Other impacts to future development include limitations on use of piling for a lined site, and the need to maintain saturated conditions in the contaminated fill.

Contamination Transport

The Elevated Upland disposal option poses greater potential for leachate generation and contaminant transport than the Excavated Upland disposal option, because of the potential for the sediments to drain and become aerobic. Physiochemical changes including oxidation-reduction potential, pH, salinity, and temperature are likely to occur under aerated conditions, which may increase the mobility of contaminants in the sediment. Results of aerobic batch leaching tests conducted by the U.S. Army Corps of Engineers as reported in the September 1986 Technical Supplement, indicate and increase of *contaminant concentration* in the leachate compared to results of the anaerobic tests.

For an unlined Elevated Upland option, leachate generation would occur as rainfall infiltrates through the cap to the dried and aerated contaminated sediments. Leachate would also be generated by consolidation of the soils during the first 1 to 3 years following placement. Migration of leachate may occur both by surface discharge from the sides of the contaminated sediments and by movement into the underlying groundwater. Control measures to limit leachate generation could include a sloped clay or synthetic cap with a vegetative cover. In addition, measures to abate potential leachate migration to groundwater or to surrounding surface waters may include options such as a liner, depending on the findings of detailed site-specific studies.

A lined Elevated Upland disposal option would reduce the drying rate of the soils, but not guarantee the sediments would always remain saturated. A liner would tend to eliminate loss of water through the walls and floor of the system, but loss through evaporation is possible. It is anticipated, though, that drying of the contaminated soils (if covered with 5 feet plus of saturated clean dredge spoils) would take several years, if not several decades.

Earthquake Considerations

The Pacific Northwest is a seismically active area, with the Puget Sound area classified as Zone 3 by NAVFAC P-355 and the Uniform Building Code. Earthquake considerations in seismically active areas include: the potential for and intensity of ground shaking; ground rupture due to faulting; and liquefaction.

Ground shaking from a major earthquake could impact the site during the service life of the facility. Peak ground accelerations of 0.15 g have an approximate 80 percent probability of nonexceedence during a 50-year period. Such accelerations would likely develop from earthquakes of magnitude 6.5 or greater.

Ground rupture due to faulting is not a concern for the site. In the Puget Sound region all of the large earthquakes have been deep subcrustal events at depths ranging from 20 to 40 miles below the ground surface.

The liquefaction potential at the site is not considered significantly different than that of other saturated fills in Puget Sound. For example, the ports of Everett, Seattle, and Tacoma are all founded over areas of hydraulic dredge filling, and sandy delta deposits. Historically the Everett site has been exposed to the two major recent earthquakes of the region, Olympia 1949 and Seattle-Tacoma 1965. During both earthquakes no major damage was noted at the Everett site. The only significant Puget Sound port damage noted during those earthquakes, that we are aware of, involved movement of a bulkhead on Harbor Island, at the Port of Seattle and some ground failure at the Port of Olympia. The damage was not catastrophic, but did require repair. Seattle and Olympia are located much closer to the center of those past earthquakes than Everett, possibly explaining why damage was not observed at Everett.

There is uncertainty associated with predicting earthquake damage in the Puget Sound region and the Everett area. This is primarily due to relatively limited data relating to major earthquakes. Analytical techniques typically predict liquefaction potential at area port facilities, while historic records (50 years) show limited damage due to liquefaction.

In the event of a major earthquake, the site could experience localized liquefaction. This could result in localized loss of foundation support, settlement, or slope distortion. Some repair of the facility might be required. It is possible that some of the contaminated sediment could be exposed by such an event.

The Elevated Upland disposal option is considered to have a greater seismic risk than the Excavated Upland disposal option. This is because in the excavation option the contaminated materials are embedded into the area land mass, having much greater confinement than the elevated option. In the event of loss of foundation support or slope distortion, it is more likely that the contaminated material would be exposed in the elevated configuration.

CONCLUSION

The Elevated and Excavated Upland disposal options appear to be geotechnically feasible at the Smith Island site. Design of either option will require collection of additional site soil and groundwater data, in addition to laboratory testing and engineering analyses.

HART CROWSER, INC.,

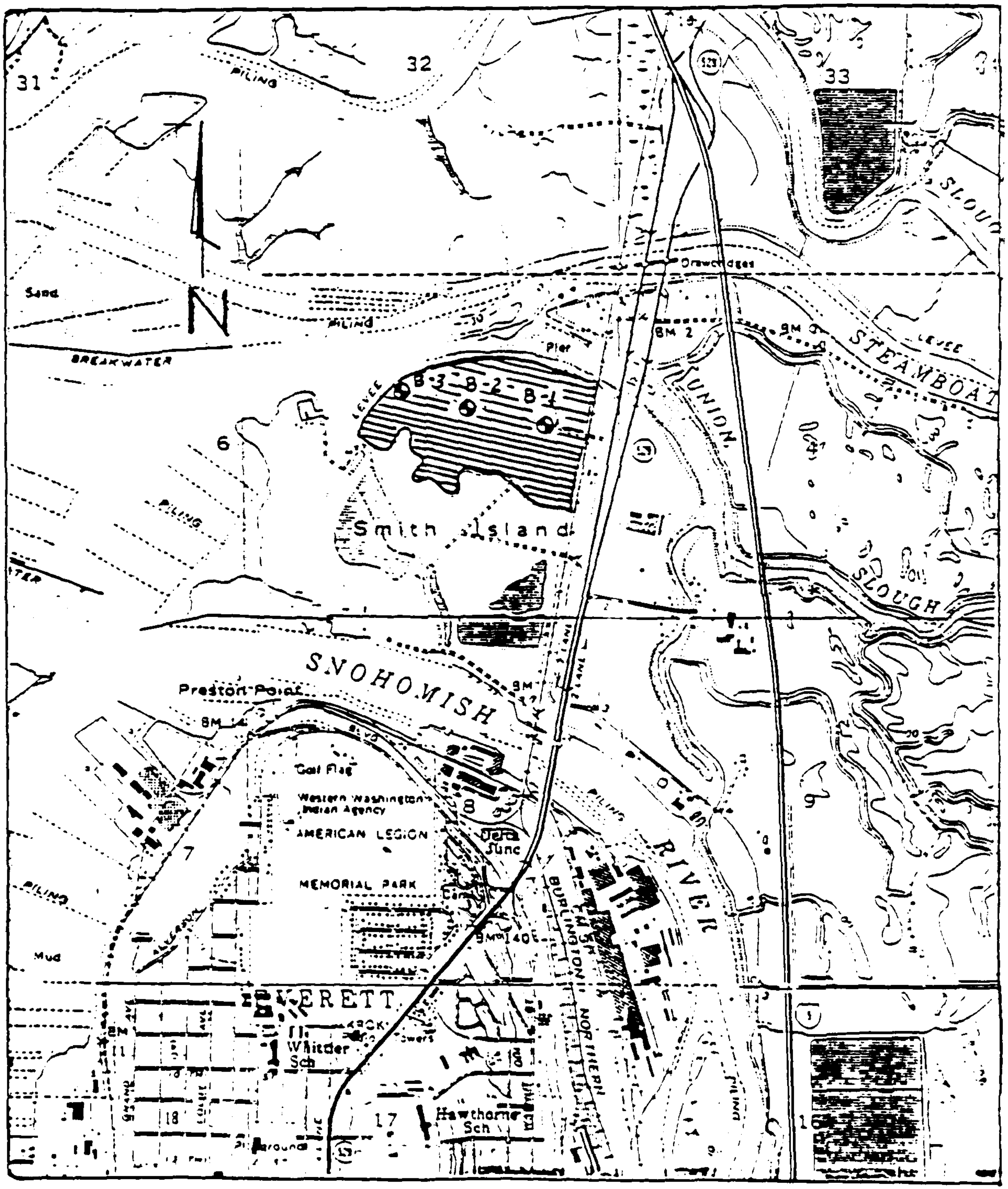
TIMOTHY J. FLYNN
Senior Staff Hydrogeologist

DANIEL W. MAGEAU, P.E.
Project Engineer

PAUL F. FUGLEVAND, P.E.
Associate Engineer

DWM/PFF:sea

VICINITY MAP AND EXPLORATION PLAN
– SMITH ISLAND SITE



B-1 BORING LOCATION AND NUMBER

0 1000 2000 3000 4000
SCALE IN FEET

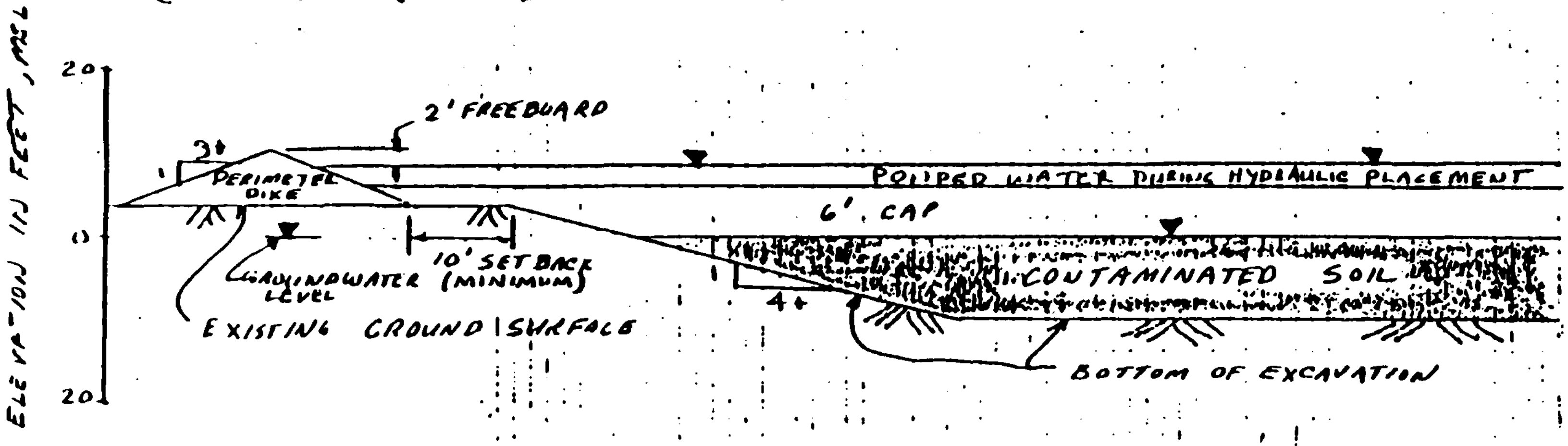
J-1827 OCTOBER 198?
HART - CROWSER, INC.

ADAPTED FROM U.S.G.S. MAP, MARYSVILLE QUAD, WASHINGTON.

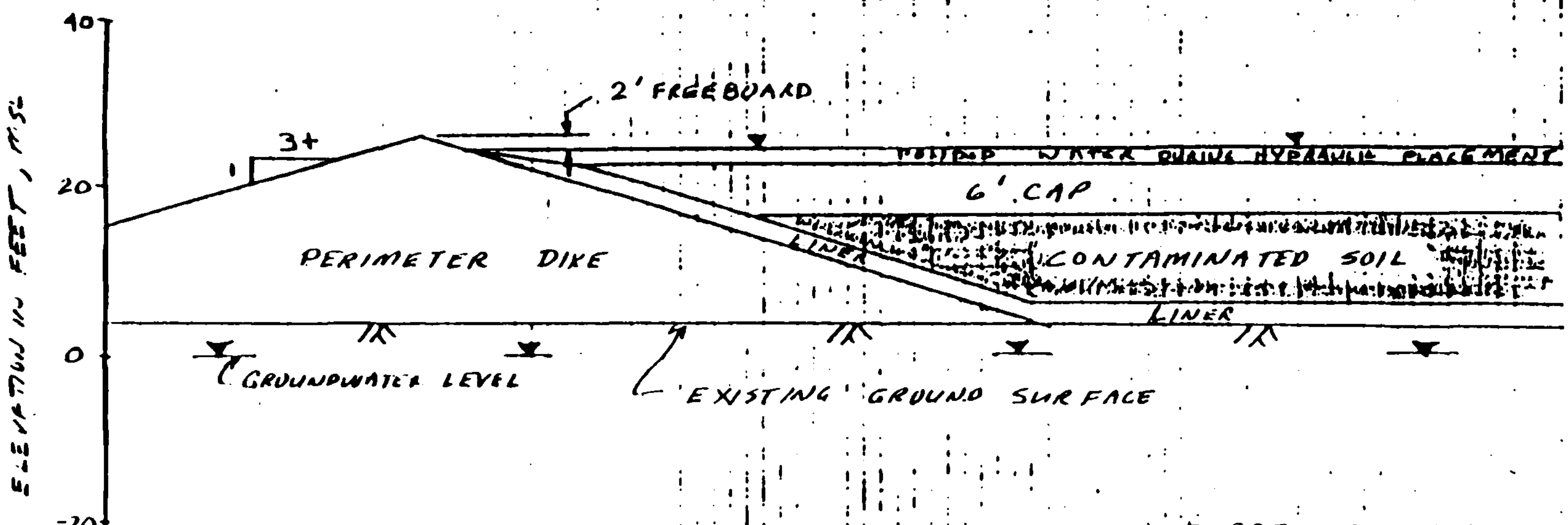
FIGURE 1.

SMITH ISLAND DREDGE MATERIAL DISPOSAL CONCEPTS

(A) "EXCAVATED" CONCEPT



(B) "ELEVATED" CONCEPT



J-1827 OCTOBER 1986

HART CROWSER INC

APPENDIX A
FIELD EXPLORATIONS

The program of subsurface explorations for this project included completion of three borings and three water well installations. The results of our exploration program are presented on the exploration logs within this Appendix. The exploration logs are a representation of our interpretation of the drilling or excavation, sampling, and testing information. The depth where the soils or characteristics of the soils changed is noted. The change may be gradual. Soil samples recovered in the explorations were visually classified in the field in general accordance with the method presented on Figure A-1. A legend for the field exploration logs defining symbols and abbreviations utilized is also presented on Figure A-1.

The exploration locations are presented on Figure .. The explorations were originally located in the field by hand taping from existing physical features. The ground surface elevations of the explorations, as given in this report, were established during a site survey by Parametrix, Inc. The ground surface elevations are presented on the exploration logs.

Auger Borings and Soil Sampling

A total of three hollow-stem auger borings, designated B-1 through B-3, were drilled on September 30 and October 1, 1986. The borings were completed to a depth of 24 feet below the ground surface. The borings were advanced with a truck-mounted drill rig under subcontract to Hart Crowser, Inc. using a 3-3/8-inch inside diameter hollow-stem auger. The drilling was accomplished under the continuous observation of an engineering geologist from our firm. Detailed field logs were prepared of each boring.

The Standard Penetration Test procedure as described in ASTM D 1587, was used to obtain disturbed samples. A standard 2-inch outside diameter, split-spoon sampler is driven into the soil a distance of 18 inches using a 140-pound hammer, free-falling 30 inches. The number of blows required to drive the sampler the last 12 inches is the Standard Penetration Resistance. This resistance, or blow count, provides a measure of the relative density of granular soils and consistency of cohesive soils. The blow counts are plotted on the boring logs at the respective sample depths. The Standard Penetration Test is a useful quantitative tool from which density/consistency is determined. The results must be used in conjunction with other tests and engineering judgment.

Soil samples were field classified and placed in specially cleaned jars with teflon-lined lids and stored on ice in coolers prior to submittal with chain-of-custody forms to Laucks Testing Laboratories. A composite of the 2.5-foot depth soil samples from B-1, B-2, and B-3 will be made by Laucks and also a composite of the 7.5-foot depth soil sample from each of the three borings, resulting in two soil samples. The composite sample will be analyzed for priority pollutant metals and PCB's.

Monitoring Well Installation

Three 2-inch-diameter monitoring wells (B-1 through B-3) were installed in the project site, as shown on Figure 1, on September 30 and October 1, 1986. The wells were drilled using hollow-stem auger to a depth of 15 feet.

The wells were installed by inserting 2-inch (I.D.) PVC screen (5-foot sections) and pipe through the auger center. As the auger was extracted, an Aqua No. 8 sand pack was installed around the well screen to 2 feet above the screen level. Native material was placed above the sandpack to within 3 feet of the ground surface. The borings were sealed to the ground surface with cement/bentonite grout. The wells were developed using a stainless steel hand bailer. The bailer was washed with alconox detergent and rinsed with deionized water between each well.

Groundwater Sampling

Groundwater samples were collected from wells B-1, B-2, and B-3 on October 1, 1986. Three casing volumes were removed from each well prior to collecting the samples. Field parameters including pH, temperature, and specific conductance were measured in the field. Groundwater samples were collected using a peristaltic pump. Clean polyethylene tubing was used for each well. Groundwater samples were collected for analyses of priority pollutant metals, total organic carbon (TOC), total organic halogens (TOX), and PCB's and hardness. Groundwater samples collected for metals analysis were filtered in the field. The samples were kept on ice in coolers prior to submittal with chain-of-custody forms to Laucks Testing Laboratories.

Key to Exploration Logs

Sample Descriptions

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling

BORING SAMPLES

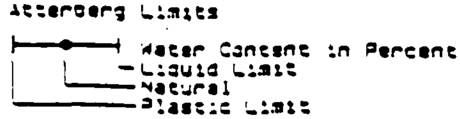
- ⊠ Split Spoon
- Shelby Tube
- Cuttings
- Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

- ⊠ Grab (Jar)
- Bag
- Shelby Tube

Test Symbols

GS	Grain Size Classification
CN	Consolidation
TUU	Triaxial Unconsolidated Undrained
TCU	Triaxial Consolidated Undrained
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Curve
AL	Atterberg Limits



Ground Water Observations

- Surface Seal
- Ground Water Level on Date (ATD) At Time of Drilling
- Observation Well Tip or Slotted Section
- Ground Water Seepage (Test Pits)

Boring Log B-1

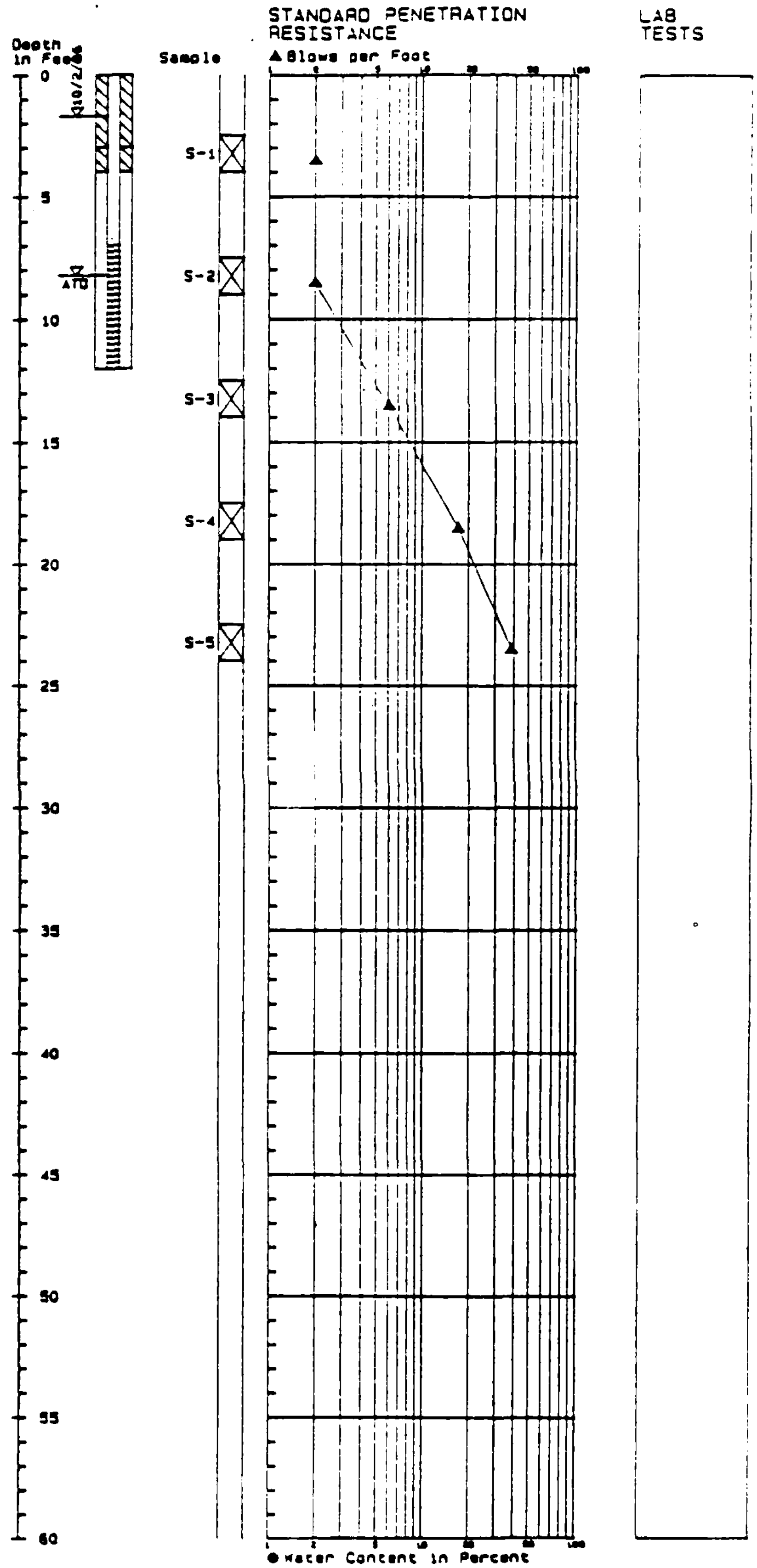
SOIL DESCRIPTIONS
Elevation Top of Casing in Feet 2.7 MSL
Ground Surface Elevation in Feet 1.9 MSL

3 inches GRAVEL on surface over very soft, wet, gray, organic, clayey SILT.

- Wood fragments at 7.5 to 8-foot-depth

Loose to medium dense, wet, gray, slightly silty, fine to medium SAND.

Bottom of Boring at 24.0 Feet.
Completed 9/30/86.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

J-1827 September 1986
HART-CROWSER & associates, inc.
Figure A-2

Boring Log B-2

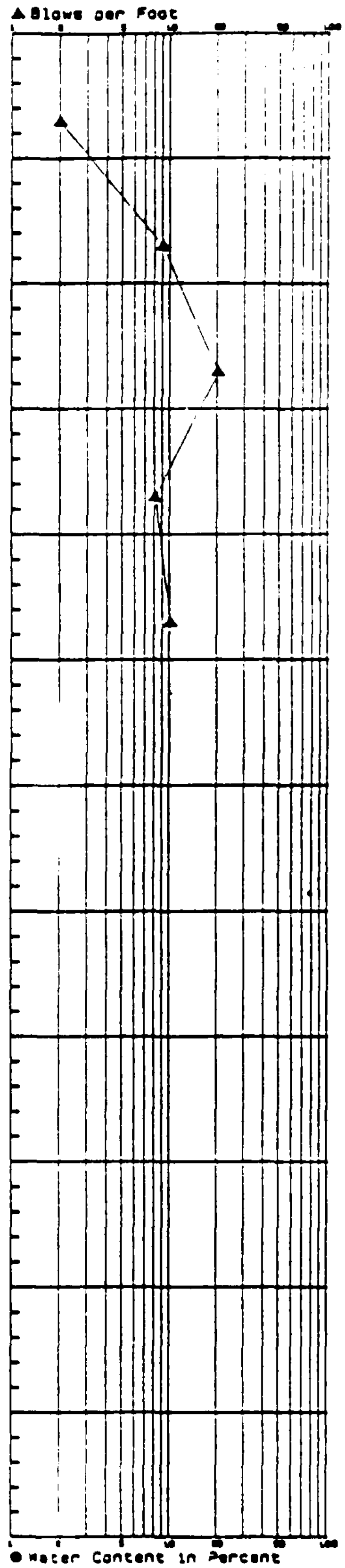
SOIL DESCRIPTIONS
Elevation Top of Casing in Feet 3.9 MSL
Ground Surface Elevation in Feet 2.9 MSL

Depth in Feet	Soil Description	Sample
0–6.5	Soft, wet, gray, organic, clayey SILT.	S-1
6.5–18	Loose to medium dense, wet, gray, silty, fine SAND.	S-2, S-3
18–24	Medium dense, wet, gray, fine to medium SAND.	S-4, S-5
24	Bottom of Boring at 24.0 Feet. Completed 10/1/86.	

10/2/86

ATD

STANDARD PENETRATION RESISTANCE
▲ Blows per Foot



● Water Content in Percent

LAB TESTS

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

J-1827 October 1986
HART-CROWSER & associates, inc.
Figure A-3

Boring Log B-3

SOIL DESCRIPTIONS
Elevation Top of Casing in Feet 4.9 MSL
Ground Surface Elevation in Feet 4.3 MSL

GRAVEL. (FILL)

Stiff to soft, damp to wet, gray, slightly clayey SILT.

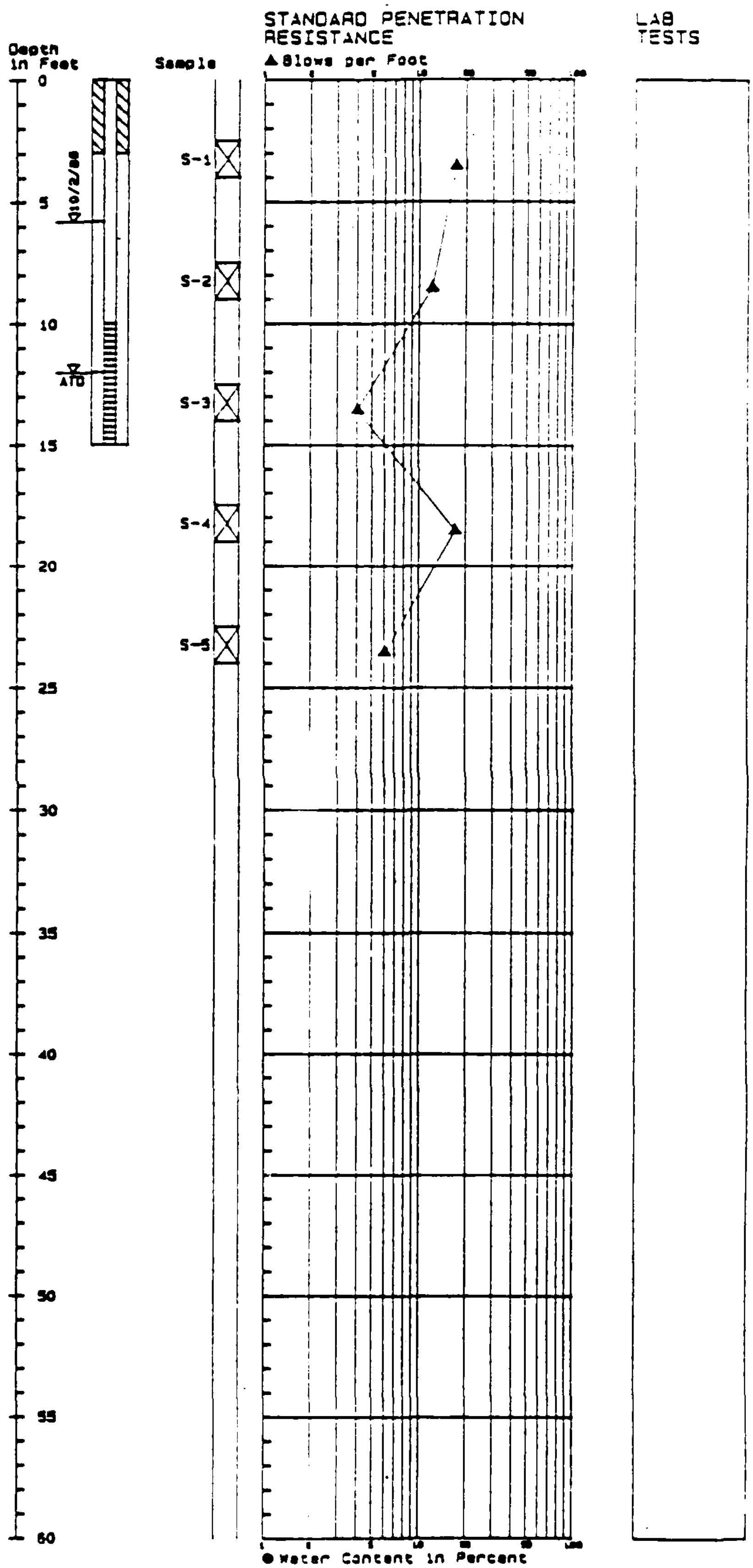
- Organics encountered below 5-foot depth.

Loose to medium dense, wet, gray, slightly silty to silty, fine SAND.

Medium dense, wet, gray, fine to medium SAND.

Loose, wet, gray, silty, fine SAND.

Bottom of Boring at 24.0 Feet.
Completed 9/30/86.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

J-182⁻ September 1986

HART-CROWSER & associates, inc.

Figure A-4

HARTCROWSER

Hart Crowser Inc.
1910 Fairview Avenue East
Seattle, Washington 98102-3699
206 324 9530

Earth and Environmental Technologies

J-1827

October 24, 1986

Parametrix, Inc.
13020 Northrup Way, Suite #8
Bellevue, Washington 98005

Attn: Jim Jordan

Re: Soil and Water Testing Results
Addendum No. 1 to Report:
Dredge Sediments Disposal - Smith Island
Geotechnical and Hydrogeological Considerations
NAVSTA - Puget Sound
October 3, 1986

Dear Mr. Jordan:

This letter presents the results of the soil and groundwater sample analyses performed by Laucks Testing Laboratories as referenced in the above noted Hart Crowser report.

A detailed interpretation of the chemical results was not performed; however, we did observe the following about the data:

- Water: The concentration of metals and PCB's in the groundwater samples meet the Federal Drinking Water Standards, referenced in Table 1 of the U.S. Army Corps of Engineers report: "Technical Supplement to Sediment Testing and Disposal Alternatives Evaluation", September 1986.

- Polychlorinated Biphenyls (PCBs) were not detected in the composite soil samples tested. In general, metal concentrations are higher in the upper composite soil sample (A) relative to the lower composite soil sample (B). In general, the metal concentrations are within ranges reported for sediments from non-industrial Puget Sound reference areas. *

*Commencement Bay Nearshore/Tideflats Remedial Investigation, Final Report, Volume 1, USEPA, WSDOE, p. 3-18.

Parametrix, Inc.
October 24, 1986

The certificates of laboratory analyses are attached. We trust this letter will meet your needs.

Sincerely,

HART CROWSER, INC.

TIMOTHY J. FLYNN
Senior Staff Hydrogeologist

PAUL F. FUGLEVAND, P.E.
Associate Engineer

TJF/PFF:sea

Attachments:
Laucks Testing Laboratories, Inc.
Soil and Water Sample Analyses Certificates
Laboratory #99118 and #99126

Laucks Testing Laboratories, Inc.

940 South Harney St. Seattle, Washington 98108 (206)767-5060

Chemistry, Microbiology and Technical Services

Certificate

CLIENT: Hart Crowser
1910 Fairview Ave. E.
Seattle, WA 98102
ATTN: Tim Flynn

LABORATORY NO: 99118

DATE: Oct. 21, 1986

REPORT ON: WATER

SAMPLE IDENTIFICATION: Submitted 10/2/86 and identified as shown below:

1) 1827 B-1 SW 10/1 10:32 SPL E
2) 1825 B-2 SW 10/1 2:22
3) 1825 B-3 SW 10/1 11:03

TESTS PERFORMED AND RESULTS:

	1	2	3
	MPN per 100mls		
Total Coliform Count	G/1600.	1600.	G/1600.
	parts per billion (ug/L)		
PCB	L/1.	L/1.	L/1.

parts per million (mg/L)

	1	2	3	Lab Blank
Total Organic Carbon	100.	84.	90.	L/0.1
Total Organic Halogens as Cl	0.41	0.10	0.29	L/0.02
Hardness	1000.	1600.	1400.	—

Laucks
Testing Laboratories, Inc.
940 South Harney St. Seattle Washington 98108 (206)767-5060

Chemistry Microbiology and Technical Services

Certificate

Hart Crowser

LABORATORY NO: 99118

Samples were analyzed for inorganic metals priority pollutants in accordance with Test Methods for Evaluating Solid Waste (SW-846), U.S.E.P.A., 1982, method 6010 and the 7000 series (metals analysis).

Inorganics

parts per billion (ug/L)

	1	2	3	Lab Blank
Antimony	L/5.	L/5.	6.	L/5.
Arsenic	L/5.	L/5.	5.	L/5.
Beryllium	L/1.	L/1.	L/1.	L/1.
Cadmium	L/1.	L/1.	L/1.	L/1.
Chromium	11.	4.	5.	L/1.
Copper	2.	1.	L/1.	3.
Lead	L/10.	L/10.	L/10.	L/10.
Mercury	L/0.001	L/0.001	L/0.001	L/0.001
Nickel	L/2.	L/2.	3.	L/2.
Selenium	L/5.	L/5.	L/5.	L/5.
Silver	L/1.	L/1.	L/1.	L/1.
Thallium	L/2.	L/2.	L/2.	L/2.
Zinc	110.	43.	9.	2.

Key

L/ = less than
G/ = greater than

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

J.M. Owens

JMO:dr

Laucks
Testing Laboratories, Inc.

940 South Harney St. Seattle, Washington 98108 (206) 767-5060

Chemistry, Microbiology and Technical Services

Certificate

Hart Crowser

LABORATORY NO: 99118

APPENDIX

Surrogate Recovery Quality Control Report

Listed below are surrogate (chemically similar) compounds utilized in the analysis of volatile and organic compounds. The surrogates are added to every sample prior to extraction and analysis to monitor for matrix effects, purging efficiency, and sample processing errors. The control limits represent the 95% confidence interval established in our laboratory through repetitive analysis of these sample types.

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
		parts per billion (ug/L)			
Lab Blank	Dibutylchlorendate	1.0	0.72	72.	24-150
1	Dibutylchlorendate	1.0	0.62	62.	24-150
2	Dibutylchlorendate	1.0	0.64	64.	24-150
3	Dibutylchlorendate	1.0	0.60	60.	24-150
Lab Blank	Isodrin	0.50	0.46	92.	43-118
1	Isodrin	0.50	0.33	66.	43-118
2	Isodrin	0.50	0.39	78.	43-118
3	Isodrin	0.50	0.32	64.	43-118

Laucks Testing Laboratories, Inc.

940 South Harney St. Seattle Washington 98108 (206)767-5060

Chemistry Microbiology and Technical Services

Certificate

CLIENT: Hart Crowser
1910 Fairview Ave. E.
Seattle, WA 98102
ATTN: Tim Flynn

LABORATORY NO: 99126

DATE: Oct. 21, 1986

REPORT ON: SOIL

SAMPLE IDENTIFICATION: Submitted 10/2/86 and identified as shown below:

1)	J 1827	B-1	S-1	2.5-4.0	1/1/1'
2)	J 1827	B-1	S-2	7.5-9.0	1/1/1
3)	J 1827	B-1	S-3	12.5-14.0	0/3/3
4)	J 1827	B-1	S-4	7.5-9.0	3/6/11
5)	J 1827	B-1	S-5	22.5-24.0	7/13/25
6)	J 1827	B-3	S-1	2.5-4.0	10/9/8
7)	J 1827	B-3	S-2	7.5-9.0	4/5/7
8)	J 1827	B-3	S-3	12.5-14.0	2/2/2
9)	J 1827	B-3	S-4	17.5-19.0	2/7/10
10)	J 1827	B-3	S-5	22.5-24.0	0/3/3
11)	J 1487	B-2	S-1	2.5-4.0	1/1/1
12)	J 1827	B-2	S-2	7.5-9.0	2/4/5
13)	J 1827	B-2	S-3	12.5-14.0	4/5/15
14)	J 1827	B-2	S-4	17.5-19.0	3/3/5
15)	J 1827	B-2	S-5	12.5-14.0	3/4/6

Samples were then composited according to the following scheme:

Composite A = Samples 1, 6, 11
Composite B = Samples 2, 7, 12

All other samples were put on hold.

TESTS PERFORMED AND RESULTS:

	A	B
	parts per billion (ug/kg)	
PCB	L/100.	L/100.

Laucks
Testing Laboratories, Inc.

940 South Harney St. Seattle Washington 98108 (206)767-5060

Chemistry Microbiology and Technical Services

Certificate

Hart Crowser

LABORATORY NO: 99126

Samples were analyzed for inorganic metals priority pollutants in accordance with Test Methods for Evaluating Solid Waste (SW-846), U.S.E.P.A., 1982, method 6010 and the 7000 series (metals analysis).

Inorganics

	A	B	Lab Blank
Total Solids, %	59.9	68.7	—
	parts per million (mg/kg) dry basis		
Antimony	L/3.	L/3.	L/3.
Arsenic	22.	12	L/0.5
Beryllium	0.6	0.5	L/0.1
Cadmium	0.1	0.2	L/0.1
Chromium	59.	47.	L/1.
Copper	42.	31.	1.
Lead	12.	5.	L/1.
Mercury	L/0.1	L/0.1	L/0.1
Nickel	42.	39.	L/2.
Selenium	L/0.5	L/0.5	L/0.5
Silver	0.2	0.1	L/0.1
Thallium	L/0.5	L/0.5	L/0.5
Zinc	76.	66.	4.

Key

L/ = less than

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

J.M. Owens

JMO:dr

Laucks
Testing Laboratories, Inc.
940 South Harney St. Seattle Washington 98108 (206) 767-5060
Chemistry Microbiology and Technical Services

Certificate

Hart Crowser

LABORATORY NO: 99126

APPENDIX

Surrogate Recovery Quality Control Report

Listed below are surrogate (chemically similar) compounds utilized in the analysis of volatile and organic compounds. The surrogates are added to every sample prior to extraction and analysis to monitor for matrix effects, purging efficiency, and sample processing errors. The control limits represent the 95% confidence interval established in our laboratory through repetitive analysis of these sample types.

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
		parts per billion (ug/kg)			
Lab Blank	Dibutylchlorendate	50.0	13.8	27.6	20-154
A	Dibutylchlorendate	50.0	22.0	44.0	20-154
B	Dibutylchlorendate	50.0	10.5	21.0	20-154
Lab Blank	Isodrin	25.0	25.0	100.	43-118*
A	Isodrin	25.0	20.0	80.0	43-118*
B	Isodrin	25.0	23.5	94.0	43-118*

* Control limits are established when a sufficient number of analyses have been performed for an analyte in a specific matrix to allow development of a statistically meaningful figure. In this case, no control limits have been established in the soil matrix and the limits given are for a water matrix and should be regarded as estimates.

APPENDIX B

LEACHATE CONTROL SYSTEM
SMITH ISLAND UPLAND DISPOSAL SITE
FEASIBILITY STUDY
OCTOBER 1986

Liner

The recommended liner includes two separate layers. The first layer would be two feet of recompacted, bentonite-amended soil with a maximum hydraulic conductivity of 10^{-7} centimeters per second. Site preparation would be minimal, requiring only clearing and grubbing and grading the existing ground surface level. The borrow source for the base soil would have to be identified. Preferred soil would be silty or clayey fine sand, sandy silt or sandy, silty, clay. Approximately 250,000 cubic yards would be required. The base soil would be admixed with a pre-determined amount of sodium bentonite in a pug-mill and placed and compacted in six inch lifts. The cost for the soil liner is estimated to be $7,500,000, including contingencies, engineering, administration and sales tax.

After the soil liner was constructed, a 100 mil High Density Polyethylene (HDPE) membrane liner would be installed. The HDPE liner would be delivered to the site in pre-cut rolls varying from 6 to 30 feet in width, depending on the manufacturer. The panels would be joined in the field using thermal fusion techniques that vary depending on the manufacturer. All manufacturers warrant field seams to be stronger than the material itself. Quality assurance during construction would be implemented to ensure proper field seaming. The estimated cost of the HDPE liner is $4,400,000. Total liner costs would then be $11,900,000. These cost figures include contingencies, engineering, administration and sales tax, and represent a planning level estimate that should be accurate to within plus 50% or minus 30%.

Leachate Collection

The leachate collection system for the upland elevated (above-groundwater) alternative would be installed within the top four feet of the clean dredge sands that will be placed over the contaminated dredge spoils. This would entrap any leachate collecting or arising over the contaminated sediments while tending to maintain the contaminated cell in its saturated anaerobic state. The collection system would include a network of six inch, perforated, plastic pipe meeting ASTM F-405 (ADS or equal). A filter fabric sock around the pipe would be used to prevent the clogging of the pipe by soil fines. The pipe would be placed at approximately 200 foot centers and sloped at a minimum of 0.2%. The collection pipes would be connected to a non-perforated, collection headerpipe within the perimeter dike. The header pipes would converge at the northeast portion of the site for further transfer to the treatment or temporary storage facilities. It is estimated that approximately 16,900 feet of perforated pipe and 4,200 feet of non-perforated pipe is required. Installation of the perforated pipe would require specialized equipment for access and burying the pipe in the unconsolidated dredge spoil material.

Capping

After the dredge spoils have consolidated the site would be capped. The objective of the capping would be two-fold. First, it would prevent the entry of oxygen into the contaminated sediment such that anaerobic conditions tend to be maintained and contaminants remain adsorbed to the sediment particles. Second, it would prevent the percolation of precipitation into the sediments with the subsequent need to treat the leachate generated.

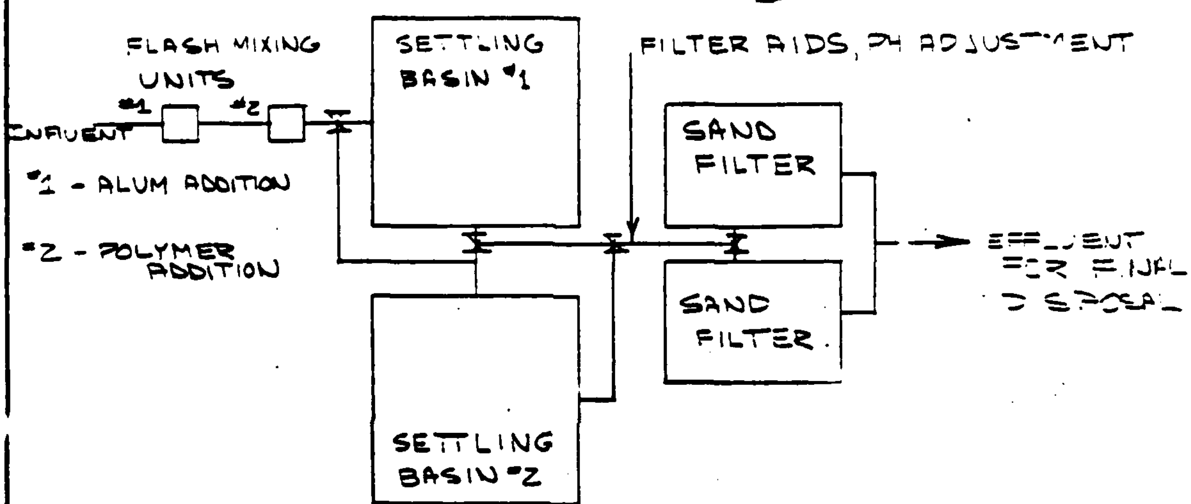
Preparation for lining would be limited to grading of the disposal site to minimum grades of 2%. After grading, a 100 mil HDPE liner would be installed. Overlying the liner, a polyethylene drainage net and filter fabric would be installed to provide a flow path to the sides of the site for infiltrated precipitation. The final layer of the cover would be three feet of topsoil. The topsoil would be hydroseeded to control erosion.

Because of heavy metal and PCB concentrations in the dredge disposal leachate, some method of treatment will be required prior to disposal in surface waters in the site vicinity. Initial analysis of the dredge spoils was used to predict heavy metal concentrations in the leachate removed from the dredge materials. These concentrations are present in Table 1 of the Technical Supplement to Sediment Testing and Disposal Alternatives Evaluation (Sept. 1986). A study by the U.S. Army Corps of Engineers concerning the treatment of dredge spoil leachate listed chemical precipitation as a viable method for removing heavy metals from the leachate. Because heavy metals are the primary concern for treatment, a system consisting of lime addition, settlement, recarbonation, and filtration was chosen for this preliminary investigation and cost analysis. The cost for this system, assuming a flowrate of 4,000 gal/day, would be about $275,000 over a five year project life. Approximately 50 percent of this cost, or $137,000, would be for initial capital expenditures, with the remaining required for operation and maintenance of the facility. Because of the relatively low flow from the site, an alternative method of treatment would be to haul the leachate to a local wastewater treatment plant. The cost of this alternative, assuming the leachate is hauled via a 3,500 gal tanker truck to the Everett Wastewater Treatment Plant, would be about $231,000 over a five year project life. The initial capital cost expenditure for this alternative would be approximately $100,000 for tanker truck acquisition and on-site storage and transfer facilities. The transportation costs could probably be reduced if this task was contracted to a public or private hauler. In short, it is recommended that the leachate be disposed of at the Everett treatment facility if the leachate meets the guidelines for disposal at the treatment facility.

DREDGE SPOIL LEACHATE TREATMENT

SCHEMATIC

,5 cont.
15 Eng
10 Admin
7.5 Sales



Assumptions:

1. Heavy metal concentrations as per Table 1 of Supplemental Report (Sept. 1986) for anaerobic conditions.
2. Biological constituents at relatively low concentrations, i.e. the treatment methods are not designed specifically for BOC or TOC removal.
3. Design Flows: 480 cu ft/day - 3,590 gal/day
4. Contingencies 15%
   Engineering 15%
   Administration 10%
   Sales Tax 7.5%

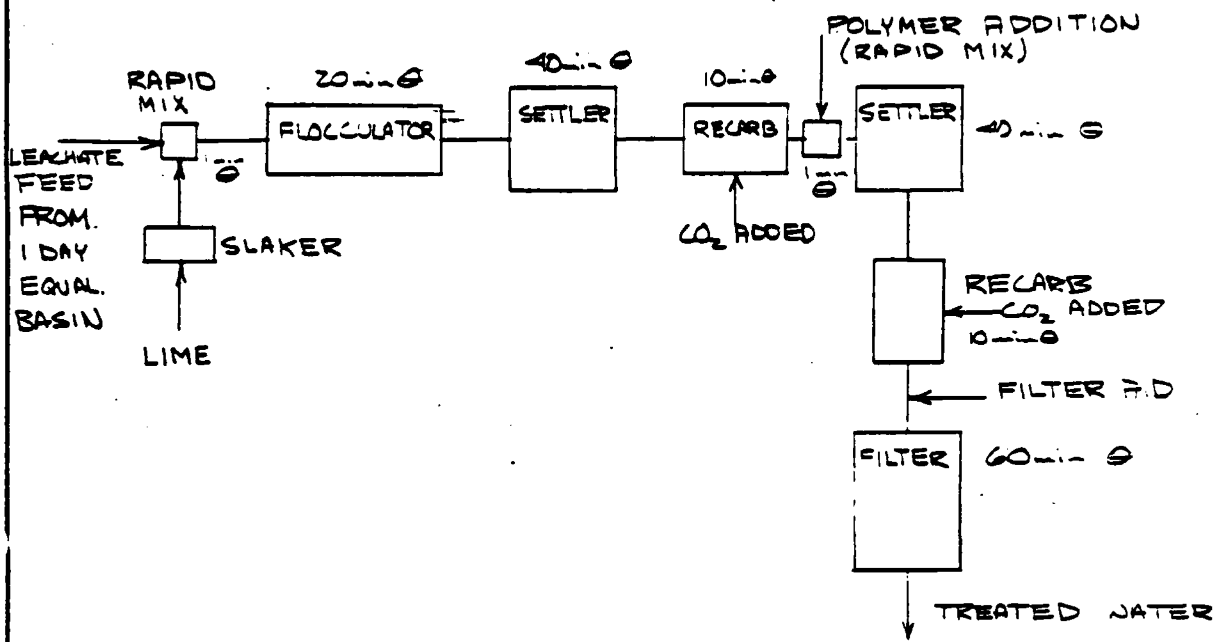
   Factor = 1.527

Parametrix, Inc.

PROJECT Navy Homeport JOB NO 55-1536-X
BY DEM DATE 10/3/86 CHECKED ______ DATE ______ SHEET 2 OF 3

DREDGE SPOIL LEACHATE TREATMENT

SCHEMATIC : LIME TREATMENT



PLANT CAPACITY: 4000 gallons (7,300,000 gal - 5 years)

OPERATION: 8 hrs, @ 500 gal./hr.

RAPID MIX: 2 @ 9 gal/each

FLOCCULATOR: 1 @ 170 gal

SETTLERS: 2 @ 340 gal/each (10 ft² surface area)/each

RECARBONATION: 2 @ 80 gal/each

FILTER: 1 @ 2 gpm/ft² 5 ft² surface area

(\$20.0/1000 gal)(402/329)(7,300 (1000 gal)) ≅ \$180,000 including
1981 costs ENR Conversion
O&M and amortization
50% for capital
≅ \$100,000 for capital cost

Cost Factor Total = 180,000 × 1.527 = \$275,000
capital = 90,000 × 1.527 = \$137,000

Parametrix, Inc.

PROJECT Homesteading JOB NO 55-1536-__

BY DEM DATE 10/3/86 CHECKED ____ DATE ____ SHEET 3 OF 3

Disposal of Leachate at Treatment Facility (Everett)

$45,000 Truck purchase (3500 gal)
$20,000 Storage basin - pump station
$65,000

Transport O & M
1/2 man-day / day @ $24,000/year = $12,000 x 5 years = $60,000
6 mile roundtrip @ $.15/mile maintenance = $400/year
$2000 + 10%/yr

Disposal costs
7,300,000 gal @ $0.40/900 cu ft = $434
double for surcharges = $900

$$\text{Total cost} = \underbrace{\$65{,}000}_{\text{capital}} + \underbrace{\$60{,}000 + \$2000 + \$23{,}000 + \$900}_{O\,\&\,M}$$

Total Cost = $65,000 + $85,900 = $151,000

Cost Factor Total - 161,000 x 1.527 = $231,000
capital - 65,000 x 1.527 = $100,000

APPENDIX C

WATER QUALITY DATA TABULATION
STEAMBOAT-UNION SLOUGHS
Oct. 1, 1986

Table 1. Water quality of Steamboat and Union Slough; samples collected October 1, 1986 at surface during low low tide (1.2 ft) and 2 hours before high high tide (11.2 ft). Station locations noted in Figure 1.

	Station 1 Steamboat/Union[1]	Station 2 Union[2]	Station 1 Steamboat/Union[3]
D.O. (mg/l)	10.3	9.8	9.7
Temperature (°C)	10.5	10.6	12.0
Sp. Conductance umhos/cm	298	141	10,640
pH	6.2	6.1	6.7
Cd (mg/l)	ND	ND	ND
Cr (mg/l)	ND	ND	ND
Cu (mg/l)	.006	ND	.018
Ni (mg/l)	ND	ND	ND
Pb (mg/l)	ND	ND	ND
Zn (mg/l)	.91	ND	ND
Total PCBs (ug/l)	ND	ND	ND

1 Steamboat/Union Slough @ 10:05 a.m.

2 Union Slough @ 10:45 a.m.

3 Steamboat/Union Slough @ 2:45 p.m.

ND: Not detected

Detection Limits:	PCBs	0.1 ug/l	Ni	.01 mg/l
	Cd	.002 mg/l	Pb	.01 mg/l
	Cr	.005 mg/l	Zn	.002 mg/l
	Cn	.002 mg/l		

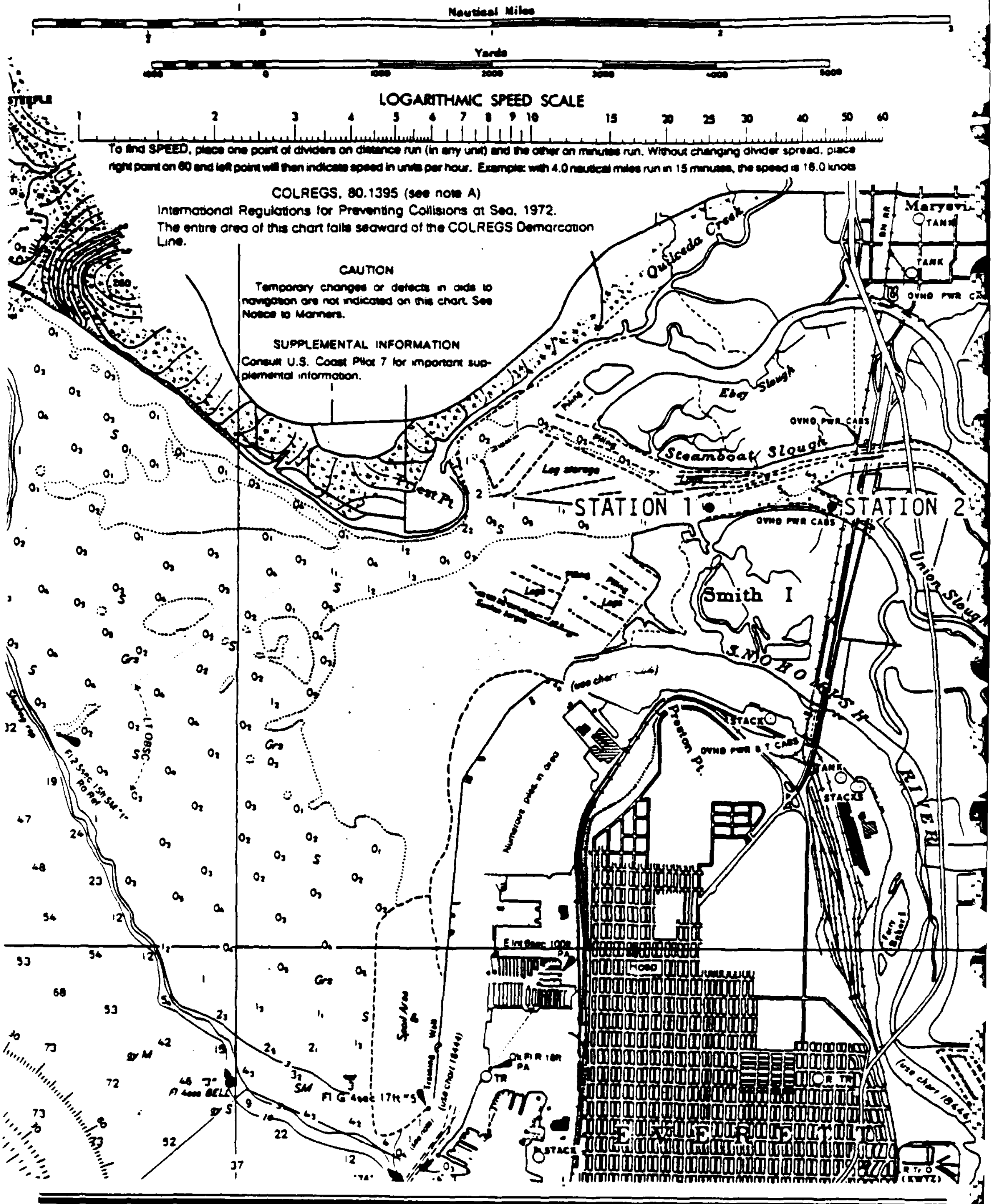


Figure 1.
Water Quality Sampling Stations;
Steamboat and Union Slough,
October 1, 1986. (NOAA Chart).

Laucks Testing Laboratories, Inc.

Certificate

940 South Harney St. Seattle, Washington 98108 (206)767-5060

Chemistry, Microbiology and Technical Services

CLIENT Parametrix, Inc.
13020 Northup Way, Suite 8
Bellevue, WA 98005
ATTN: Wally Trial

LABORATORY NO. 99078

DATE Oct. 3, 1986

REPORT ON RIVER WATER

SAMPLE IDENTIFICATION Submitted 10/01/86 and identified as shown below:

1) Station 1 W. Trial 10/01/86 10:05 am R. Whitman
2) Station 2 W. Trial 10/01/86 10:45 am R. Whitman
3) Station 1 W. Trial 10/01/86 02:30 pm R. Whitman

TESTS PERFORMED AND RESULTS

	parts per million (mg/L)		
	1	2	3
Arsenic	L/0.005	L/0.005	L/0.005
Cadmium	L/0.002	L/0.002	L/0.002
Chromium	L/0.005	L/0.005	L/0.005
Copper	0.006	L/0.002	0.018
Nickel	L/0.01	L/0.01	L/0.01
Lead	L/0.01	L/0.01	L/0.01
Zinc	0.91	L/0.002	L/0.002
	parts per billion (ug/L)		
PCB	L/0.1	L/0.1	L/0.1

Key

L/ indicates "less than"

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

J. M. Owens

JMO:laj

Laucks
Testing Laboratories, Inc.
940 South Harney St. Seattle Washington 98108 (206)767-5060
Chemistry Microbiology and Technical Services

Certificate

PAGE NO 2

Parametrix, Inc.

LABORATORY NO 99078

APPENDIX

Surrogate Recovery Quality Control Report

Listed below are surrogate (chemically similar) compounds utilized in the analysis of volatile and organic compounds. The surrogates are added to every sample prior extraction and analysis to monitor for matrix effects, purging efficiency, and sample processing errors. The control limits represent the 95% confidence interval established in our laboratory through repetitive analysis of these sample types.

parts per billion (µg/L)

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
Blank	Isodrin	0.1000	0.0406	40.6*	43-118
1	Isodrin	0.1010	0.0487	48.7	43-118
2	Isodrin	0.1005	0.0384	38.1*	43-118
2	Isodrin	0.1020	0.0402	40.2*	43-118
Blank	Dibutylchlorendate	0.2000	0.0940	47.0	24-150
1	Dibutylchlorendate	0.2020	0.0677	33.5	24-150
2	Dibutylchlorendate	0.2010	0.0877	43.6	24-150
3	Dibutylchlorendate	0.2040	0.0673	33.0	24-150

* Persistently poor surrogate and spike recoveries signal a laboratory problem and the need for re-extraction and re-analysis. However, occasional outliers are regarded as anomolies and, in this case, re-analysis was not deemed necessary because other indicators were in control: DBC

APPENDIX D

WETLAND DETERMINATION

NPSOP-RF

30 September 1986

MEMORANDUM FOR RECORD (MFR)

SUBJECT: Wetland Determination for the U.S. Navy's Homeport Alternative Disposal Site on Smith Island near the Snohomish River at Everett, Washington

1. Introduction. The Corps of Engineers has permitting responsibility under Section 404 of the Clean Water Act for the discharge of dredged or fill material into waters of the United States (including adjacent wetlands), 33 CFR 323.3. The purpose of this MFR is to determine if waters of the United States, including adjacent wetlands, exist on the site pursuant to the Corps regulatory responsibility under 404.

Wetlands identified in the report are not necessarily delineated to their full extent. The field investigation for this report is a review of three parameters; vegetation, soils, and hydrology, using them as environmental indicators to determine if they characterize a wetland situation.

2. Project Description. This approximately 120-acre site is being considered as an alternative location for the proposed disposal of approximately 3.3 million cubic yards of contaminated and uncontaminated dredged materials to be dredged from the East Waterway for the U.S. Navy Homeport project.

3. Site Investigations. Two site investigations were conducted on this site during September 1986. On 9 September 1986 Tom Mueller, Walt Farrar, and John Malek of the Seattle District, Corps of Engineers; Judy Aitken, Bob Landes, and Gerry Ervin of the Everett Planning Department; and Ed Lukjanowicz of the U.S. Navy met on the Smith Island site. The entire site was reviewed to determine if wetlands were present on the site. A second site investigation was required to delineate the wetlands. On 19 September 1986 Sam Casne and Tom Mueller of Seattle District's Regulatory Branch revisited the site. The following discussion is the result of these two site visits.

4. Description of Area. The overall site is bordered on the east by the Burlington Northern Railroad, on the north by Steamboat Slough, on the south by a remnant drainage slough, and on the west by a tidal slip that leads to Steamboat Slough. The entire site encompasses approximately 120 acres in parcels of 66, 47, and 8 acres. Each parcel is owned separately. The majority of the eastern half of the property is best described as pasture and the western half as an abandoned log sorting yard. Drainage ditches are located around the perimeter on the Steamboat Slough side (northern boundary) and split the overall site into four different sized portions. Standing water was noted in some of these drainage ditches. In general, the water was 2 to 3 feet lower in elevation than the adjoining pastureland.

3282s

This wetland determination applies only to the areas located inside the diked area described above. The northern side of the site between the dike and Steamboat Slough has previously been determined to be an adjacent wetland which is considered to be under the regulatory authority of the Corps of Engineers under Section 404 of the Clean Water Act.

5. Environmental Indicators. A multiparameter approach was utilized in making the wetland determination for this report. This methodology requires positive evidence of wetland vegetation, wetland soils, and wetland hydrology for a determination that an area is a wetland. The following is a review of these parameters and is based upon the above site inspections. The report is presented as an overview rather than a comprehensive evaluation.

a. Vegetation. A plant list was prepared identifying plants found on the site. The plants found onsite were compared with the U.S. Fish and Wildlife (USFWS) Region 9 wetland vegetation indicator status list. The USFWS list was prepared for use as a reference to identify the relative affinity each plant species has for wetland habitats. This allows us to establish whether a particular plant species would normally be found in a wetland (i.e. hydrophytic). The indicator terms used were originally developed by USFWS for use in the National Wetlands Inventory and are defined as follows:

OBL - Obligate: always found in wetlands (frequency greater than 99%)

FACW - Facultative Wetland: usually found in wetlands (frequency 66 - 99%)

FAC - Facultative: found about equally in wetlands and uplands (frequency 33 - 66%)

FACU - Facultative Uplands: usually found in the uplands (wetland frequency less than 33%)

If a plant species is not on the plant list, we show UPL, meaning an upland plant.

No transects were taken. The site was investigated to note the various plant associations and dominance in such areas. The eastern two-thirds of the site is pastureland. The northern portion is currently being grazed while the southern portion is not. The property was divided into seven different portions as a result of this survey and has been mapped in enclosure 1.

Areas 1 and 2. Both of these areas were being grazed and were dominated by the same association of grasses. These grasses included velvet grass (*Holcus lanatus* - UPL), colonial bent grass (*Agrostis tenuis* - UPL), quackgrass (Agropyron repens - UPL), Kentucky bluegrass (Poa pratensis - FACU+), timothy (Phleum pratensis - FACU), and common orchard-grass (Dactylis glomerata - FACU). Area 1 contains a swale with a distinct plant community. The swale, which was probably the borrow area for the adjoining levee, is lower than the surrounding original ground. It was revegetated by soft rush (Juncus effusus - FACW+), cinquefoil (Potentilla spp. - FAC TO OBL), smartweeds (Polyonum spp. - FACU to OBL), and reed canarygrass (Phalaris arundinacea - FACW).

Blackberries (Rubus spp. - FAC to UPL) were found in the higher areas and along fencerows and drainage ditches. Hardhack (Spiraea douglasii - FACW) was also common along most of the drainage ditches.

Area 3. This area is an abandoned log sorting yard. It is generally higher in elevation than the surrounding pastureland, but the ground surface is very irregular. The area is a mixture of sand, gravel, and wood waste fill and the surface is rutted, probably due to activities associated with it being a log sorting yard. The area is dominated by velvet grass and clover (Trifolium spp. - UPL), interspersed with Scotch broom (Cytisus sp. - UPL), and young red alder (Alnus rubra - FAC). The rutted areas were vegetated by rushes (Juncus spp. - OBL to FACW), marsh willow-herb (Epilobium watsonii - FACW), velvet grass, smartweed, and clover. Less commonly occurring species include cattail (Typha latifolia - OBL), devils beggartick (bidens frondosa - FACW+), reed canarygrass, and some sedges (Carex spp. - OBL to FACU).

Area 4. This area is approximately 100 by 100 feet and was the lowest area in the western portion of the site. It lies between the log sort area and the remnant drainage slough. The vegetation was predominately rushes and smartweeds with the smartweeds being associated with what appeared to be recently dewatered depressions. Velvet grass dominates as you move higher, fringing this rush/smartweed association.

Area 5. This area is east of Area 4. It is dominated by redtop (Agrostis alba var. alba - FACW), interspersed with velvet grass and rush.

Area 6. This area contains the same grass assocation as Areas 1 and 2, but includes more blackberries. Thistle (Cirsium spp. - FACU to OBL) was common, and a few spruce trees (Picea sp. - FAC) were noted. Rushes were evident near the road.

Area 7. This area contained the same grass association as Areas 1 and 2, but was not being grazed. There was a minor rush and thistle component.

b. Soils. The Snohomish County Soil Survey (Debose and Klungland, 1983) indicates that the majority of the site is Puget silty clay loam. Puget silty clay loam is a very deep mineral soil in depressional areas on flood plains and has usually been artifically drained. The soil formed in alluvium and the permeability of this soil is slow. The effective rooting depths is 60 inches or more. A seasonal high water table is at a depth of 24 to 48 inches from November to April. Because the rooting depth is restricted by the seasonal high water table, trees are occasionally subject to windthrow. This soil is partially protected from flooding; however, rare periods of flooding occur from December to March. Flooding can be controlled by the use of levees and dikes.

This soil series is listed as a hydric soil in the State of Washington by the Soil Conservation Service (Rasmussen, 1981). Hydric soils are soils that for a significant period of the growing season have reducing conditions (i.e., free of dissolved oxygen) in the major part of the root zone and are saturated within 25 cm (10 in) of the surface. This condition is limiting to plant growth. The assumption is that a soil supports whatever vegetation it is capable of supporting. Therefore, a soil that is saturated (i.e., has reducing conditions) for significant periods of the growing season could support a prevalence of plants that have adapted to life in saturated soils conditions. A hydric soil may be either drained or undrained and a drained hydric soil may not continue to support hydrophytic vegetation.

Six holes were dug to establish if the soil exhibited characteristics of a reduced condition (see enclosure 1 for locations). Five of the holes were dry and at 6-10 inches had a color of 2.5Y 4/2 with mottling at 10 inches. The hole dug in Area 4 had a color of 5Y 4/1 (found in the gleyed chart) and had mottling to the surface. The soil was moist, but did not appear to be saturated.

c. Hydrology. The term "wetland hydrology" encompasses all hydrologic characteristics of areas that are periodically inundated or have soils saturated to the surface at some time during the growing season. Areas with evident characteristics of wetland hydrology are those where the presence of water has an overriding influence on characteristics of soils and vegetation. Such characteristics are usually present in areas that are inundated or have soils that are saturated to the surface for sufficient duration to develop hydric soils and support vegetation typically adapted for life in periodic anaerobic soil conditions.

Indicators of wetland hydrology may include, but are not necessarily limited to: drainage patterns, drift lines, watermarks, observation of saturated soils.

No evidence of standing water was found at the site except Area 4 (i.e., dewatered depressions). This was the only area that showed positive hydrological indicators.

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SUBJECT: Wetland Determination for the U.S. Navy's Homeport Alternative Disposal Site on Smith Island near the Snohomish River at Everett, Washington

d. Review of Indicators.

	VEGETATION	SOILS	HYDROLOGY	MET ALL PARAMETERS
Area 1	No (upland grasses)	Yes	No (drained)	No
2	No (upland grasses)	Yes	No (drained)	No
3	No (upland plants)	No (Imported sand, gravel, wood waste)	No	No
4	Yes (rush/smartweed)	Yes	Yes	Yes
5	Yes (redtop)	Yes	No (drained)	No
6	No (upland plants)	Yes	No (drained)	No
7	No (upland plants)	Yes	No (drained)	No

Using the multiparameter approach, the only area that exhibited wetland characteristics for all three parameters is Area 4. This area would then be a wetland by Corps definition. It would appear that the drained condition of the remainder of the site has been sufficient to preclude the presence of either a predominance of hydrophytic vegetation or a hydrologic regime over most of the site. The USFWS classification for this wetland as used for the National Wetlands Inventory would be Palustrine Emergent Persistant (Soft rush), Seasonally Flooded (diked), (Cowardin et al., 1979).

6. Fauna. No comprehensive survey was done during the field trips. The following discussion summarizes observations made during the site visits. Three redtailed hawks and a northern harrier were noted. Various sparrows, goldfinches, and house finches were utilizing the site. Gulls and several ducks were flying in the vicinity. Starlings were also noted congregating in the trees near the borders of the site and around a barn in Area 7. A dead field mouse was seen in Area 6 where heavy equipment had recently disturbed the area.

7. Corps Jurisdiction. The Corps of Engineers has permitting responsibility for the placement of dredged or fill material into waters of the United States (including adjacent wetlands) under Section 404 of the Clean Water Act. Current Department of the Army regulations issued July 22, 1982, defines "waters of the United States" (33 CFR 323.2) as follows:

(1) All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;

(2) All interstate waters including interstate wetlands;

(3) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation or destruction of which could affect interstate or foreign commerce including any such waters:

(i) Which are or could be used by interstate or foreign travels for recreational or other purposes; or

(ii) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or

(iii) Which are used or could be used for industrial purposes by industries in interstate commerce;

(4) All impoundments of waters otherwise defined as waters of the United States under this definition.

(5) Tributaries of waters identified in paragraphs (a)(1)-(4) of this section;

(6) The territorial sea;

(7) Wetlands adjacent to waters (other waters that are themselves wetlands) identified in paragraphs (a)(1)-(6) of this section.

The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

As defined, wetlands would only exist in Area 4 of the site. This area had hydric soil, showed evidence of standing water, and had a predominance of wetland vegetation. This area is not considered to be "adjacent" wetland as it is not considered to be bordering, contiguous, or neighboring other waters of the United States and does not have a surface water connection to the remnant drainage slough. The wetland appears to be maintained by a combination of ground water and runoff accumulated in a low area. The lower water table of the remnant slough is a good indicator of this.

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SUBJECT: Wetland Determination for the U.S. Navy's Homeport Alternative Disposal Site on Smith Island near the Snohomish River at Everett, Washington

The area wetlands can only be under Corps jurisdiction if they can meet the qualifications for "all other waters" at 33 CFR 323.2(a)(3) (see above), and meet the specific criteria listed by the Environmental Protection Agency (DAEN-CWO-N letter dated 8 November 1985, subject: EPA Memorandum on Clean Water Act Jurisdiction over Isolated Waters). To be under Section 404 it must be demonstrated that the wetlands are waters of which the use, degradation, or destruction could affect interstate or foreign commerce. The destruction of this wetland would not be expected to have any impact on waters from which fish or shellfish are or could be taken and sold in interstate or foreign commerce; that are or could be used by interstate or foreign travelers for recreation; or which are or could be used for industrial purposes by industries in interstate commerce. The wetlands would not be expected to be habitat for endangered species. These wetlands are not used to irrigate crops sold in interstate comerce. Migratory birds were noted on the overall project site. Birds such as the red-tailed hawk, marsh hawks, and various sparrows and goldfinches could use this wetland area for feeding and/or nesting. Therefore, this wetland, even though it is isolated, would be considered a wetland under the Corps of Engineers regulatory jurisdiction.

8. Conclusion. Based on available information, the wetland in Area 4 would be considered a water of the United States subject to regulation by the Department of the Army under Section 404 of the Clean Water Act. This wetland is less than 1 acre in size. Placement of fill or dredged material into this area would be authorized by the nationwide permit described in 33 CFR 330.5(a)(26) which applies to wetlands located above the headwaters of streams or in isolated waters. Wetlands are dynamic conditions of the environment and their limits or existence can change dramatically in a short period of time. This determination should only be considered conclusive for a period of 1 year; thereafter, it should be updated to reflect current conditions.

Oct. 2, 1986
Date

Thomas F. Mueller
THOMAS F. MUELLER
Biologist
Chief, Processing Section
Regulatory Branch

Oct 2, 1986
Date

Samuel R. Casne
SAMUEL R. CASNE
Biologist
Chief, Environmental and Procession Section
Regulatory Branch

References.

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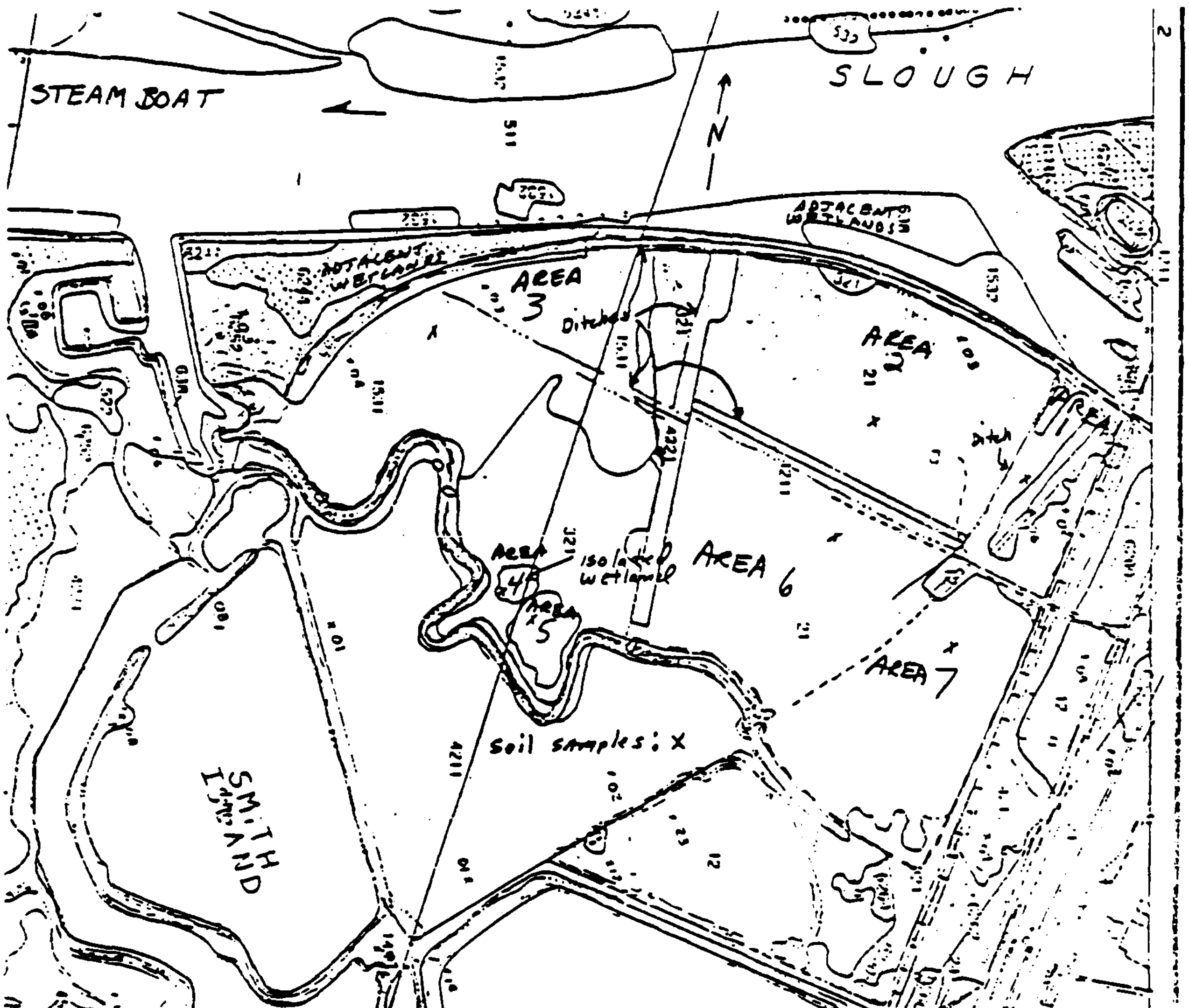
STEAM BOAT
SLOUGH
N
ADJACENT WETLANDS
ADJACENT WETLANDS
AREA 3
Ditches
AREA 2
AREA 1
ditch
AREA 4
isolated wetland
AREA 5
AREA 6
AREA 7
soil samples: x
SMITH ISLAND
SNOHOMISH
RIVER
RANGE

Encl 1

APPENDIX D

BIOLOGICAL ASSESSMENTS

BIOLOGICAL ASSESSMENT FOR MARINE MAMMALS AND REPTILES

WITHIN THE CARRIER BATTLE GROUP

PUGET SOUND SHIP HOMEPORTING PROJECT

INTRODUCTION

The Norton Avenue Terminal site in Everett, Washington, has been selected as the preferred site for a U.S. Navy carrier battle group homeport facility (Figure 1). A significant amount of construction will be necessary to homeport the carrier battle group at the preferred site. Section 7 of the Endangered Species Act of 1973, as amended, requires Federal agencies to assess whether their proposed project may result in impacts to listed species that occur in the project area. The purpose of this biological assessment is to evaluate the possible effects of construction of the Homeport facility, and operation of the Carrier Battle Group on seven endangered whales and the endangered leatherback sea turtle. The U.S. Fish and Wildlife Service (USFWS) and Washington Department of Game (WDG), wanted to know if project development could result in impacts on overwintering California sea lions and harbor seals. To provide baseline information, a study was undertaken with the specific objectives of determining overwintering habitat use by California sea lions from October 1984 through June 1985. Reportings of harbor seal and Northern sea lion are also documented.

PROJECT DESCRIPTION

Operation of a Carrier Battle Group Homeport at the Everett site would require construction of new facilities and demolition of most of the existing Norton Terminal structures to to provide support for the Carrier Battle Group (Figure 2). Construction of ship berthing facilities in the East Waterway would necessitate the removal of approximately 3.3 million cubic yards of materials. Dredging operations will be done with both a clamshell and hydraulic dredge. Dredged material will be deposited in a confined aquatic disposal site (CAD) located approximately 1.6 nautical miles southwest of Norton Terminal in water depths of approximately 300 to 350 feet. Confined aquatic disposal would be provided for the estimated 928,000 cubic yards of contaminated sediments. CAD project features include a lateral containment berm and capping with approximately 2.4 million cubic yards of clean native sediment removed from the East Waterway. Other project features include construction of a 1,600 foot long breakwater, a 1,600 foot long breakwater, and a 2,100 foot central marginal wharf.

METHODS

From October 1984 through June 1985, standardized boat transects as well as generalized surveys of the entire study area, which included eastern Possession Sound, Port Gardner and the East Waterway, were undertaken (Figure 3). Several additional site visits were made after that date to verify additional information. Visual counts of marine mammals were recorded. Individ-

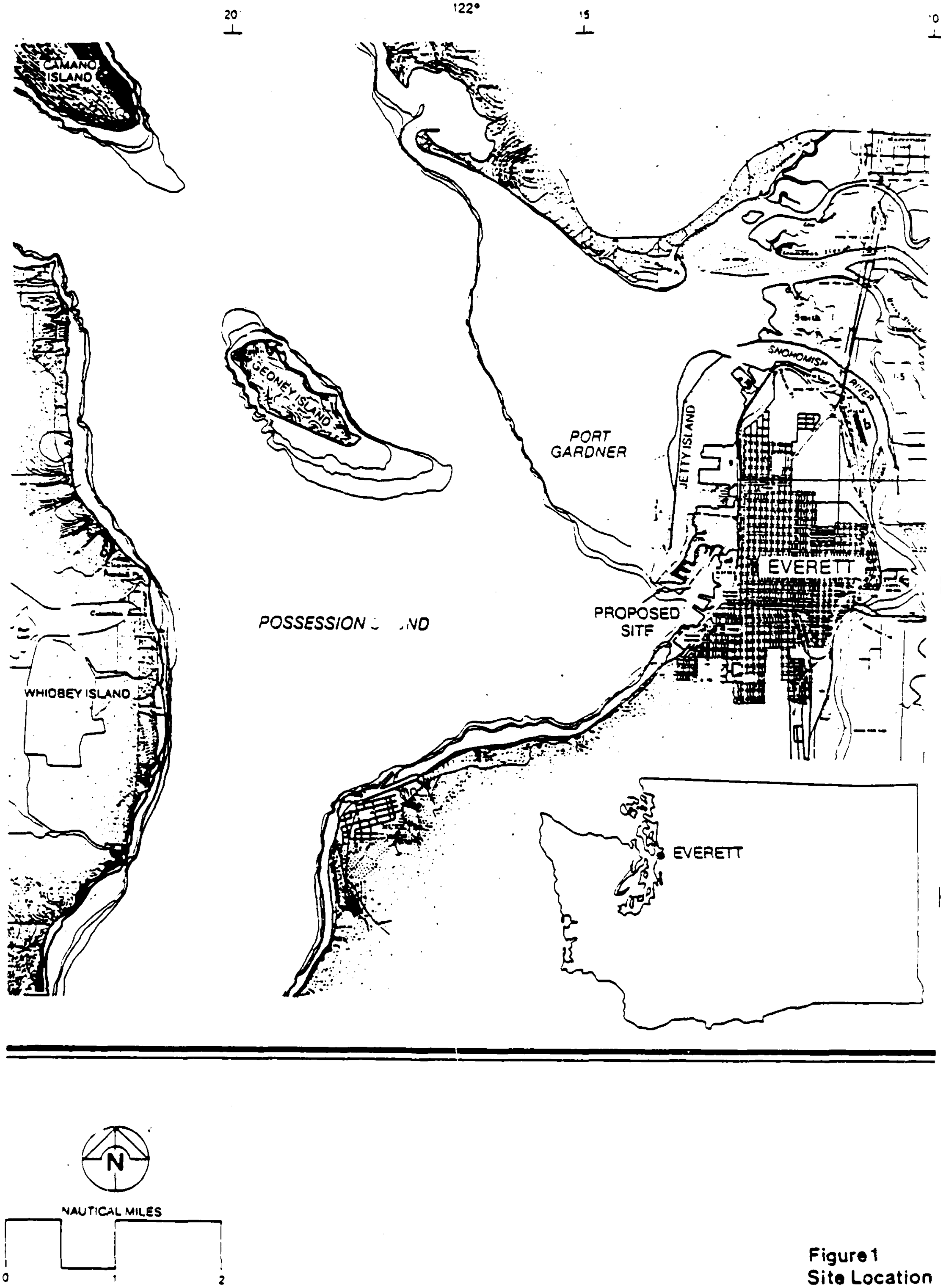

Figure 1
Site Location

AD-A175 114 CARRIER BATTLE GROUP (CVBG) HOMEPORTING IN THE PUGET SOUND AREA WASHINGTON STATE TECHNICAL APPENDICES(U) CORPS OF ENGINEERS SEATTLE WA SEATTLE DISTRICT NOV 86 6/7

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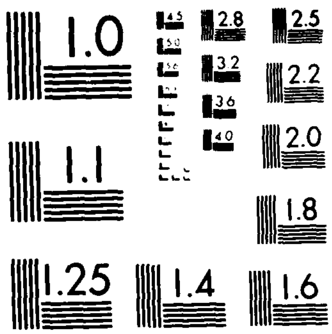


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

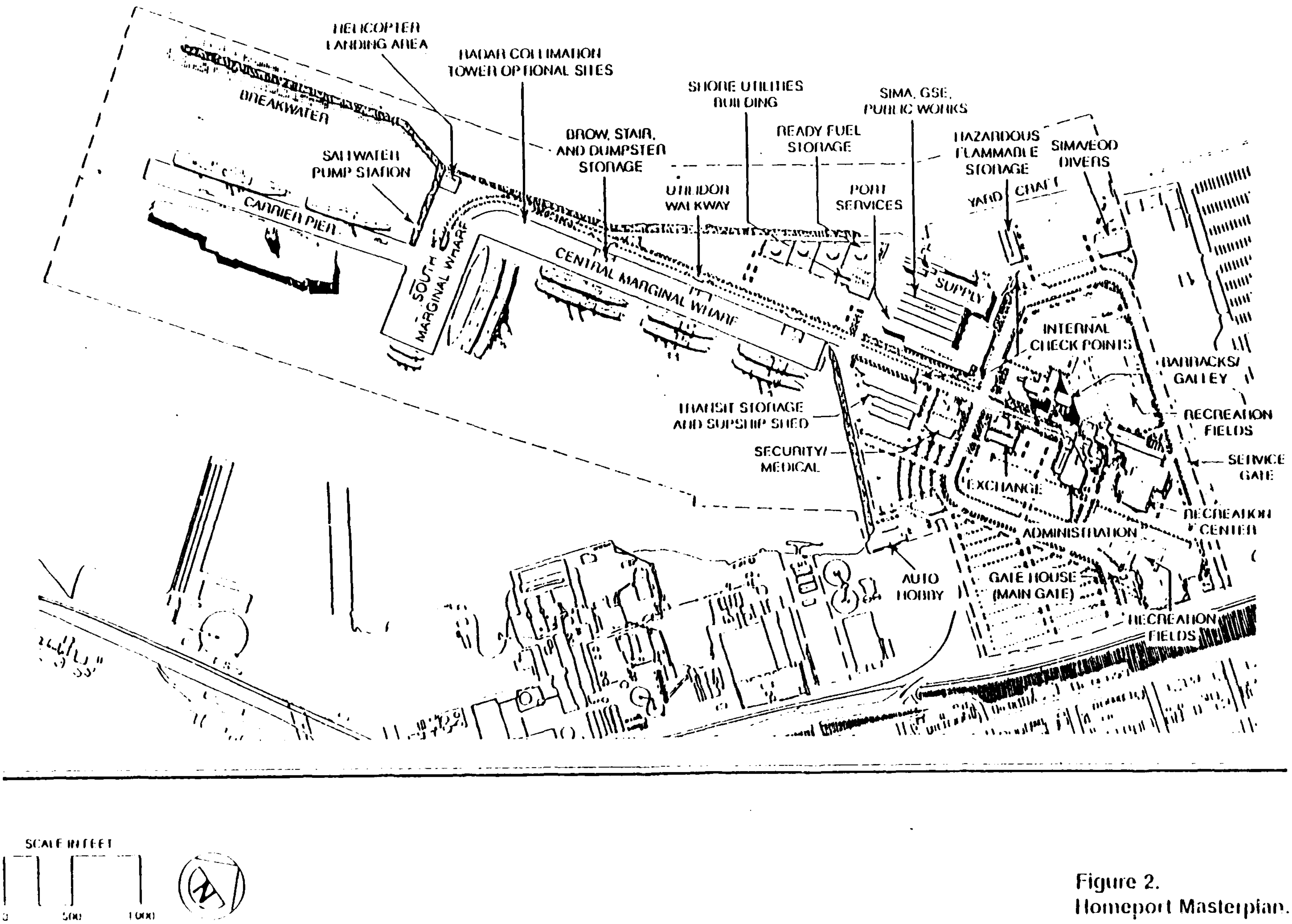


Figure 2.
Homeport Masterplan.

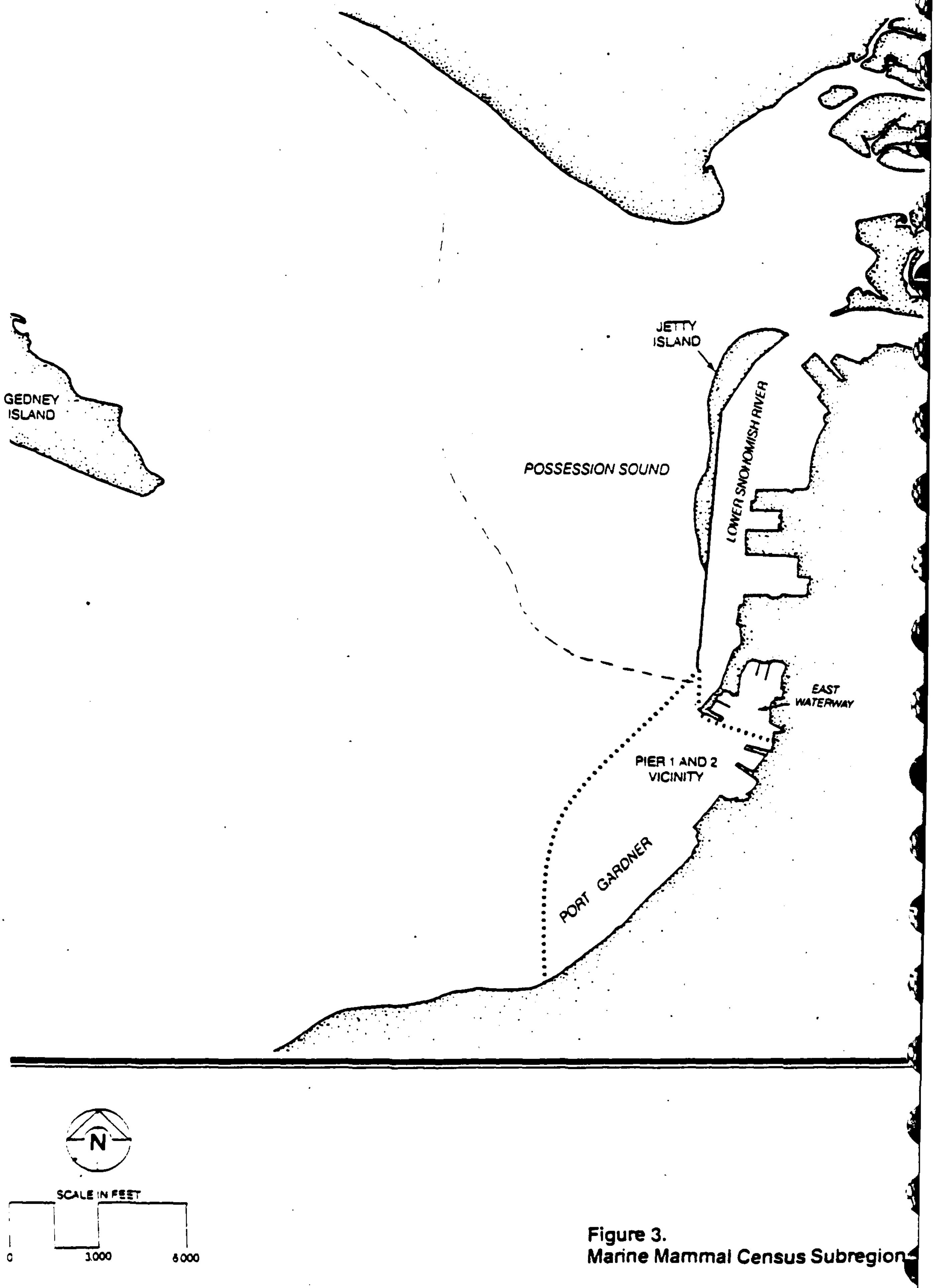


Figure 3.
Marine Mammal Census Subregion

uals knowledgeable about the use of the project area by the listed marine species were contacted and interviewed. Additionally, available literature describing range and habitat use of listed species was reviewed, and pertinent material was referenced for this assessment. Starting in April 1985, separate weekly sea lion censuses were conducted to gather additional detailed information on numbers, habitat use, and behavior. Individual animals were classified when possible into age groups, and descriptions of behavior of individual animals and/or pods during various conditions of time, weather, and tides were noted.

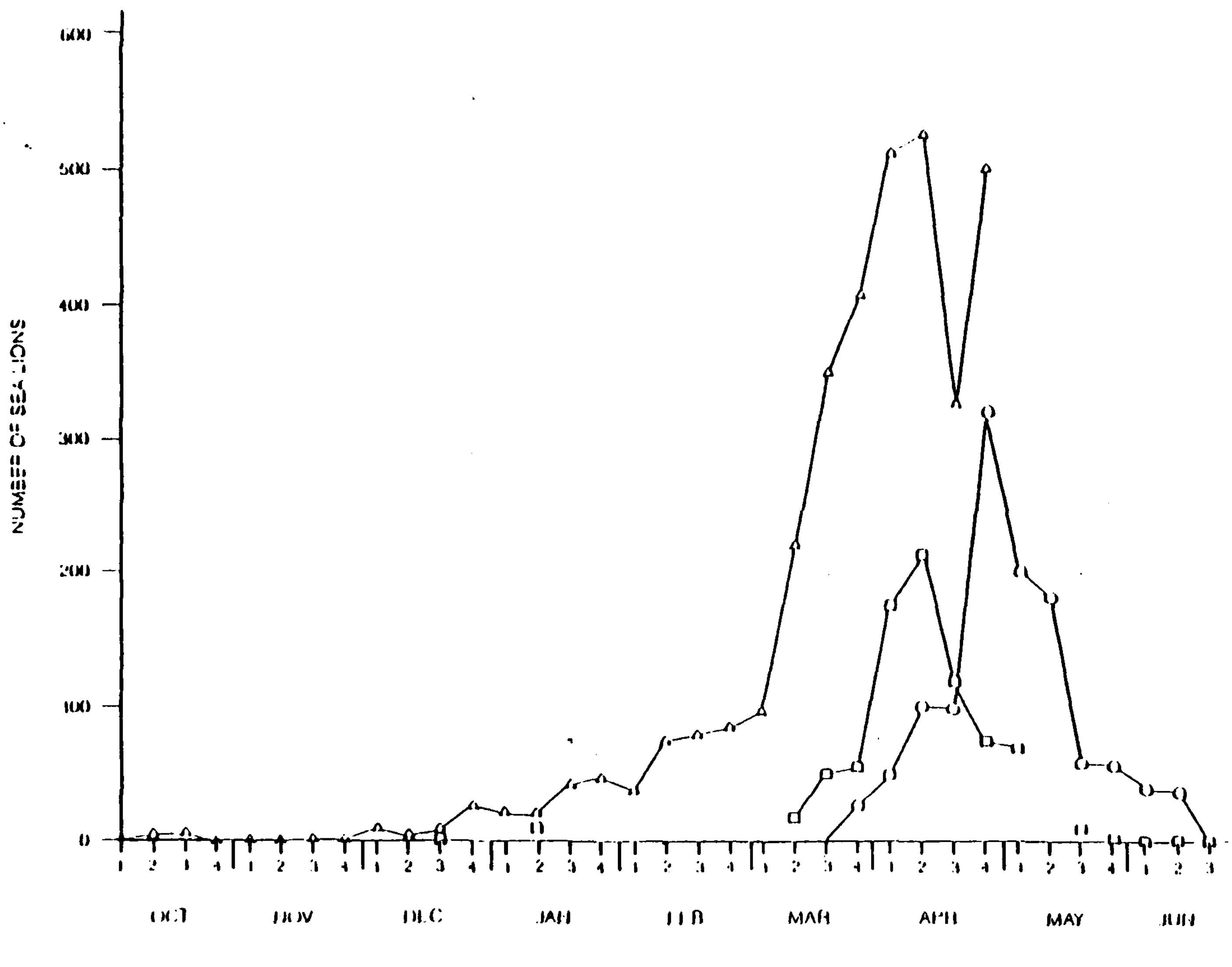
RESULTS

Marine mammals known to inhabit coastal waters and the inside waters of Washington, including the Straits of Juan de Fuca and Puget Sound, are listed in Table 1. Species classified as endangered under Section 7 of the Endangered Species Act of 1973, as amended, include only the Mystecetid whales and the leatherback sea turtle. Of these listed species, the right whale, sei whale, sperm whale and leatherback sea turtle have never been reported to occur within the inland waters, and are not expected to be present near the project site (National Marine Mammal Laboratory, NWAFC 1980). The blue, humpback and fin whale, although listed by personnel of the Marine Mammal Laboratory, only rarely occur within Washington's inland waters.

The gray whale are more abundant in Puget Sound than previously thought in light of the increasing number of sightings during recent years.. Sightings by individuals occurred off Gooseberry Point and Lummi Point in 1976, near Viti Rock off of the southwest shore of Lummi Island in June 1978, in Possession Sound during June 1978, and within Hale Passage in July 1978 (Everitt et al., 1979, 1980). More recently, four gray whales were sighted at Kayak Point just north of yjr Tulalip Reservation in the spring of 1984. Tugboat operators on daily patrol in the East Waterway observed one gray whale just off of the Port of Everett's Pier 3 in December 1984 (Davis and Tonnes, 1985). No gray whales, however, were sighted by tugboat skippers from June 1985 through mid-March 1986 (Davis, 1986). Some whales may even stay, as established from whale sightings for every month of the year (Everitt, 1980).

California Sea Lions

Weekly winter population estimates from 1982 (Munn, 1984) through 1985 (this study) suggest that California sea lions are now arriving earlier in autumn and are also present in larger numbers earlier in the winter than in the past (Figure 4). Sea lions were first recorded in the study area during the 1982-33 and 1983-34 seasons on December 15 and December 16, respectively. In 1984-35, animals were first sighted on October 10, 1984, when four sea lions were observed swimming northwest over intertidal



Source: 1982-1983 and 1983-1984 Data Provided by John Monn (1984)

□ 1982-1983

○ 1983-1984

△ 1984-1985

Figure 4.
Estimated number of California Sea Lions in Possession Sound during the 1982-1983, 1983-1984 and 1984-1985 over-wintering period.

Table 1. Marine Mammals Conceivably Present Within the Inside Waters of Washington. Underlined Species Federally Listed as Endangered.

Order	Species	Scientific Name
Carnivora	River Otter	Lutra canedensis
	California Sea Lion	Zalophus Californianus
	Northern Sea Lion	Eumetopias jubatus
	Northern Fur Seal	Callorhinus Ursinus
	Harbor Seal	Phoca Vitulina Richardsi
	Northern Elephant Seal	Mirounga Augustirostris
Mysticeti	<u>Sperm Whale</u>	Physeter macrocephalus
	<u>Sei Whale</u>	Balaenoptera borealis
	<u>Gray Whale</u>	Eschrichtius robustus
	<u>Blue Whale</u>	Balaenoptera musculus
	<u>Fin Whale</u>	Balaenoptera physalus
	<u>Humpback Whale</u>	Megaptera novaengliae
	<u>Right Whale</u>	Balaena glacialis
Odontoceti	Whitehead Grampus	Grampus Griseus
	Pacific White-Side Dolphin	Lagenorhynohus Obliquidens
	Saddle Back Dolphin	Delphinus Delphis
	False Killer Whale	Pseudorca Crassidens
	Shortfin Pilot Whale	Globicephala Macrorhynchus
	Killer Whale	Orcinus Orca
	Harbor Porpoise	Phocoena phocoena
	Dall Porpoise	Phocoenoides Dallii
	Pygmy Sperm Whale	Kogia Breviceps
	Goosebreak Whale	Zipius Cavirostris
	Northern Pacific Giant Bottlenose Whale	Berardias bairdi

sandflats west of Jetty island. Sea lions were sighted during the next two weekly censuses and then were not sighted again for several more weeks. Beginning with mid-November and continuing through April, sea lions were present during every survey. By December 15, 1985, ten sea lions had regularly been observed in Eastern Possession Sound.

California sea lions first arrived in moderate numbers (5 to 37 animals) during the last week of December through the first week in March. On March 13 sea lion numbers suddenly increased from 97 counted on March 9 to 219 total animals. Animals counts peaked at a high of 525 on April 9. Stable counts of at least 500 sea lions were observed throughout April. Including unseen animals, total numbers in Possession Sound could have been in excess of 600 animals.

Weekly sea lion counts varied widely depending on weather and time of census. On windy days with high waves and rough seas, California sea lions did not form the easily countable resting and sleeping pods observed floating on the water's surface on calm days. In addition, during such rough conditions sea lions did not haul out on beaches on which they normally were found at other times. However, several observations made on entirely calm days indicated that regardless of weather, California sea lion numbers appear to increase through mid-morning and decrease in the afternoon (Table 2).

As tidal fluctuations became more pronounced in spring, a more detailed examination of weekly counts revealed a possible tidal influence both in diurnal sea lion numbers and habitat use pattern (Figure 5). Using April 25 data as typical of patterns observed in spring, 472 California sea lions were hauling out by early morning adjacent to the southwest shore of Jetty Island. Of these, 321 (68 percent) were on the sunken barge and 128 (27 percent) were in the water near the barge (Table 3). As high tide approached, new arrivals and those sea lions that had already been floating adjacent to the barge attempted to haul out on the barge. This continued past the peak of high tide until about the midpoint of the outgoing tide. Until mid-tide (+5 feet), some sea lions were successful at accessing the barge. Thereafter, the water had receded to a point where the height between the water and the barge had become too great to overcome. Individuals left the barge on a regular basis, while two major "stampedes" at 10:14 a.m. and 11:10 a.m. caused 52 and 152 animals to suddenly leave the barge en masse. No noticeable harassment or unique incident was observed at those times.

Once off the barge, some sea lions immediately departed the site. Others joined groups that were either hauled out in shallow water along the beach or were in deeper water forming floating pods. Those sea lion groups hauled out on the beach followed the retreating the advancing tides in order to maintain a preferred

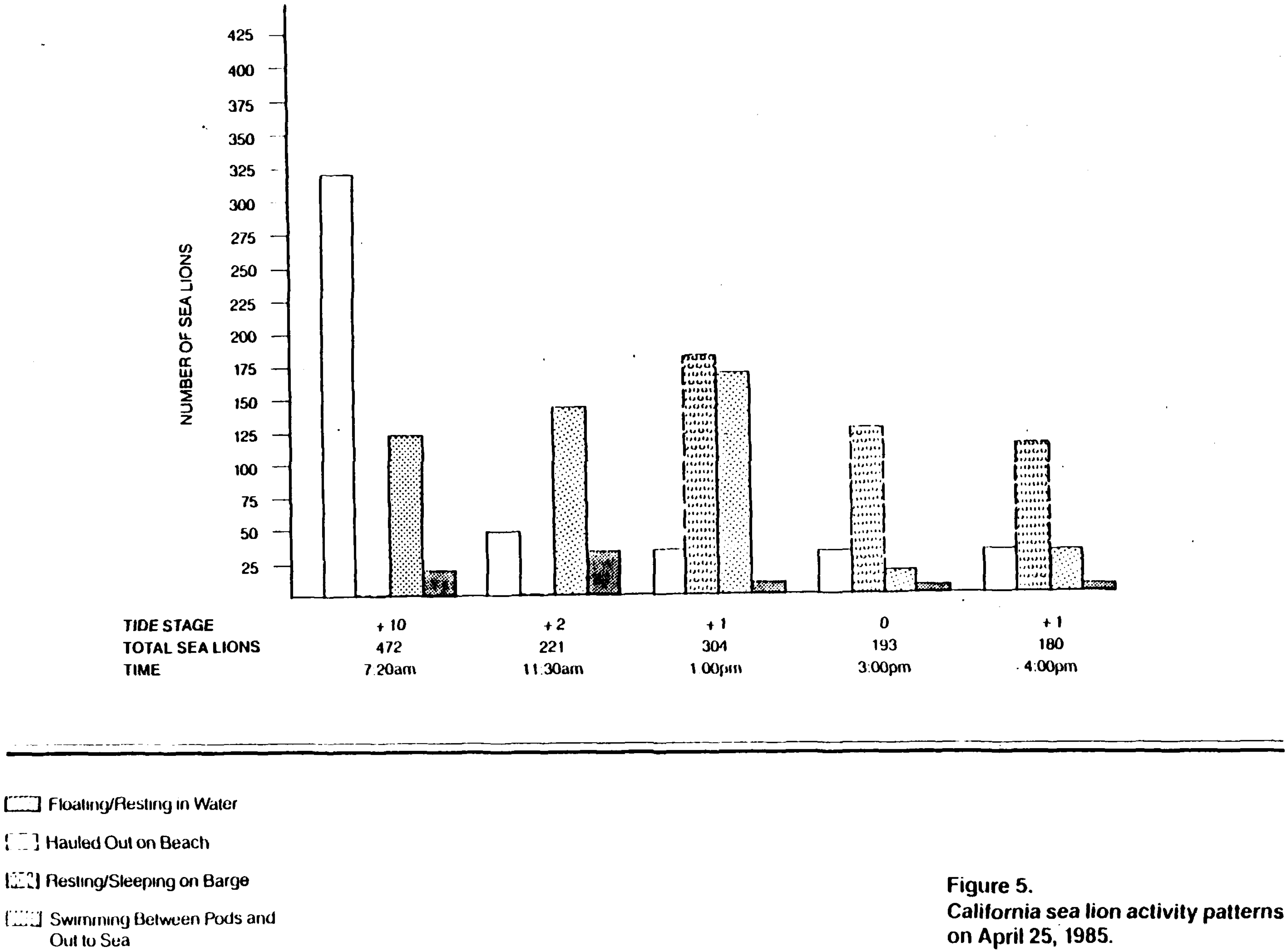


Figure 5.
California sea lion activity patterns on April 25, 1985.

Table 2. Contrasts Between Morning and Afternoon Distribution of California Sea Lions in April.

	7:20 a.m. No. (% Ttl)	4:00 p.m. No. (% Ttl)	8:46 a.m. No. (% Ttl)	2:42 p.m. No. (% Ttl)	10:04 a.m. No. (% Ttl)	2:39 p.m. No. (% Ttl)
Habitat						
On barge	321 (68)	33(18)	250 (56)	28(38)	200 (63)	150(94)
On beach	0	112(62)	0 (0)	8(11)	120 (37)	
In shore pods	128 (27)	16 (9)	153 (33)			
Outer bay pods		12 (7)				
Swimming	23 (5)	7 (4)	53 (11)	38(51)		10 (6)
TOTAL	472(100)	180(38)	456(100)	74(10)	320(100)	160(30)
Weather						
Wind Speed (mph)	8	1	8	15	8	15
Sea State	2	1	2	3	1	2
Tide Stage	-10	+1	+5	+4	-4	-9
Temperature (°F)	42	57	47	52	52	53
Precipitation	0	0	1	0	0	1

LEGEND

SEA STATE	PRECIPITATION
1 - calm or rippled	0 - None
2 - choppy	1 - Drizzle
3 - rough	2 - Rain

Table 3. Arrival Times of California Sea Lions From Southern Possession Sound

Time	Group Size 1	2	3	4	Total Animals	Percent of Total Animals	Cumulative Animals
7:00 - 8:00							
7:00 - 7:15	0	0	0	0	0		0
7:16 - 7:30	0	0	0	0	0		0
7:31 - 7:45	2	1			4		4
7:46 - 8:00	1	2			5		9
					9	(13)	
8:00 - 9:00							
8:01 - 8:15		1			2		11
8:16 - 8:30		5			10		21
8:31 - 8:45	1	5			11		32
8:46 - 9:00	4	1			6		38
9:00 - 10:00							
9:01 - 9:15	2	3			8		46
9:16 - 9:30	2	3	1	1	15		61
9:31 - 9:45		2			2		63
9:46 - 10:00	2				2		65
					27	(39)	
10:00 - 11:00							
10:01 - 10:15	2	1			3		68
10:16 - 10:30	0	1			1		69
10:31 - 10:45	0				0		
10:46 - 11:00	0				0	(6)	—
					4		
TOTAL GROUPS	8	11	1	1		TOTAL NO.	69

position in shallow water. By mid-afternoon following ebb tide, groups using shallow water, deeper nearshore water, and barge habitats stabilized, with a constant number of sea lions within their respective groupings.

From these and other data, a general profile of California sea lion temporal habitat use emerges which indicates a relationship of daily spring tides to sea lion behavior. Sea lions that feed at night return to the southwest side of Jetty Island by early morning. During mid-morning some additional sea lions return from feeding. During high tide they haul out on the barges and congregate in large floating/resting pods nearby. With approaching low tide sea lions leave the barge and depart the Jetty Island congregation area, haul out in shallow water adjacent to the barge, or join floating pods in the bay. Small groups of sea lions continue to leave the floating pods and depart the area to feed.

Harbor seal (Phoca vitulina richardsi) and Northern (Steller's) sea lion (Eumetopias ursinus) were the only two other species of marine mammal sighted during the censuses. Up to two harbor seals were sighted on a regular basis within the lower Snohomish River, along the Port of Everett piers, and adjacent to the west side of Jetty Island. Sometimes they were observed near California sea lion pods, but most frequently they were observed swimming in shallow water among log rafts. Occasionally, they were sleeping on log rafts. Harbor seals are the only resident marine mammal in local waters. Therefore, it is most likely that our sightings were of the same individuals rather than of different animals, suggesting a local population of two to four animals.

Two Northern sea lions were sighted among California sea lions hauled out adjacent to the southern side of Jetty Island. Their behavior and habitat use was identical to that described for California sea lions. Based on existing information, Northern sea lions are not expected to occur in large numbers in eastern Possession Sound (Everitt et al., 1980).

Impacts of Project on Listed Marine Mammals

Endangered Species

The absence of any documented sightings of right whales, sei whales, sperm whales and leatherback sea turtles within the inland waters of Puget Sound clearly indicates that the construction of this project and the Navy operations within the confines of Puget Sound will not have an impact on these four listed species. The rare sightings of the blue, humpback, and fin whales also suggest that the proposed project will not have an impact on these whales.

The low numbers of gray whales that have been sighted in the Project vicinity indicates that the construction and berthing of a Carrier Battle Group at Everett will have non-significant impact on the gray whale population. Additionally, dredge material disposal at the deep delta CAD site will not play a significant role in influencing their rare and intermittent use of the project vicinity. Disposal of East Waterway dredge material at the Snohomish River Channel site, an area of intertidal log storage, will also not pose a threat to these whales.

Commercial barging has been shown to change gray whale distribution and habitat use in lagoons and bays (Gardner, 1974 in Everitt et al., 1979); however, the sparse number of whales in the inland waters of Washington State indicate that detrimental impacts from the carrier fleet are not anticipated.

California Sea Lion

Project construction activities will be localized within the East Waterway, the east bank of the Lower Snohomish River adjacent to the Norton Terminal site, and south into Port Gardner beyond the Western Gear dock. The few sea lions that are occasionally observed within the East Waterway will most likely avoid the site during the construction period. Since the East Waterway does not provide any permanent habitat to sea lions, the loss of this area during construction will not be significant. Construction noise and disturbance may deter sea lions from swimming by the entrance to the Lower Snohomish River. Since only an occasional group of animals was sighted within the river during 1984-85, any decrease of sea lion usage of this area is not anticipated to be significant. Noise associated with breakwater and carrier pier construction is not expected to create a significant impact to the few sea lions that were occasionally found swimming between the Lower Snohomish River, the East Waterway, and the Port of Everett Pier 1 and 2 vicinity.

Construction noise and site preparation activities are predicted to not have influence on habitat use west of Jetty Island because existing waterfront construction, boat repair and other marine related activity have not to date influenced habitat use in this area. Since it is within this area that most of the California sea lions are found, sea lions are expected to be well insulated and unaffected by construction.

Any temporary losses of food resources due to turbidity and substrate disturbances will be minimal and localized to the immediate area of dredging in the East Waterway and the deep delta CAD site. Dredging and other marine construction activities will result in localized substrate disturbance and cause fish to avoid the immediate project vicinity. California sea lions were never observed feeding in the East waterway, Lower

Snohomish River, or in the vicinity of the Port of Everett Pier 1 and 2. Instead, our studies suggest that sea lions swim to outer Possession Sound to feed; thus, direct impacts to sea lion food resources would not occur. Dredging will not be scheduled from March 15 through June 15, the period of greatest potential disturbance to most of the sea lions, thus further reducing the impacts from Navy construction activity.

Operational impacts on sea lions and harbor seals have been identified as potentially arising from activities related to maintenance and routine daily operations of ships in port such as accidental oil spills and increased useage of marine waters related recreational use within the project vicinity.

The studies of 1984-85 overwintering sea lions indicated that only a few sea lions enter the East Waterway. Therefore, any accidental spillage of petroleum products will not result in a significant impact on California sea lions here.

The spillage of fuel oil from a major accident poses a greater impact. This impact will be proportionate to the combined effects of location, quantity of spill, wind, tides, and currents. A detailed analysis of potential oil spill scenarios was presented in the Navy's Final EIS of June 1985. Little conclusive evidence exists for the effects of fuel or oil on marine mammals (National Research Council, 1980). In the immediate project vicinity, California sea lions would be directly affected by decreased thermoregulatory capabilities concomitant with the contamination of preferred haul-out areas under the worst case scenario. In addition, they would be indirectly impacted by possible contamination and reduction of food resources.

Naval ships using existing shipping lanes will have little effect on sea lion distribution or habitat use because of the distance between deep water lanes and shallow water haul out areas west of Jetty Island. In addition, the Navy fleet will constitute only a transient and small part of total marine shipping and therefore not pose a disturbance to swimming or feeding sea lions in Possession Sound.

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E.
BIN C15700, Bldg. 1
Seattle, Washington 98115

September 8, 1986 F/NWR5:AG

Mr. J. E. Roth
Department of the Navy
Commander Naval Base
Seattle, Washington 98115

Dear Mr. Roth: Re: Biological Assessment for Proposed Navy Homeport Facility in Everett, Washington

In accordance with Section 7 of the Endangered Species Act, we have reviewed the Biological Assessment concerning effects of the construction and operation of the proposed U.S. Navy Homeport Facility on threatened and endangered species listed under jurisdiction of the National Marine Fisheries Service.

We concur with the Biological Assessment that the proposed facility is unlikely to affect the listed species. Unless new information should indicate otherwise, no further Section 7 consultation is required.

Sincerely,

Thomas E. Kruse
for Rolland A. Schmitten
Regional Director

cc: F/NWR5 - Ed Murrell

BIOLOGICAL ASSESSMENT FOR THE BALD EAGLE

WITHIN THE CARRIER BATTLE GROUP

PUGET SOUND SHIP HOMEPORTING PROJECT

INTRODUCTION

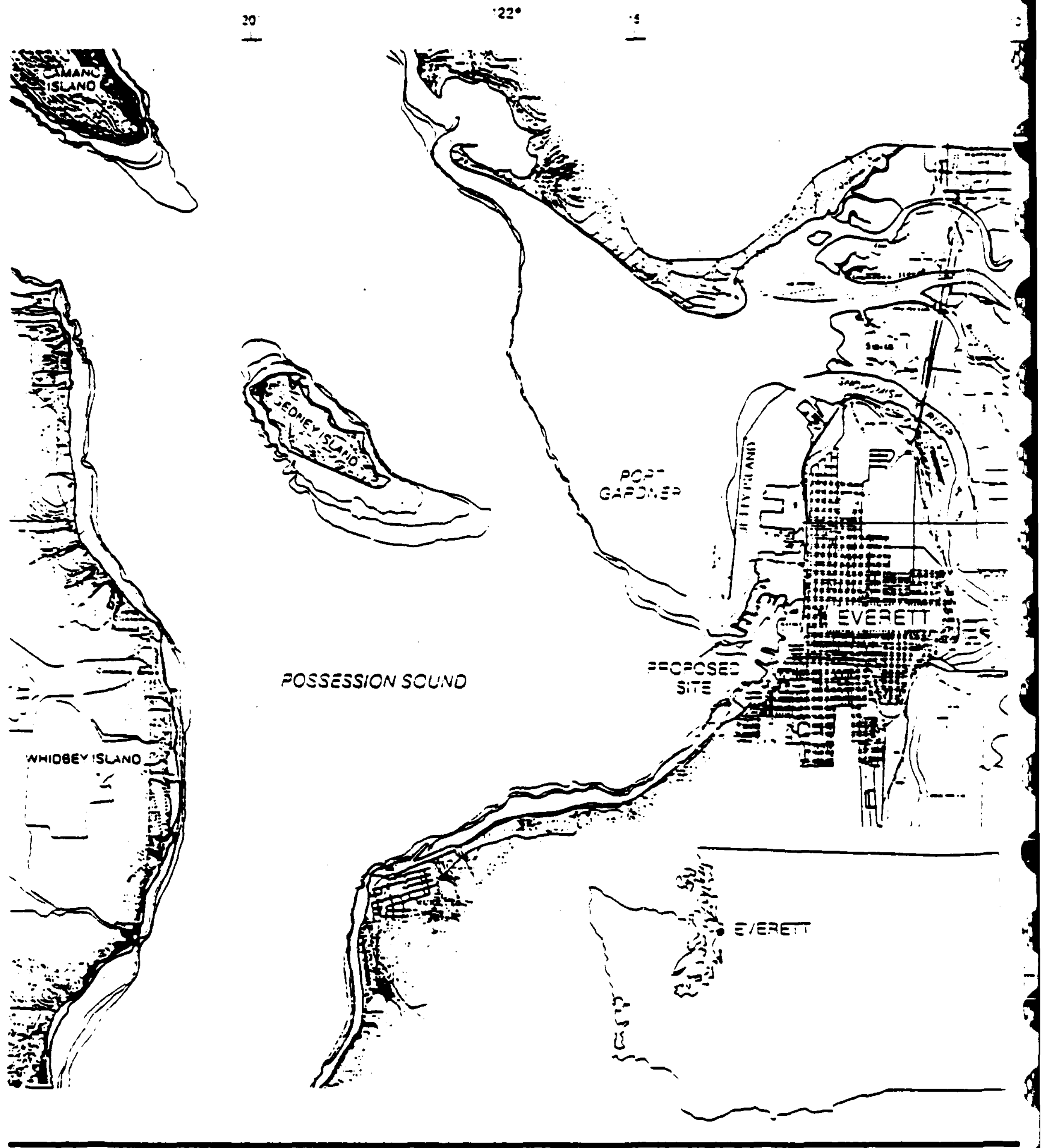
The Norton Avenue Terminal site in Everett, Washington, has been selected as the preferred site for a U.S. Navy carrier battle group homeport facility (Figure 1). A significant amount of construction will be necessary to homeport the carrier battle group at the preferred site.

Section 7 of the Endangered Species Act of 1973, as amended, requires all Federal agencies to ensure that their actions have taken into consideration impacts to federally listed or proposed threatened or endangered species for all federally funded construction, permitted, or licensed projects. The Act further requires that Federal agencies consult, pursuant to Section 7 of the Endangered Species Act of 1973, as amended, with the U.S. Fish and Wildlife Service if they determine that their actions may affect a listed species. This biological assessment fulfills the Navy's responsibility to provide information on listed species. An extensive discussion of this subject is also included in the U.S. Army Corps of Engineers Draft Supplemental Environmental Impact Statement on the Navy homeporting project.

The U.S. Fish and Wildlife Endangered Species Team has identified the bald eagle (Haliaeetus leucocephalus) as the only listed and proposed endangered, threatened, or candidate species that may occur within the project area. The project area includes the Norton Avenue Terminal site, the East Waterway, the Port Gardner deep delta confined aquatic disposal site, and the old Weyhaeuser mill site across the East Waterway (U.S. Fish and Wildlife Service, 1984). An intertidal dredge material disposal site at the Snohomish River Channel site (south of the E.A. Nord Comapny and north of the Port of Everett public boat launch) also received careful analysis with respect to bald eagle use.

PROJECT DESCRIPTION

Operation of a Carrier Battle Group Homeport at the Everett site would require construction of new facilities and demolition of most of the existing Norton Terminal structures to provide support for the Carrier Battle Group. Construction of ship berthing facilities in the East Waterway would necessitate the removal of approximately 3.3 million cubic yards of bottom materials. Dredging operations will be done with both a clamshell and hydraulic dredge. Dredged material will be be deposited in a confined aquatic disposal site located approximately 1.6 nautical miles southwest of Norton Terminal in water depths of approximately 300 to 350 feet. Confined aquatic disposal would be the method of disposal for the estimated 928,000 cubic yards of contaminated sediments. The CAD project features include a lateral containment berm and capping with



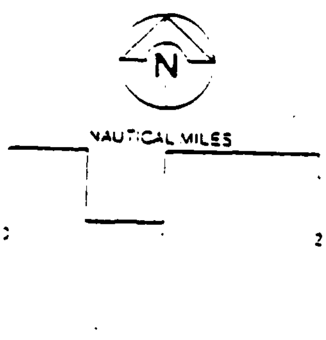


Figure 1
Site Location

approximately 2.5 million cubic yards of clean native sediment removed from the East Waterway. Other project features include construction a 1,600 foot long breakwater, a 1,600 foot long carrier pier a south marginal wharf and a 2,100 foot central marginal wharf.

METHODS

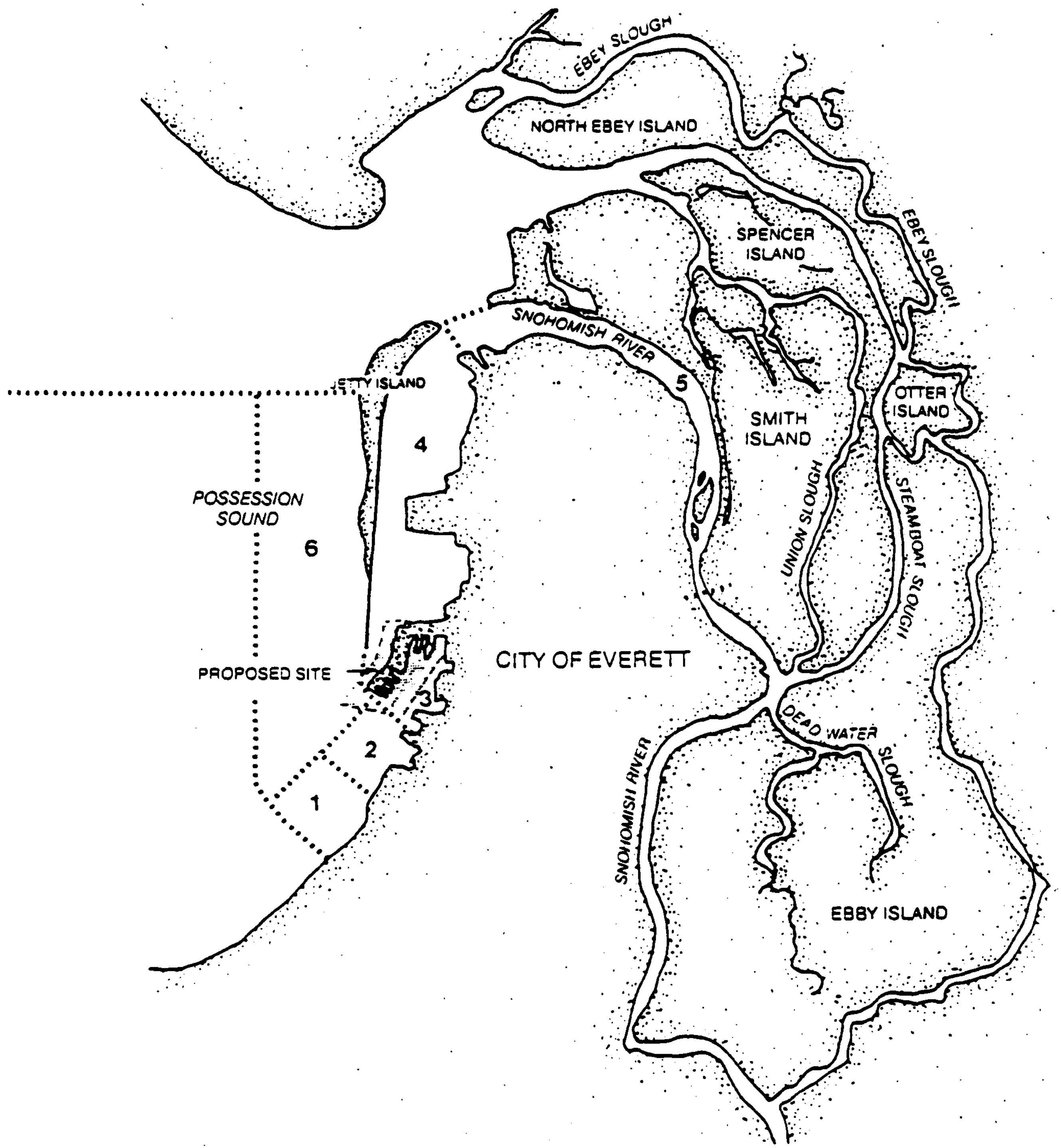
Bald eagle sightings were recorded during field surveys from April 24, 1984, through June 6, 1985. Several additional site visits subsequent to this time to verify additional information. Formal surveys included standardized boat transects. Additional ad-hoc surveys were carried out to document specific bird occurrences. The survey area included eastern Possession Sound, Port Gardner, the East Waterway, the Snohomish River delta, and affiliated islands west of Interstate Five (Figure 2). Individuals knowledgeable about bald eagle use of the project area were contacted and interviewed. Finally, available literature describing bald eagle range, habitual use, and general ecology was also consulted and abstracted for this assessment.

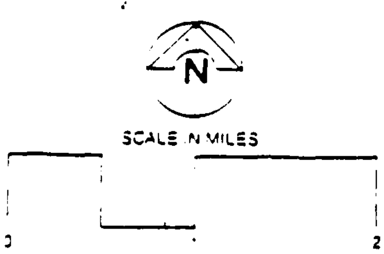
RESULTS

Level of Eagle Use

A Washington State Coastal Area of Major Biological Significance (AMBS) for bald eagles is identified in Port Gardner, on Indian Point across Possession Sound, and south in Elliott Bay (Gardner, 1981). Bald eagles, however, are regularly sighted along most of the inland waters of Puget Sound; their greatest abundance occurs in winter when eagles concentrate in areas of high anadromous fish populations. Within Port Gardner and the Snohomish River delta, the presence of eagles is not only a function of the abundance of anadromous fish, but also the availability of a wide variety of prey items that primarily include marine carrion such as stranded fish, marine invertebrates, birds, and most likely small mammals.

Bald eagle nesting has been documented to occur outside of but near the project site. One bald eagle territory is located south of the project site at Pigeon Creek. This territory contains two nests within the same coordinates. Only one of these nests, however, is consistently utilized. Nevertheless, formerly used nests are considered potential nest sites as bald eagles often use alternative nests in different years (USDI Fish and Wildlife Service, 1981). A second active bald eagle nest was verified on Otter Island during this study (Richter, 1985). One eagle has successfully fledged from this nest as determined by a census on June 10, 1985 (McAllister, 1986). Although this nest is more than a mile northeast of the project site, eagles are opportunistic and will fly long distan-





Pigeon Creek Delta	1	Lower Snohom... Rive...	
City of Everett Pier 1 and 2 Vicinity	2	Mid Snohomish Ri...	5
Waterway Harbor	3	Possession Sound	6

Figure 2.
Waterbird Census Subregions.

ces to exploit concentrated and readily available food sources (Edwards, 1969).

Bald eagles often roost communally during the night, especially from fall through spring. Searches of shoreline forests and tree stands present on Snohomish River delta islands were therefore conducted to document the prevalence of old large trees and snags, which traditionally are favorite roosting areas for eagles. No stands of perching and roosting trees were discovered within the project vicinity as a result of this survey. Old snags in the upper delta are noted to be used by red-tailed hawks, osprey and other raptors and are expected to be used by bald eagles as well.

Bald eagle feeding may occur within the project region anywhere and at anytime. Both adults and fledglings from the nearby nests described above are known to utilize the food supply available within the lower Snohomish River delta, Port Gardner and eastern Possession Sound. Adult bald eagles from the Pigeon Creek nest have more recently been sighted perching on pilings and dolphins just south of Port of Everett Pier Number 1, and also feeding on salmon while resting on these structures (Davis, 1986). Reoccurring sightings on these pilings south of Pier 1 suggests a preference for this site that is most likely affiliated with proximity to the Pigeon Creek nest and freedom from harassment. Despite ongoing marine operations, it does not appear that eagles are intimidated by such activity.

Twenty-three weekly and biweekly bird censuses from April 24 through December 27, 1984, did not result in a single bald eagle sighting within the project area. Low numbers of bald eagles were observed during the remainder of the surveys. Between January 4 and May 6, 1985, only 1 bald eagle was observed during 9 of the 23 censuses. A total of two bald eagles were counted during two censuses, and during one census, three eagles were observed in the area (Table 1). Winter sightings occurred along the east side of Port Gardner near the Weyerhaeuser dock, the mouth of the Snohomish River, and the Pigeon Creek delta. These eagles were seen flying toward and away from the Pigeon Creek nesting territory.

In spring, most of the sightings occurred during low-tide on the west side of Jetty Island. Most flights were again toward and away from Pigeon Creek, thus it may be assumed that the adults observed were affiliated with the Pigeon Creek nest. Immature eagles, such as those observed nesting and feeding on the vast open beaches exposed during low tides on the northwest side of Jetty Island on May 3, may be assumed to be non-nesting eagles opportunistically utilizing the area for feeding.

Site visits during the late summer and fall of 1985 did not result in any bald eagle sightings. Nevertheless, it may be

Table 1. Bald Eagle Sightings During 1985 Census.

Census Date	# of Eagles Sited	Location	Activity
01/04	0	---	---
01/08	1	Pigeon Creek Valley	Flying up valley
01/11	0	---	---
01/15	2	Weyerhaeuser Terminal Pier	Perching on log raft & pilings
01/18	0	---	---
01/22	0	---	---
01/29	1	Pigeon Creek Valley	Flying south toward Mukilteo
02/06	0	---	---
02/08	1	Snohomish River at mouth	Flying north towards river end of Jetty Island
02/15	0	---	---
02/22	0	---	---
02/27	0	---	---
03/06	0	---	---
03/13	1	Snohomish River at mouth	Flying with fish toward Pigeon Creek
03/21	0	---	---
03/27	3	Northwest Side of Jetty Island	Feeding off sand spit & pier
04/02	1	Snohomish River at mouth	Flying toward Eby Island
	1	East Side of Jetty	Flying north
04/09	1	West Side of Jetty Island	Flying over intertidal zone
	1	West Side of Jetty Island	Perched on beached driftwood
04/17	1	Pigeon Creek Valley	Perched on Douglas Fir
04/22	0	---	---
04/23	1	West Side of Jetty Island	Flying south along shoreline
04/30	0	---	---
05/06	0	---	---

presumed that eagles were present in the greater project vicinity because of prior observations.

Impacts From Project Construction

Studies on overwintering bald eagles indicate a variable tolerance to human activity by different populations (Stalmaster, 1978, Hunt et al., 1980). Eagles will tolerate higher levels of activity in optimal habitats, and lower levels in less preferred sites (Steenhof, 1976). In some populations, disruptions cause eagles to leave the area (Shea, 1973). In this project area, habituation to marine activity by bald eagles is demonstrated by their continued use of pilings and dolphins while shipping, tug boat activity, and log loading ensues within the East Waterway and the Lower Snohomish River. As long as people remain on their boats and ships, and do not approach the eagles, the eagles in this area appear to remain unaffected. Thus, it is not anticipated that project construction will result in any habitual use changes of the area by bald eagles. Clearly, if blasting or any other extremely disturbing activity takes place, eagles will circumvent the construction site. Eagle flights over the project are currently so rare however, that activity such as blasting, etc., is not expected to occur concurrently with overflights and result in a permanent habitual use change.

Although proposed construction will occur at the periphery of the secondary buffer zone of the Pigeon Creek eagle nest, construction at the site will not detrimentally affect nesting eagles. Nesting eagles are acclimated to East Waterway activity and will not be disturbed by construction at the Norton Terminal site.

Construction activities would affect the utilization of the project area by vertebrates and invertebrates. Altered utilization by these animal groups may result in the altered distribution of these food resources to eagles. Presently adult Dungeness crabs, the prime invertebrate food species, exist in low densities within the East Waterway. The absence of any documented evidence of eagles feeding along the shoreline within the construction area suggests that shoreline modification will not detrimentally affect eagles currently in the general area.
The prime impact affiliated with project construction is the accidental spillage of fuels, lubricants and other construction chemicals. These would pose a potential localized, short-term impact.

Project Operational Impacts

The impacts of project operation on bald eagles will be non-significant. There will be no loss of habitat, displacement of eagles, disturbance or loss of nesting and roosting sites, or effect on food supply and food resources. Any temporary impact that may have occurred during construction will cease to be a problem. Additionally, habitual use of the area may increase as eagles acclimate to routine operations at the site, and as the ecological conditions associated with the recovery of benthic communities improve.

Impacts from project operation may result from the accidental spillage of oil or other toxic chemicals. Spillage of small quantities of fuel during topping-off operation is not expected to seriously impact bald eagles as minute quantities would immediately be contained and cleaned up. Larger spills, although unlikely, could result in ecological damage to the East Waterway, Snohomish River delta, Port Gardner, and Possession Sound. Clearly, such a spill could result in major impacts to the entire marine and/or estuarine community and either directly or indirectly detrimentally impact bald eagles in the area. A worst case scenario, in which a spill occurred at the most inappropriate time, would result in the loss of eagle survivorship and nesting success. A complete review of the potential impacts of dredging on marine birds may be found in the U.S. Fish and Wildlife Service's Publication Energy Related Use Conflict for the Columbia River Estuary (Garcia et al., 1983).

The disposal of dredge material at the Port Gardner deep delta CAD site will not directly affect bald eagles in the project area. Indirect effects of dredge disposal of this site could arise through depressed Dungeness crab recruitment to other areas of the study site, and particularly on the abundance of stranded crabs on the west side of Jetty Island. Crabs, however, comprise such a minor percentage of bald eagle diet that reduced numbers of crabs are unlikely to affect eagle food supply and existing habitat use.

Impacts of Intertidal Dredge Disposal

The mud flats and log storage area south of the E.A. Nord Company and North of the Port of Everett's public boat launch, i.e., Snohomish Channel site, were considered as an intertidal nearshore dredge disposal site for East Waterway material. This site is characterized by bark and other wastes overlying a mudflat. These mud covered tide flats with their dolphins, pilings and stored logs are not utilized by bald eagles. Thus, the deposition of dredged material at this site would not have a direct impact on bald eagles. Nesting, roosting, and feeding also does not occur near this area. Hence, these aspects of eagle behavior would be unaffected by dredge disposal within this area.

The primary indirect effect on bald eagle population by using this area as a dredge disposal site would be through the possible relocation and reduction of overwintering waterfowl and seabirds that are known to utilize this area. As potential food for bald eagles, a loss of these birds might require eagles to alter their feeding habits. Such behavioral adaptations are expected to be minor and not considered to be a detriment to eagles.

A second indirect effect could be the removal of at least 120 acres of mud flat from use by aquatic fauna of the Snohomish River Estuary. This area, however, has been documented as being relatively unimportant to migrating juvenile salmonids, encompassing only .34 percent of this habitual type in the entire Snohomish River Estuary (Everett Planning Department, 1980). Nevertheless, it would result in a very small, but incremental loss of potential salmon and other food sources for the existing bald eagles.

Impact of Upland Dredge Disposal

The upland dredge disposal sites currently under consideration (see U.S. Army Corps of Engineers DEISS on this project) are not utilized by bald eagles. Hence, there will be no displacement of eagles from nesting, roosting, or feeding sites. Additionally, upland disposal will not affect any existing food sources or supplies on which the bald eagles in the vicinity depend.

Secondary Impacts From Port of Everett Development

The Port of Everett is planning to expand its activities south along the East Waterway to the old Weyerhaeuser docking facility. Port of Everett development at the old Weyerhaeuser site will occur well within the secondary bald eagle management zone established to buffer the primary nesting habitat. Development of the Weyerhaeuser site could result in some disturbance to the pair of bald eagles that enter and leave the nesting territory on Pigeon Creek; however, the local topography that includes a ridge between the primary nesting territory and the existing vegetation including a dense stand of Douglas fir which offers visual isolation between the primary nesting territory and the Weyerhaeuser site, will minimize the impact of shoreline development and other human activities, and thus offer continued protection to nesting eagles adjacent to Pigeon Creek. It is expected that redevelopment along the Weyerhaeuser site will not result in a loss of the nesting site at Pigeon Creek.

During construction at the Weyerhaeuser facility, bald eagles will lose use of a segment of the secondary buffer zone. They will change their flight patterns, circumventing the construction site, and enter their territory by flying over open water and up the Pigeon Creek valley or fly further inland and down the hillside above their nest. It is anticipated that eagles will return to pre-construction flight patterns after consturction is completed and routine operations occur at the new facilities.

One threat from construction at the Weyerhaeuser site to bald eagles comes from the removal of in-water support structures that currently serve as landing and mooring places for vessels and log rafts. Construction would eliminate the pilings and dolphins that are utilized by resting and feeding bald eagles just south of the City of Everett Terminal 1. Eagles would therefore have to find perch sites at other presumably less preferred locations.

Impacts resulting from Port of Everett development will not include a disturbance or loss of roosting sites, as none currently exist within the development area. Although development at the site will affect the aquatic ecology that currently characterizes the old Weyerhaeuser site, this area is not utilized by feeding eagles, and thus will not directly affect food supply and food sources.

Impacts of Dredging on the Food Supply

There will be no impacts of dredging on the bald eagle food supply. Bald eagles are not reported to feed within the East Waterway and other areas under consideration for dredging. Therefore, there are not direct impacts affiliated with dredging.

Dredging could result in turbidity and some resuspension of some toxins found in the East Waterway sediments. These toxins are sediment bound and short-term secondary impacts would not arise from the bioaccumulation of toxins through marine food chains and terminating in eagles.

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APPENDIX E

RESPONSES TO DREDGING AND DISPOSAL REVIEW COMMENTS BY THE U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

Letter #	Source
F 1	U.S. Environmental Protection Agency - 9/2/86
F 2	U.S. Department of the Army - 8/14/86
F 3	U.S. Dept. of Commerce, National Marine Fisheries Service - 9/4/86
F 4	U.S. Department of the Navy - 9/3/86
F 5	U.S. Dept. of the Navy, NAS Whidbey Is. - 7/21/86
F 6	U.S. Dept. of Agriculture - 8/4/86
F 7	U.S. Fish and Wildlife Service - 9/5/86
F 8	U.S. Dept. of Health and Human Services - 8/25/86
F 9	U.S. Dept. of Transportation - 8/22/86
F10	Stillaguamish Tribe - 8/22/86
F11	Tulalip Tribe - 9/2/86
S 1	Washington Department of Ecology - 9/2/86
S 2	Washington Department of Fisheries - 8/25/86
S 3	Washington Dept of Game - 8/27/86
S 4	Washington Department of Natural Reources-8/11/86
S 5	Washington Interagency Committee for Outdoor Recreation - 7/15/86
S 6	Puget Sound Air Pollution Control Agency - 8/29/86
S 7	University of Washington - 7/29/86
L 1	Port of Everett - 9/2/86
L 2	Mayor, City of Everett - 9/2/86
L 3	Municipality of Metropolitan Seattle - 8/23/86
L 4	Snohomish Health District - 8/4/86
L 5	Snohomish Health District - 8/19/86
G 1	Puget Sound Allianace - 8/30/86
G 2	Pilchuck Audubon Society 8/26/86

G 3	Pilchuck Audubon Society - 8/25/86
G 4	Port Angeles Pilots - 7/19/86
G 5	Friends of the Snohomish River Delta - 9/2/86
G 6	Friends of the Earth - 9/1/86
G 7	Laebugten Salmon Chapter - 8/29/86
G 8	Washington Environmental Council - 9/2/86
G 9	Everett/Snohomish County Impact Coordinating Council - 9/2/86
G10	Navy Response Team - 8/27/86
P 1	Morris and Rodgers - 8/28/86
P 2	Scott Paper Company - 8/29/86
P 3	Merle D. Gors - 8/21/86
P 4	Richard A. Grant Sr.
P 5	Anne Robison - 8/25/86
P 6	Ronald L. Strong - 8/20/86
P 7	W.M. Lider - 9/1/86
P 8	Rodney J. Johnson - 8/29/86
P 9	Nancy Sosnove - 8/27/86
P10	Harry E. Wilbert, Col(Ret) 8/28/86
x	Public Hearing Response - 8/19/86
H 1	Pat McClain, City of Everett
H 2	Steven Roy, Bureau of Indian Affairs, Everett
H 3	Ted A. Muller, Department of Game
H 4	Dennis Gregoire, Port of Everett
H 5	David Ortman, Freinds of the Earth
H 6	W. Arthur Noble, Washington Environmental Council
H 7	Benella Caminiti, Washington Environmental Council

H 8	Thomas M. Faney, Scott Paper Company
H 9	Curtiss Howard, Pilchuck Audubon Society
H10	Robert F. Baril, Everett-Snohomish County Impact Coordinating Council
H11	Randall W. Brink, Nuclear Free Zone For Snohomish County
H12	Lorena A. Havens, Friends of the Snohomish River Delta
H13	Gary L Wold, Laebugten Chapter of Trout Unlimited
H14	Bernie Sigler, Everett Chamber of Commerce
H15	Chuck Mahlum, Association of Western Pulp and Paper Workers
H16	Tony Rowse, Citizen
H17	Richard D. Born, Citizen
H18	Guy Ames Stitt, Citizen
H19	John Fisher, Citizen
H20	Rodney J. Johnson, Citizen
H21	Gail P. Chism, Citizen
H22	Sally A. Van Niel, Citizen
H23	Jim Haley, American Maritime International

17 September 1986

FINAL ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT
RESPONSE CATEGORIES

Categories.

1. Dredging and Disposal
2. Site Alternative
3. Water Quality
4. Fisheries
5. Air Quality
6. Endangered Species
7. Soils and Geology
8. Native American Concerns
9. Traffic and Transportation
10. Population and Zoning
11. Secondary Impacts to Port of Seattle
12. Sewage Treatment Plant
13. Nuclear Hazards
14. Mitigation
15. Miscellaneous

Planning Branch 17 September 1986

SUBCATEGORIES
TO
FEISS RESPONSE CATEGORY

1. Dredging and Disposal.

1.1 Sediment Characterization and Chemistry.

a. Dredge volumes/amount of contaminated sediments

b. Basis of compositing sediment samples

c. Contamination of Phase III "native" sediments

d. Differing chemical testing results between PNL and WES

e. Comparison of East Waterway sediments to PSDDA proposed guidelines

1.2 Disposal Alternatives Analysis.

a. Identification of contaminant pathways

(1) Mechanical dredging and contained aquatic disposal (CAD)

address:
- o dredging resuspension
- o transport leakage
- o sea surface microlayer
- o water column stripping
- o mass release (nepheloid)
- o deposited mound (before cap)

(2) Hydraulic dredging and upland disposal

address:
- o dredging resuspension
- o volatilization
- o effluent
- o runoff
- o leachate
- o animal/plant uptake (before cover)

(3) Key contaminant pathways

CAD
- o mass release
- o bulk of contamination reaches bottom

UPLAND
- o effluent
- o leachate (new data available here)

b. Control and treatment options

(1) CAD

(2) UPLAND

c. Available remedial action techniques

(1) CAD

(2) UPLAND

d. Tradeoffs analysis

(1) in situ effects (as a reference)

(2) CAD versus UPLAND

1.3 Design and Monitoring.

a. Accuracy and reliability of the dump model predictions (mass release)

b. Size of CAD site ("footprint")

c. Capping effectiveness and thickness requirements/predictions

d. Monitoring needs

1.4 Smith Island Upland Disposal Site Alternative.

a. Key information needs

b. Possible issues (e.g., floodplain, wetlands, groundwater, etc.)

NPSEN-PL September 18, 1986

RESPONSES TO DREDGING AND DISPOSAL REVIEW COMMENTS
ON NAVY HOMEPORT DRAFT ENVIRONMENTAL
IMPACT STATEMENT SUPPLEMENT (EISS)

Category 1.1, Sediment Characterization and Chemistry. Clarification of computations for dredged material volumes for contaminated and uncontaminated sediments.

Response: In June 1984, a contaminated sediments assessment program for the East Waterway of Everett Harbor was developed by the Seattle District, Corps of Engineers (COE) in coordination with key Federal and state agencies. Two distinct layers of marine sediment within the zone proposed to be dredged had been described by Crecelius, et al (1984). Nineteen stations in East Waterway were sampled in July 1984 by the COE using vibracore sampler. Sediment cores were recovered for depths up to 15 feet. Sediment horizons were visually characterized and subsamples taken for chemical analysis. The results of this chemical analysis was reported by Anderson and Crecelius (1985) and COE (1985a). Based upon the only Puget Sound sediment criteria in existence at that time (i.e., Four Mile Rock disposal site in Elliott Bay), COE (1985a) calculated that approximately 800,000 cubic yards (c.y.) of material within the area proposed to be dredged by the Navy was unacceptable for unconfined disposal in open water. An additional approximately 40,000 c.y. of this same sediment judged to be unacceptable for unconfined open-water disposal was below the dredging depths proposed by the Navy. Approximately 500,000 c.y. of the underlying native sediments were found to contain specific metals and organic compounds at levels slightly elevated above then-estimated background levels for central Puget Sound. All chemical values of the native sediment layer were below the Four Mile Rock interim criteria.

The above volumes were calculated considering both the results of chemical analyses of the vibracore sections, and the general limits of precision attainable for conventional dredging equipment. A 200 x 200 feet grid was overlain on the most recent bathymetric survey map for East Waterway, and volumes were calculated by assigning a grid block to the nearest station. This defined a "dredged material management unit" associated with each of the 19 vibracore stations. Generally, the volumes for the overlying contaminated layer include the entire layer defined as "contaminated" by the chemical testing, a midzone interval (if one was identified), and approximately a foot of overdredge allowance. Bottom cuts between stations were squared off in order to ease calculations, and where adjacent stations showed very different depths of contamination an additional foot or more of overdredge allowance was added to the shallower grid as a conservative measure to assure complete removal of the contaminated sediment. In addition, volumes were rounded up to the next thousand for each grid block. The area outside of East Waterway (generally, south of the mole pier) was assumed to be contaminated only in the surface foot (based on station E-19), but an additional foot of overdredge allowance was added because of the limited precision of dredge equipment. These volumes were then totalled. The management unit under the contaminated sediment layer was similarly defined. Because the vibracore tends to distort the vertical profile of the sediments somewhat (e.g., loose silts can be shaken down and compacted slightly while compacted sands can be expanded), these volumes were considered only approximations.

Another 20 sediment samples were collected in February 1985 from the East Waterway, again using the vibracore sampler, for the purpose of biologically testing the 500,000 c.y. of questionable native sediment called "gray" in the previous report. Sediment samples collected included material from the midzone interval. The upper contaminated layer was not tested because the sediment samples were taken in the same areas as the 1984 locations. Results of this testing effort are reported in Anderson (1985) and COE (1985b) and indicated that all of the native material would be acceptable for unconfined open-water disposal under the current criteria. The term "gray" material was eliminated and all material was defined as either "contaminated" or "clean native" sediments. Total volume of clean native sediment to be dredged was then estimated to be 2,700,000 c.y. Both Anderson (1985) and COE (1985b) postulated that some contaminants had been attenuated in the upper layer of native sediments. As this portion of the native sediments had already been categorically included in previous calculations as part of the contaminated layer, volume estimates by COE were considered still applicable.

Under separate contract to the Navy, Hart-Crowser performed geotechnical studies that included collection of piston core samples in the East Waterway. Piston coring does not deform the vertical profile of the sediments and so was considered a much more accurate representation of the sediment layers in East Waterway. Several piston core samples and logs were examined by the COE, Battelle-Pacific Northwest Laboratory (PNL), and Hart-Crowser in mid- and late-1985. There proved to be good, although not exact, agreement between vibracores taken by the COE and PNL, and the piston cores taken by Hart-Crowser. A characterization methodology was developed to visually define the contaminated sediment layer; parameters included grain size, color, petroleum odor, presence of woodchips, etc. Using this methodology, the Navy's consultants identified and calculated an "in-situ contaminated" sediment volume (described in the draft EISS). To this in-situ contaminated sediment, overdredging allowances were added to achieve a dredging plan that could be related to actual dredging conditions. This was defined as the "dredge contaminated" sediment volumes (928,000 c.y.) in the draft EISS. The remaining sediment volumes (2,377,000 c.y.) were described as "dredge clean."

Dredging will result in some sloughing and mixing of sediments, and dredging precision is at best limited to about 2 feet for mechanical and about 1 foot for hydraulic plants. The dredge contaminated volume, which must include overdepth allowances, represents the only meaningful, practical volume for purposes of removing and confining contaminated material whether this material is destined for contained aquatic, nearshore, or upland disposal. Because the Navy's dredge contaminated volumes were calculated based on the piston core samples and include at least 2 feet, and generally more, of overdepth dredging based on practicable dredging precisions, the 928,000 c.y. is a reasonable estimate of contaminated sediment quantities to be removed from East Waterway.

Category 1.1, Sediment Characterization and Chemistry. Use of the composited sediment sample for contaminant mobility testing.

Response: The Waterways Experiment Station (WES) has developed a management strategy (Francingues, et al, 1985) and decisionmaking framework (Lee, et al, 1985) for contaminated sediments which incorporates the results of a suite of tests protocol that assesses the effects of physicochemical changes on contaminant mobility from placement of dredged material into various disposal environments. The COE prepared a program of contaminated sediment disposal and management studies for East Waterway. The program was coordinated with key state and Federal agencies, including the Office of Oceanography and Marine Services of the National Oceanic and Atmospheric Administration (NOAA), and the Northwest and Alaska Fisheries Center of the National Marine Fisheries Service (NMFS), two research offices that have extensive expertise and experience with Everett Harbor sediments. The tests require a substantial volume of material. Performing the entire suite of environmental tests on multiple samples from a project is economically and logistically impractical. Homogenization of samples for such testing is an accepted practice and has been employed in numerous studies similar to Everett. The particular sampling distribution and compositing scheme used for the Everett project was developed by the Seattle District based on a careful examination of both physical and chemical characterization of individual core samples. The objective of the compositing scheme was to obtain a sample which was as representative as possible of the entire volume of contaminated sediments to be dredged. The Corps of Engineers finding of the contaminated sediments' homogeneous nature and judgement that a representative composite sediment sample from contaminated East Waterway material be tested was reviewed by the key state and Federal agencies who indicated that the proposed approach was acceptable.

In June 1985, contaminated sediment samples were obtained from 16 stations inside East Waterway and mixed to form 8 c.y. of composited sample and provided to WES for the suite of tests. One c.y. of native sediment was also collected for the testing. Subsamples of the composite and native sediments were concurrently provided to PNL for separate chemical and biological tests.

This was done to maintain the continuity of analyses between Phases I and II, and Phase III by having the same laboratory performing the same analyses on the composited sediment as had been conducted on prior sediment samples. Results of the Phase III analyses by PNL were reported in Crecelius and Anderson (1986). Crecelius and Anderson (1986) concluded that the concentrations of contaminants in the contaminated composite were similar to concentrations reported by previous studies. Comparison of PNL chemistry for the composited sediment with the range of chemical values from individual cores previously analyzed (Anderson and Crecelius, 1985) indicated that the composite sediment was representative of the more, though not the most, contaminated sediments previously encountered. Separate chemical analyses on the composited sediment were performed by WES to establish a reference for the extensive mobility tests to be performed and to develop a selected list of specific compounds that would be tracked during the testing. Sediments were stored at 4 degrees C until used; no frozen sediment was used for any testing by either PNL or WES. Because different analytical techniques were used by WES and PNL, the chemical values are not directly comparable.

Category 1.1, Sediment Characterization and Chemistry. Comparison of sediment chemical values from analyses performed by PNL and WES.

Response: Gas chromatography (GC) is a technique for separating chemicals based primarialy on their vapor pressure and their polarity. A variety of detectors are available for GC, e.g., flame ionization (FID), electron capture (ECD), mass spectrometry (MS), Hall electrolytic (HED), flame photometric (FPD). The methods and their results are not directly interchangable or comparable. GC analyses generally have lower detection limits, but can be less precise in differentiating individual compounds than GC/MS analyses. A peak from a GC/FID analysis indicates that a chemical eluted at a specific retention time under a set of specific conditions and produced a specific peak that can be related to amount of chemical. However, to accurately identify the chemical, the sample must be analyzed by GC/MS which yields a spectrum of the chemical. GC/MS is normally used for qualitative information and FID for quantifications. GC/MS equipment, and hence analysis, is much more expensive than GC.

COE (1985a) and Anderson and Crecelius (1985) reported chemical values for contaminated and native sediments in East Waterway. Chemical analyses were performed using GC/FID and GC/ECD. This same equipment was used to obtain values reported by COE (1985b) and Anderson (1985). Phase III analyses by PNL and reported in Crecelius and Anderson (1986) and COE (1986b), were also performed using GC/FID and GC/ECD; additionally, to confirm that GC analysis was properly identifying the many polynuclear aromatic hydrocarbon (PAH) compounds, an extract was also analyzed using gas chromatograph/mass spectrophotometer (GC/MS) at the PNL facility at Richland, Washington. WES chemical analyses were performed using GC/MS with FID and ECD. In addition to the different analytic methods employed by PNL and WES, different extraction procedures, sample variability, and different means of quantifying chromatographic peaks can lead to large discrepencies in analytical data from various laboratories. Approved QA Project Plans were prepared and included with the reports from each lab.

Category 1.1, Sediment Characterization and Chemistry. Comparison of Phase III native sediment sample with prior native sediment chemistry.

Response: Approximately 1 c.y. of native sediment was required for the detailed tests performed by WES. Previous samples of East Waterway native sediments had been collected using vibracore sampler. The vibracore penetrates the sediments and emerges with a tube of sediment that is relatively intact throughout the column. Sediment can be collected at discrete levels through the core according to sediment horizons observed. "Contamination" of deeper sections of the core by surface material does not occur. Chemical analyses performed on native sediment collected with the vibracore, therefore, more accurately reflects the in-situ condition of the native sediments underlying East Waterway. The barrel of the vibracore used for sampling East Waterway sediments is only 4 inches in diameter. Vibracore sampling to obtain the 1 c.y. of native material would be time-consuming, expensive, and was not considered practicable. Previous sampling by vibracore indicated the surface layer of contaminated sediment in the area of station E-19 to be relatively thin (0.5 foot). The Phase III "native" sediment was collected using a .5 c.y. clamshell bucket, which has a maximum penetration of about 2.0 feet, from the vicinity of station E-19. An attempt was made to remove the surface organic layer and penetrate to the cleaner underlying material. As reported in COE (1986b), the bucket may not have penetrated into the cleaner underlying sediment, and may have entrained some of the overlying contaminated sediments as well. The contamination of the native sediment sample was discovered later by both PNL and WES, and was commented upon in their respective reports.

Category 1.1, Sediment Characterization and Chemistry. Comparison of Everett Harbor composited surface sediment sample to proposed PSDDA guidelines.

Response. The results of chemical and biological tests conducted on the Everett Harbor (EH) "contaminated" sediments have been interpreted using available interim criteria for dredged material proposed for discharge at the Fourmile Rock and Port Gardner disposal sites. (The Port Gardner interim criteria are essentially identical to the Puget Sound Interim Criteria.) These EPA and Ecology interim criteria are the only ones currently available for regulatory purposes in Puget Sound and are expected to govern through completion of the proposed Navy project. Several reviewers of the DEISS commented on the relation between the EH test results and the new disposal guidelines being developed by the Puget Sound Dredged Disposal Analysis (PSDDA). Expected to be available in late 1987, the new disposal guidelines will eventually replace the interim criteria. They will be applicable primarily to the multi-user sites designated and managed by the Washington Department of Natural Resources (DNR) for unconfined, open-water disposal of dredged material in Puget Sound.

Though the new guidelines have not been completed or distributed at this time, information available from PSDDA technical reports allows a preliminary comparison of EH chemical and biological test results with the developing interpretation guidelines. For purposes of an alternatives analysis and the preparation of a joint Federal and state EIS, PSDDA has defined four alternative levels of adverse biological effects that might be considered "acceptable" at the unconfined, open-water disposal sites. These four "categories" represent increasing chemical concentrations that might be allowable in the dredged material coupled with increasing biological testing effects. PSDDA, after public review and comment on the draft products, will select one of these alternatives for management of the unconfined, open-water sites. Current draft technical reports available from PSDDA suggest that category 2 should be recommended in their draft EIS. This category limits all possible adverse chemical effects to within the site boundary and allows no significant acute toxicity in laboratory tests. The PSDDA categories are defined both by upper level chemical concentrations and bioassay response guidelines.

A comparison of the EH contaminated surface composite (using PNL data from the Phase III testing results) with the August 1986 proposed PSDDA guidelines indicates that the EH material would be labelled as Category 4. This is due primarily to the high levels of polyaromatic hydrocarbons (PAH's) and the bioassay responses (several species indicated greater than 90 percent difference between the EH surface sediments and reference sediments). Current PSDDA recommendations would require that the EH material not be discharged unconfined in Puget Sound. Confined disposal (either aquatic, land or shore) would be required. In summary, the current PSDDA proposals would not alter the classification or requirements for dredging and disposal of the EH "contaminated" sediments.

<u>Category 1.1, Sediment Characterization and Chemistry</u>. Technical approach for capping test protocol questioned.

<u>Response</u>. Once dredging and disposal takes place, any zoning of contaminant concentrations will be destroyed and the dredged material mound will tend to be homogenized as compared to the sediment mass prior to dredging. Actual contaminated material need not be present in the test since the objective is

to determine requirements for chemical isolation, which would be independent of the thickness. Actual thickness of cap was not tested because the objective of the test was to determine a minimum required thickness for isolation. A margin for bioturbation was then added. As a part of the research conducted for development of the test, comparisons were made between long-term tests and the various time periods. Results for the long-term tests were the same as for the testing period adopted as the standard. Therefore, long-term diffusion is accounted for in the test. Water currents were not used in the test because the objective of the test is to determine the requirements for isolation under the most conservative conditions. The presence of currents would cause a dilution and the presence of contaminants would likely not be detected even for very thin cap thicknesses.

Category 1.1, Sediment Characterization and Chemistry. EPA criteria may not be accurate measurement of chronic effect and does not take into account synergistic effects.

Response. EPA criteria are based on the best available technical information. Use of the criteria for comparison with test results is an accepted practice. Note that both acute and chronic criteria were used in the comparisons for the Everett project.

Category 1.1, Sediment Characterization and Chemistry. Everett sediment is highly contaminated and associated with serious biological effects.

Response. Chemical and biological analyses have been made and were presented in Appendix D of the draft EISS. See also comparison of Everett analyses to proposed PSDDA guidelines.

Category 1.1, Sediment Characterization and Chemistry. Appropriateness of reference water sample and use of evaluation criteria.

Response: A water sample, taken near the bottom just outside of East Waterway, was analyzed by WES to provide a reference for evaluating detailed tests. Although the water sample is more representative of the dredging area than of the subsequently defined CAD site waters, this has no bearing or relationship to how the sample was used. Another reference water could easily be used and additional comparisons made. Considering the fact that only five chemical parameters were above detectable concentrations in the sample used, it is unlikely that use of any other reference water sample would change the basic results of the comparisons, because the reference water was not the basis of final evaluation. Results of elutriate and surface runoff tests were compared with Federal water quality criteria for the protection of saltwater aquatic life. For the leachate tests, results were compared with EPA or State of Washington drinking water standards. These comparisons were presented in technical appendixes to the draft EISS. For essentially freshwater situations, comparison of results with EPA water quality criteria for the protection of freshwater aquatic life would be appropriate. Although water quality criteria are not ideally suited to sediment quality concerns, they do represent the best available, generally recognized, standards that presently exist.

Category 1.1, Sediment Characterization and Chemistry. Suspended solids at the hydraulic disposal operation would violate State of Washington standards. Sediment resuspension estimates for cutterhead dredges questioned.

Response. The results of elutriate tests were compared with Federal WQ criteria. The results are summarized in Appendix A of Appendix B of the draft EISS. With a dilution factor of 13, all parameters will meet the WQ criteria. This mixing would be achieved within a short distance of the dredging operation.

The estimates of sediment resuspension are based on the best available data. Extensive field data clearly shows that cutterhead dredges produce the least sediment resuspension of any conventional dredge. Concentrations on the order of 100 mg/l could be expected at distances less that 1,000 feet from the dredge. Total sediment resuspended is estimated at 1 percent for a cutterhead. It should also be noted that a significant portion of this resuspended material will settle within a short distance of the cutterhead and may later be dredged.

There is apparent confusion between resuspension due to the dredging action of the cutterhead and the suspended solids resulting from the cutterhead dredge disposal. The comment quotes studies where a "pipeline cutterhead discharge" resulted in large turbidity plumes. There should be a clear distinction between turbidity resulting from dredging and that which would be associated with unconfined disposal from the dredge pipeline.

Category 1.1, Sediment Characterization and Chemistry. Significance of contaminant release questioned and presence of unknown compounds.

Response. Total concentrations cannot be validly compared with WQ criteria which are based on the dissolved concentration. A few parameters in the dissolved form exceed the WQ criteria upon initial release, but the criteria can be met with minimal mixing. A thorough discussion of this topic is given in Appendix B of the draft EISS.

Regarding the presence of unknown compounds, the WES studies considered only a list of compounds of concern which was developed by COE. WES Analytical Laboratory Group did not identify any unknown complex of chemicals in the

Everett sediments. PNL performed detailed chamical analysis to identify the "unresolved chemical envelope" noted by Malins, et al (1982), and COE (1985a). These data were included in Appendix C of Appendix B of the draft EISS.

Category 1.1, Sediment Characterization and Chemistry. Mass release performance goal.

Response: A performance goal of 5 percent for total mass release for contaminants from both dredging and disposal was specified as a means to evaluate the efficiency of performances of conventional dredging equipment and return parthways (e.g., effluent, disposal discharge, etc.). The 5 percent goal does not consitute a standard to be met in any regulatory or contractural sense nor does it have any direct application to environmental impact. All mass release estimates were made based on the best current information and all tend to be conservative. For example, the 2 percent resuspension during clamshell dredging was assumed to be completely lost for purposes of performance evaluation. This overestimates dredging mass release, as a significant percentage of the suspended material will resettle in the dredge area and be removed in the next dredging pass. The mass release performance goal allows a manager to compare performances of hydraulic versus mechanical dredges or of individual disposal sites. This evaluation can suggest also that controls could be useful to reduce mass releases via a particular return pathway (e.g., effluent return). The appropriateness and need of additional control is a separate regulatory decision.

Category 1.1, Sediment Characterization and Chemistry. Disagree that contaminant levels are similar throughout East Waterway. Data indicate a general gradation of contamination with specific hot spots for some individual pollutants.

Response: This is what was reported by COE (1985a) and Anderson and Crecelius (1985). However, variability across the dredging prism is not sufficiently different to suggest that different dredging or disposal techniques are appropriate. Evaluation of the trends of contamination and physical properties of the East Waterway sediment indicated that the contaminated mass should be handled as a single management unit. This conclusion was coordinated with key Federal and state agencies.

Category 1.2 Disposal Alternatives Analysis. Numerous reviewers commented on the relative advantages and disadvantages of the alternative disposal options being considered for disposal of the Everett Harbor contaminated sediments. Many of these comments concerned only one aspect of the dredging and disposal alternatives addressed in the DEISS. This response generally addresses all pertinent contaminant pathways and related comments in the context of a comparison of disposal alternatives. This response addresses disposal alternatives in a generic way, not site-specific. Response to comments concerning the location of the CAD site and issues associated with the Smith Island upland disposal site alternative are addressed elsewhere.

Response: Response first addresses contaminant pathways for each disposal method, identifying the key pathways and effects. Control and treatment options available for each disposal method are summarized, along with remedial action techniques. Last, a comparison of alternatives is presented, noting the important issues and tradeoffs associated with each disposal option.

Identification of contaminant pathways. The processes involved with the release or immobilization of most sediment-associated contaminants are regulated to a large extent by the physicochemical nature of the disposal environment. Where the physicochemical nature of a contaminated sediment is altered by disposal, chemical and biological processes important in determining environmental consequences of potentially toxic materials may be affected.

Physicochemical (oxidation-reduction, pH, and salinity) conditions of dredged material at a disposal site influence the mobility and bioavailability of most contaminants. Typical marine dredged sediments are anoxic (reducing) and near neutral in pH. Depending on the disposal methods selected and the properties of the dredged material, changes in the physicochemical conditions at the disposal site may result in substantial mobilization of certain contaminants. Understanding the interaction between contaminants, dredged material properties, and physical, chemical and biological conditions at a proposed disposal site will permit selection of disposal methods that will minimize potential contaminant release in many cases. In aquatic disposal, dredged material remains water-saturated, anoxic, reduced and near neutral in pH. In contrast, when sediment is taken out of the water and allowed to dry in an upland site, it becomes oxic and the pH may drop. Nearshore disposal sites could have a combination of anoxic, reduced conditions below tidal elevation and oxic conditions in the dredged material placed above the tidal elevation.

There are several physical, chemical and biological processes that can result in transport of contaminants through a sediment/water environment. These mechanisms include:

- o diffusion of dissolved chemicals down a concentration gradient

- o convection and dispersion of dissolved chemicals due to water flow through the sediment (groundwater, precipitation, runoff, tidal action) and sediment consolidation

- o bioturbation of the sediment

- o scour and suspension of surface sediment particles by water and air currents

- o gas generation and ebullition within and through the sediment.

All of these mechanisms can be active in some of the disposal options, while only one or two may be active in others. Though there will be some active transport mechanisms operative in all disposal options, and none of the options will provide a permanent, complete isolation of the contaminants from the environment, environmentally sound disposal of dredged material can be achieved using any of the major alternatives if appropriate management practices and technologies are employed.

Three basic types of disposal are typically considered for contaminated dredged material: contained aquatic, nearshore (intertidal) and upland. Though nearshore/intertidal sites were identified and studied for the Navy project, these do not appear feasible at this time for environmental and economic reasons . Therefore, the discussion here will be focused primarily on the two types of disposal still under evaluation: contained aquatic and upland. To further clarify the analysis, dredging methods for each of these alternatives will be constant. Consequently, two basic approaches to dredged material disposal are discussed: mechanical dredging with contained aquatic disposal (CAD option) and hydraulic dredging with upland disposal (UP option).

The potential contaminant effects and pathways are quite different for each of these options. For the CAD option, mechanical dredge resuspension, barge transport leakage, sea surface microlayer releases, water column stripping, nepheloid layer (near bottom) losses and the animal effects and uptake that might be associated with the exposed mound of deposited sediment on the bottom (prior to capping), must all be considered. For the UP option, hydraulic dredge resuspension, volatilization, effluent releases, sea surface microlayer releases, runoff, leachate and animal/plant effects and uptake from the deposited sediment (prior to covering), must be considered. The importance of these are further addressed below.

CAD Option Pathways. Mechanical dredging generally results in greater resuspension of sediment at the dredging site than does hydraulic dredging. The action of the mechanical bucket through the water column results in resuspension estimated to be about twice the amount expected with hydraulic dredging (2% versus 1% mass resuspension). When compared to turbidity resulting from shipping activities and natural storms, and given the generally disturbed nature of many waterways where dredging occurs, resuspension at the dredging end is considered less important than potential effects elsewhere in the dredging and disposal process. The elutriate testing, discussed below, provides an assessment of the resuspended contaminants that might result at the dredging site.

Barge transport leakage, while conceptually possible, is not considered a major contamination pathway. Fine-grained sediments usually hold their moisture content; plus consolidation of the material in the barge will usually push water to the surface of the barge, not to the bottom. Of course, improper operation of the barge equipment (not ensuring a complete closure of the barge before loading) must be avoided.

The sea surface microlayer (SSM), consisting of the top 100 microns (um) (0.002 in.) of the sea surface, has been shown to contain increased numbers of bacteria, phytoplankton, and animal eggs and larvae. In addition, the SSM often concentrate materials that are not very soluble, are lighter than water, and/or are adhered to floatable matter and debris. These surface concentrations are a natural event, often comprised of chemicals derived from marine plants and animals. However, the SSM also has been shown to contain increased concentrations of contaminants, from 2-125 times higher metal concentrations and 100-1,000,000 times higher organics concentrations relative to subsurface waters. Once in the SSM, these contaminants can adversely affect marine eggs and larvae, and can be carried to nearby beaches. While solar and bacterial degradation of some of the contaminants occurs over time, the wind and surface currents often concentrate rather than disperse the surface materials.

Dredging and dredged material disposal.represent disturbances of the bottom sediments that also result in the release of fine particles and organic matter to the water column. Visible "slicks" and occasional "sheens" have been reported during dredging in the Elliott Bay area. Though most of the dredged material solids will settle to the bottom, most dredged material will contain some material that could float to the surface if released.

One reviewer of the DEISS noted that the PSDDA study had suggested that sea surface microlayer contamination during dredging activities would require assessment if the material were sufficiently contaminated to be considered "category 3 or 4." (See category 1.1 for further information on the PSDDA "categories.") As recommended by the PSDDA technical studies to date, an assessment of the microlayer contamination potential of the Everett Harbor sediments was conducted. Recently completed studies on the Everett Harbor contaminated sediments indicate that the fraction of the sediment metals and extractable contaminants found in the microlayer in experiments designed to simulate the dredging and disposal sediment disturbances varied between 0.01 and 0.02 percent. The less soluble contaminants, such as PCB's and pesticides, were not released in measurable quantities. Though additional biological testing is still under analysis, these data suggest that the bulk of the sediment contamination will remain associated with the sediment particles, and that the sea surface microlayer losses for the Everett Harbor sediments are not expected to be a significant loss.

As the discharged dredged material descends through the water column, the sediment mass can entrain water and particles can be "stripped" away. These water column losses can contain both dissolved and particulate-associated contaminants. Both losses have been assessed by use of the elutriate testing procedures. The fraction of the sediment contamination that is released into the dissolved state varies between 0.0 and 0.08 percent. Though the fraction loss is low, the actual concentrations associated with the dissolved fraction are evaluated by comparison to water quality criteria and background conditions. In the most severe case (PCB's), a dilution factor of 13 would be required to dilute the predicted dissolved concentration to the level of the criteria.

Several reviewers of the DEISS commented on the validity of relying on water quality criteria to assess the dredged sediments. They noted that assessing each contaminant indpendently did not allow for consideration of synergistic effects, and that water quality criteria did not necessarily protect against contamination of sediments and bioaccumulation of contaminants by aquatic species. They asked whether chronic effects could be adequately considered using the criteria, and whether the effects could be correctly labelled "temporary." One reviewer suggested that the use of dilution and mixing to achieve the criteria levels was not a legally valid approach.

Synergism cannot be addressed by use of the single chemical criteria. That was the reason for conducting biological tests on oyster larvae and bioluminescent bacteria (microtox) to assess the water column losses. These tests allow animals to "experience" all the contaminants present in the water, whether measured or not. Similar reasoning was behind the need to conduct benthic bioassays and bioaccumulation testing in order to assess direct sediment contamination pathways. Regarding chronic effects, both "chronic" and "acute" EPA water quality criteria were used in the analysis. While the actual long-term fate of released contaminants cannot be ascertained, the natural mixing and dilution, along with tendency for contaminants to work their way back into the sediment, suggest that adverse effects would not persist. This is supported by the fact that historic assessment of dredging projects, which emphasized the water column issues, have not shown significant adverse effects resulting from dredging projects. The sediment contamination chemically prefers to remain with the sediment particles.

All data from chemical analyses and bioassays using elutriated contamination (in water or suspended form) should be interpreted in light of mixing. This is necessary since biological effects (which are the basis for water quality criteria) are a function of biologically available contamianat concentration and exposure time of the organism. In the field, both concentration and time of exposure to a particular concentration change continuously. Both factors will influence degree of biological effect. There is ample precedent and substantive reference to dispersion, mixing and dilution in current law. The Clean Water Act specifies the consideration of effects, persistence, concentration, dispersal, rates, volumes, loads, and permanence of contamination and associated consequences in the establishment of standards and criteria (see sections 303, 304, 307, 403). The related Section 404(b)(1) guidelines define a "mixing zone" where standards will not be met initially, providing factors for determining acceptability of a needed zone, and requiring permitting authorities to consider mixing in evluating water column effects. Several of the water quality criteria are based on 96 hour "LC 50's," which require a mixing analysis to determine if a concentration will persist for that period of time. In addition, the State of Washington routinely prescribes dilution zones for dredging activities related to State water quality standards.

Particulate losses in the water column primarily occur near the bottom. These losses are predicted by use of disposal models and past information from other dredging projects. Some of the material released during water column descent will settle out in the disposal site. Some of it will drift off the site. This latter fraction is currently estimated at 1.9 percent of the discharged mass. (See related response 1.3 and further discussion below.)

The disposal mound, the deposited sediment, is estimated to contain over 95 percent of the material originally dredged from the Everett Harbor site. Having returned the material to a neutral, anaerobic geochemical environment will reduce the potential for contaminant release into the water column. But until capped, the material will still be exposed to animal contact and passive diffusion of surface contamination. Though in a similar state to that present in the waterway prior to dredging, the material would now be located in an area previously less directly exposed to that degree of contamination.

UP Option Pathways. As mentioned above, resuspension at the dredging site will be less with the hydraulic dredge than with a mechanical dredge. Since a hydraulic dredge uses water movement to move sediments, the suction forces generated by the pump will entrain much of the suspended material given proper operation of the dredge equipment. However, this efficiency advantage of hydraulic equipment results in the need to address added water and associated mobilized contamination at the disposal end of the process.

Transport of the dredge slurry typically occurs via pipeline. Though leakage at the pipe joints is common on routine operations, design features for transporting contaminated slurries will reduce this potential loss.

The greater degree of agitation provided by the hydraulic dredging process, including the initial discharge into the disposal site, can result in volatilization of certain contaminants to the air. This phenomenon is usually only a significant concern if the contamination is relatively volatile, which does not include the major types of contamination present in the Everett Harbor sediments. As the sediments dry out over time, contaminant losses to the air may increase. Changes in atmospheric pressure can "barometrically pump" air through the sediment mass and facilitate chemical losses. Aerobic degradation of the organic matter matrix that currently binds many of the chemicals will render additional chemicals mobile and subject to air loss. Again, the significance of this potential contaminant pathway is dependent on the type of contamination present. For the Everett Harbor material it is not anticipated to be an important pathway.

After most of the solids have settled in the disposal site, the dredge slurry water will be discharged back into the environment. This effluent can be a significant carrier of contamination, both dissolved and particulate-bound. The assessment of this potential loss was based on the results of the modified elutriate tests. Dissolved contaminants were either present at background levels, at or below water quality criteria, or, in one case, at levels that would require a small dilution zone to mix the concentration down to criteria levels. With upland disposal, determining whether the necessary mixing zone is acceptable can often be more of an issue than with aquatic disposal. This is because effluent discharge will normally occur in a smaller water body, with less dilution potential, and because the discharge is relatively continuous over the dredging project construction period (not discrete like barge disposal). The final determination of mixing zone acceptability is site-specific. The amount of contamination present in the particulate phase of the effluent is also site specific. This is because contamination is dependent on the amount of particles left in the effluent, and particle settling depends on the site configuration and discharge rate into the site.

Floatable contamination present in the effluent would be contributed to the sea surface microlayer. These losses could be more important than those associated with the CAD disposal option given the degree of disturbance resulting with hydraulic dredging. Though treatment of the effluent (discussed below) can significantly reduce the contaminant losses via the effluent, treatability of microlayer contamination in the effluent is not a subject that has been sufficiently researched to determine effectiveness.

Sediment consolidation will extrude interstitial water (mostly to the sediment surface). This water, combined with runon and precipitation water, ill result in site runoff, another potential carrier of contaminants. Site runoff is typically an issue during the initial dewatering of the disposal site. Assuming that a cover is eventually placed over the site, and that basic runon controls will be provided, long-term runoff problems can be minimized. As with effluent, contamination in the runoff is both dissolved and particle-bound. Unlike the effluent, longer-term geochemical changes due to oxidation in the upland site can render additional contamination mobilized and available for transport by water. Runoff tests were conducted on the Everett Harbor sediments to assess the significance of this pathway.

Related to surface runoff, contaminant effects due to plant and animal uptake can result if the dredged material is left exposed for sufficient period of time. Cover material, placed after initial dewatering is complete, will reduce both runoff and uptake losses.

Upland disposal can also result in leaching of the contaminants to the groundwater or back to surface waters (seeps). Based on the leachate tests conducted on the Everett Harbor sediments, the geochemical changes associated with aerobic disposal on land would result in mobilization of a large fraction of some of the contaminants. If the material could be placed under the water table at a given site (usually more of an option for nearshore/intertidal disposal), this mobilization would be significantly reduced. The leaching tests indicate that mobility of metals and organic contaminants is low under anaerobic conditions. Under aerobic conditions, some of the metals are mobilized in large quantities. The fraction of metals that was resistant to anaerobic leaching was generally greater than 90 percent of the bulk sediment concentration. Under aerobic conditions, over 85, 65, and 49 percent of the Zn, Ni and Cd was mobilized in the tests. This higher metal release observed in aerobic testing is related to pH: the pH in aerobic testing was lower than the pH in anaerobic testing. Recently available data from the leachate tests confirm the earlier assessments, as shown in Table 1.

TABLE 1

CONTAMINANT LEACHING CONCENTRATIONS
(mg/l)

Contaminant	Anaerobic	Aerobic	Federal/State Drinking Water Standards
As	.039	0.005	0.05
Cd	.010	0.034	0.010
Cr	.080	2.27	0.05
Cu	.096	0.023	1.0
Ni	.052	0.449	NA
Pb	.058	0.210	0.05
Zn	.181	3.5	5.0
PCB	.00036	0.00176	NA

The table shows that Cr and Pb predicted leachate qualities for the anaerobic disposal environment slightly exceed drinking water standards. In aerobic disposal environments, Cd, Cr and Pb would exceed standards by a substantive amount. Though the application of drinking water standard as criteria for the design of an upland site may not be appropriate for sites not in proximity to potable groundwater, these data clearly suggest that potential leachate losses would need to be addressed for the upland option.

Key Contaminant Pathways for the CAD and UP Options. Summarizing the above discussion, the key contaminant pathways that require consideration for the Everett Harbor sediments are as follows:

CAD: deposited mound
near-bottom mass release

UP: effluent releases
leachate releases

Though biological effects are the key to assessing the acceptability of potential contaminant releases, the mass release of contaminants cannot be directly or easily related to effects. This is because the fate of the released materials cannot be ascertained. This is true for both the CAD and UP options. Dispersion of the particle-associated mass releases will reduce concentrations and thereby reduce potential effects. At best, we know that far-field effects of particle-associated mass releases are not expected to exceed, and will likely be much less than, the original observed effects in the lab. For the dissolved fractions, released contaminants will be rapidly diluted to levels not associated with adverse effects.

For the CAD option, current estimates of the mass release at for the combined dredging and disposal are around 4.1 percent, split evenly between the dredging and disposal sites. Though the estimated mass release for the UP option depends on the specific site involved, releases for the upland or nearshore sites in the Everett Harbor area would vary from 4.3 to 5.5 percent. The primary differences between CAD and UP mass releases is the potential for using effluent treatment to reduce contaminant losses. Given the unknown fate of the releases, proper siting of the disposal site and reasonable management practices (including design and performance goals) are the primary tools for addressing mass releases. The fact that the bulk of the contamination still remains with the deposited sediments is also salient. Further discussion of mass releases is contained in Category 1.1 and 1.3.

Control and Treatment Options. Proper siting of a disposal site is the usual key to successful disposal of contaminated sediments. Once acceptable site locations have been found, any type of disposal site can be designed to confine contaminants acceptably. In other words, "acceptability" of a given design for contaminant control is partially independent of the site location. Certainly, the necessary and acceptable design will be greatly influenced by the site location and characteristics. These, in turn, influence cost of disposal and final selection of preferred disposal option.

There are many control and treatment options that could be applied at a specific disposal sites. Even though many of the technologies are not demonstrated or do not appear to be demonstratable in the near future, the number of feasible control and treatment alternatives needing evaluation still represent a reasonable number of choices. These major alternatives for restricting contaminant migration are discussed below.

The alternatives are ranked in order of increasing cost and contaminant management effectiveness. In other words, these ranks represent the general order in which they may be considered and applied in order to achieve acceptable design at any given site.

The development of schemes that address contaminant resuspension at the dredge must first consider the type of dredging operation, i.e., mechanical or hydraulic. Primary control and treatment alternatives addressing the resuspension at the dredge include:

- o Mechanical Dredging

    (1) Operational Controls
    (2) Operational Controls + Water Tight Bucket
    (3) Operational Controls + Water Tight Bucket + Silt Curtains
    (4) Hydraulic dredging

- o Hyraulic Dredging

    (1) Operational Controls
    (2) Operational Controls + Dredge Modifications
    (3) Operational Controls + Dredge Modifications + Silt Curtains
    (4) Special Purpose Dredges
    (5) Special Purpose Dredges + Silt Curtains

Primary control and treatment schemes that address the pathways of aquatic disposal include:

(1) Operation Controls
(2) Operational Controls + Downpipe
(3) Operatioinal Controls + Downpipe + Diffuser
(4) Lateral Confinement
(5) Capping
(6) Lateral Confinement + Capping

The development of schemes that address the surface water pathway must consider both short and long term contaminant release. Short term releases result from the discharge of effluents during active dredging operations, particularly hydraulic dredging operations. Long term releases result from: direct rainfall runoff, rainfall runon and subsequent runoff, and dredged material dewatering processes. Primary control/treatment schemes that address contaminant migration through the surface water pathway include:

- o Effluent (Short Term)

    (1) Collection and Treatment of Effluent
    (2) Mechanical versus Hydraulic Dredging

- o Runoff (Long Term)

    (1) Runoff/Runon Control + Cover
    (2) Runoff/Runon Control + Direct Rainfall Collection
    (3) Runoff/Runon Control + Cover + Direct Rainfall Collection

Primary control/treatment schemes which address contaminants released through the leachate/groundwater pathway include:

- o Runoff/Runon Controls
- o Runoff/Runon Controls + Cover
- o Runoff/Runon Controls + Single Liner
- o Runoff/Runon Controls + Cover + Single Liner
- o Runoff/Runon Controls + Double Liner
- o Runoff/Runon Controls + Cover + Double Liner
- o Runoff/Runon Controls + Cover + Single Liner + Leachate Collection
- o Runoff/Runon Controls + Double Liner + Cover + Leachate Collection
- o Solidification/Stabilization of Dredged Materials

Primary control/treatment schemes that address the plant$and animal uptake pathway include:

- o Site security
- o Chemical treatment
- o Covers
- o Site security + Covers

Primary control/treatment schemes that address the direct contact pathway include:

- o Site security
- o Covers
- o Site security + covers

Primary control/treatment schemes that address the air pathway include:

- o Covers
- o Buffer zones
- o Cover + Buffer zone
- o Solidification/Stabilization of Dredged Material

Disposal of contaminated sediments in the upland environment may produce contaminated liquids including effluent produced during active dredging operations, runoff water produced during initial dewatering and rainfall events, and leachate produced during initial dewatering and subsequent rainfall events. Six levels of treatment for site waters can be identified as follows:

Level I is the removal by sedimentation of suspended solids and particulate-bound contaminants from disposed and site-derived water. This level would remove 99.9 percent of solids, 80-99 percent of heavy metals, and 50-90 percent of organic contaminants.

Level II is additional treatment to remove soluble metals. This level would increase heavy metals removal to 99 percent.

Level III is treatment to remove soluble organics. This level increases organics removal to 95 percent.

Level IV is treatment to remove nutrients such as ammonia and phosphorus.

Level V is treatment to remove dissolved solids. This level would increase organics removal to 99 percent, but is primarily designed to remove nonmetallic, inorganic contaminants (e.g., nutrients and common anions).

Level VI is disinfection for destruction of pathogenic organisms.

Disposal sites represent chemical gradients from high contamination levels within the site to lower levels outside the site. These gradients naturally tend to drive contamination out of the site. Factors affecting the rate of movement include the solubility of the chemicals (all chemicals are soluble to some degree), the geochemical condition of the sediment matrix (aerobic or anaerobic), and physical forces (such as water and air movement in and around the sediment mass).

Consequently, there is no permanent confinement, no technology that is guaranteed to work in the long term. CAD capping material and upland liners will, over the long term (decades or longer), become saturated with moving chemicals. Even water treatment technologies, such as chemical clarification or more intensive methods, do not completely remove contaminants. Additionally, most treatment technologies result in "spent" or concentrated, contaminated materials that must be disposed of elsewhere. Technology for upland disposal sites is much more developed and proven than for CAD sites. On the other hand, chemical mobility and geologic stability favors aquatic sites. In either case, the consequences of technology failure must be weighed, and long term potential releases should be considered. This again emphasizes the importance of proper site selection.

Available Remedial Action Techniques. There are two types of remedial responses that can be utilized in the dredging and disposal of contaminated sediments. During the construction phase, contingency plans (short-term remediation) will specify how unexpected events will be addressed to prevent uncontrolled release of contaminants. In the longer term, remedial response is an integral part of the monitoring plan at the disposal site. Monitoring data are used to determine when remedial actions are needed and what they should be. (See category 1.3 for discussion of the monitoring plan.)

For the CAD option, the placement of additional or different capping materials is the primary method for remediation. One reviewer of the DEISS questioned how more material could fix a problem that the original cap could not handle. The response to this comment is best understood by considering an assessment of the possible reasons for failure of the original cap. These reasons include:

- incomplete original capping (or inadequate thickness)
- unexpected animal or human bioturbation
- unexpected physical erosion or geologic disturbance
- through-cap diffusion of chemicals
- ebullition (gas formation) and cap disruption

Of these five possibilities, the first three are more likely possibilities than the latter two. These three are effectively addressed by adding more cap material. Through-cap diffusion is a very slow process. Ditoro estimated PCB movement through sediment caps to be less than 1 cm per year (or 100 years for a 100 cm cap). This diffusion rate can be easily monitored via cap coring and analysis (sand caps are self healing after coring). More cap material can effectively continue to prevent release of the contamination. Ebullition can result in gas-transported contaminant loss, but is greatly reduced in anaerobic environments relative to aerobic ones. Any physical cap disruption can be repaired by more cap material. Again, the key to this activity is an effective monitoring program.

Though not expected to be necessary, different cap materials can be brought to the site to improve thickness, provide resistance to erosion, reduce permeability, etc., as needed.

Remedial response at upland sites is much more diverse. Once the site has been completed, typical monitoring includes leachate and runoff quality measurements. Assuming runon controls and surface covers are in place, and gas formation is not a major issue, the emphasis in the long-term is ground water and surface water seeps. Sites can be designed to include second liner systems and leachate collection drains, though these types of designs are usually specified for more dangerous and hazardous waste. With these systems, leachate can be monitored, collected and treated, as necessary. Without these systems, leachate loss into the groundwater is difficult to remediate, at best, and may often be impossible. Rates of ground water movement and frequency of the monitoring measurements are important factors here. Longevity of these underground systems is also dependent on geologic stability of the area.

Disposal Site Tradeoffs Analysis. As noted above, the "acceptable" design for a given site is not necessarily dependent on an analysis of several sites with varying design. Given enough money and time, any site can be designed to acceptably contain contaminated sediments. Consequently, there is "technically" no best option from the perspective of contamination confinement, the keys are usually site availability and costs of necessary design to achieve acceptability. Considering siting issues without regard to design is a logical first step (i.e., what resources are at risk?). At the heart of this siting decision is the weighing of very different types of resources and conditions present at the different types of sites. Socioeconomic and political considerations play major roles in this weighting.

The consideration of the adverse effects associated with the sediment in place in the waterway (in situ effects) is often useful as a reference in determining acceptability for the design at different sites. The sediments in Everett Harbor currently represent an area impacted by contamination and reduced dissolved oxygen levels. Biological value of the area is relatively low as a result. Final conditions that would exist in the disposal sites should be considered in relation to pre-project conditions. While the dredging project would relocate and isolate this material to other areas not currently exposed to this degree of contamination, conditions within the harbor are expected to improve. This comparison to existing conditions was done as part of the "no action" alternative analysis in the EIS.

The key considerations involved with disposal method effectiveness are:

- the class of contaminants of concern,
- the similarity of the disposal site condition to in situ conditions,
- the number and magnitude of contaminant transport mechanisms operating at the disposal site,
- the degree of control or treatment possible to intercept migrating contaminant fractions, and
- the risk of significant adverse effects from contaminants released by the disposal method.

Heavy metals often will go into solution and become mobile in oxidized, unsaturated sediments (e.g., in an upland site). Organic contaminants tend to remain partially soluble regardless of how wet or dry the sediment stays. Therefore, they will have greater mobility where greater exchange of water within the sediments occurs. Nearshore sites have greater water exchange than upland, and upland has greater exchange than open water.

In general, leaving, or disposing of, contaminated sediments in a chemical environment as close as possible to their in situ state favors retention (especially metals). Geochemical changes associated with air and oxygen in upland and nearshore sites can change sediment pH (mobilizing metals) and alter (dissolve, degrade, or volatilize) sediment organic carbon (mobilizing organics). Based on this, many contaminants would tend to stay bound to sediments better in an open-water, capped site than a nearshore or upland site.

Open-water sites, especially those in deep water, have fewer transport mechanisms (e.g., air is absent) than upland sites. Nearshore sites have the most transport routes available and are located in a very active environment; therefore, nearshore disposal is the least preferred method for long-term confinement of contaminants.

In terms of controlling contaminant release, open-water disposal allows for very few controls of releases other than cap thickness. However, increasing cap thickness is a relatively simple and effective control method. Upland disposal, on the other hand, allows for the greatest control through design features, monitoring capabilities, backup contaminant intercept systems, and treatment facilities.

Mass releases will occur at several phases of the project and at all types of disposal sites. The mechanical/CAD option will have losses at the dredging site, during transport, to the microlayer, during water column stripping, to the nepheloid, and prior to and during capping. The hydraulic/upland option will have releases at the dredging site, from pipeline joints during transport, to the air upon discharge to the site, in the effluent, via the leachate and prior to and during covering operations (runoff), if included. Different controls and treatments can assist in reducing these releases. Since the fate and effects of these released contaminants is unknown, the conclusion is that reasonable management practices are needed in direct relation to nearby resources that might be at risk, that is, mass releases are substantively addressed by proper site location. Additional technology can be utilized as necessary.

The factors that differ between the basic options of CAD and upland are shown below. The arrows indicate the site type that is favored by the factor.

CAD		UP
----▷	technology remediation monitoring	----▷
----▷	mass release with treatment	---▷
----▷	marine water quality	---▷
----▷	aquatic animals/habitat	----▷
<----	terrestrial animals/habitat	<----
<----	human exposure	<------
<----	groundwater	<-----
<----	geochemistry/mobility	<----
<----	project cost with treatment	<----
<----	high energy potential	<----
<-----	project time	<----
<----	volatilization	<----
<-----	dilution buffer	<-----

In summary, assuming that effluent treatment is conducted at the upland site, the CAD option represents a situation of higher short-term mass releases, but has opportunities for longer-term control due to lower mobility of chemical contamination. On the other hand, the upland option relies more heavily on technology, has less short-term mass releases, but greater long-term concerns due to mobilized contamination (and the very steep chemical gradients that result) and the active physical forces that can move contamination.

In the comparison of sites (which is ideally done without specified design alternatives for contaminant confinement), the relative value of resources, the ascribed importance of costs and time relative to risk amelioration, and the favoring of either technology (upland site approach).

Category 1.2, Disposal Alternatives Analysis. Upland disposal alternative, incorporating hydraulic dredging, has the greatest potential to reduce mass release.

Response. Upland/nearshore alternatives would have the greatest "potential" to reduce mass release. Note that the three intertidal alternatives evaluated in Appendix B of the draft EISS had total mass release of between 4.3 and 5.5 percent. For intertidal alternatives, addition of chemical clarification would effectively limit the mass release. For upland alternatives, clarification and controls for leachate would likely be required. Controls for leachate will significantly add to the cost of disposal.

Category 1.2, Disposal Alternatives Analysis. All alternatives are not objectively discussed. Assessment of CAD feasibility and impacts questioned.

Response. WES evaluations were made using a Management Strategy based on 15 years of intensive research on dredging and disposal. CAD, intertidal, and upland alternatives, especially the potential contaminant pathways associated with each alternative, were evaluated. The evaluations are based on results of testing protocols designed especially for dredged material disposal, not conjecture or opinion. Further, considerably more resources were expended on the intertidal/upland evaluations than were expended on the CAD evaluation. Appendix B of the draft EISS presents the results of the testing and evaluations.

Category 1.3, Design and Monitoring. CAD has not been attempted at proposed depths. Accuracy and reliability of the dump model predictions are questionable because stripping loss and resuspension from previous dumps is not accounted for comparison of loss with reported values from Duwamish and New York Bight.

Response. While it is true that CAD has not yet been attempted in over 100 feet of water, the field work of Yale University under the DMRP found that the same placement processes during open-water disposal occurred in depths ranging from about 60 to 220 feet. Therefore, we feel that the present work is more an extension of existing technology than new technology.

Regarding nonverification of the model, Dr. Al Wastler, EPA HQ Ocean Disposal, states that the Koh-Chang model (guts of the WES model) is certainly a valid model if not the most valid model currently available for these evaluations. EPA is considering its use for evaluation of ocean disposal of sewage, sludge, and other wastes in addition to dredged material disposal.

Although the models do need additional field verification, a wide range of data collected by Yale verified that the models do compute the proper behavior of dredged material disposed at open-water sites. In these field studies, water depths ranged from 60 to 220 feet and dredged material included dense, cohesive silt-clay dug with clamshell buckets as well as sand and dilute silty material from hopper dredges. The quantities released ranged from 30 to 6,000 c.y. In all cases, Yale observed that less than 1 percent was stripped from the descending cloud. Within a few minutes about 95 percent of the material had settled to the bottom within a radius of a few hundred feet, e.g., a 500-600 foot radius. The maximum thickness of the bottom surge was about 15 percent of the water depth in all cases. Thus, for a depth of 265 feet, as was modeled for the Everett Deep Delta Site, the maximum thickness of the collapsing cloud on the bottom would be about 40 feet. Assuming the worst case of particle settling of 0.0017 f.p.s. yields a time of about 23,500 seconds required for the remaining 5 percent to be deposited. In a 4,000 by 4,000-foot site, with the dump at the center, and bottom current of 0.1 f.p.s., a time of 2,000 seconds would be required to transport a particle out of the site. Thus, an additional 3 to 4 percent of the material will be deposited within the site, leaving 1 to 2 percent that will be transported out. This is exactly what the model tells us for the Everett case.

Regarding resuspension from previous dumps, it is true that the model does not account for this behavior. However, the capping material will hydraulically be disposed to generate a "raining" effect. The capping process was modeled as a series of small clouds, and the model indicated that bottom impact velocities will only be about 0.5 f.p.s. Since the contaminated material will be disposed in a clumped condition and will have experienced some consolidation an impact velocity of 0.5 f.p.s. should not cause a problem. Even if a small amount of the material is initially resuspended it will quickly settle and will be draged back to the bottom by the continuous supply of capping material. Therefore, there will be no release of contaminated material as a result of placement of the cap material.

Regarding the capping project in the Duwamish River, material releases quoted by Truitt (1986) of 7 to 15 percent cannot be directly compared with releases quoted in the Everett reports. Truitt was interested in the percentage of material which would not settle to the bottom within the footprint of the depression used for the Duwamish demonstration which was approximately 100 by 150 feet. He established a cylindrical control volume described on page 29 and 30 of his report. The 7 to 15 percent release quoted by Truitt refers to that portion of the disposed material which was transported outside the control volume, not the portion of the material remaining in suspension after 1,800 seconds as in the Everett report. Most of the material in the Duwamish demonstration dump settled within a short distance of the depression. The processes acting at the Duwamish site are similar to those which would act at the Everett site and the mass of materials which could be considered as a true release would be similar.

Operations in the New York Bight reported by O'Conner involved a mixture of projects with differing sediment types and dredging and disposal methods. We are not certain what the 4 percent figure refers to, but releases during disposal of softer clay-like sediment could be within this range. Note that the Everett sediment contains a significant fraction of sand and chips with very efficient settling properties. It is reasonable to expect lower releases for the Everett material, even with the deeper water depths.

In fact Port Gardner several major advantages over many of the previous CAD sites which were located in relatively shallow open ocean conditions. Because the disposal site at Port Gardner is located in deep protected water it is not subject to scour by large waves, or to erosion by high speed tidal currents. The surrounding land mass also facilitates placement of instruments which will allow extremely precise positioning for disposal and monitoring operations.

Category 1.3, Design and Monitoring. Actual mound spread is unknown.

Response. Estimates of mound spread have been made using conservative assumptions. The extent of mound spreading as given in the WES reports is different from in the Navy's proposed design because the WES estimate assumed that no confining berm would be constructed.

Category 1.3, Design and Monitoring. Increasing the water depth increases the size of the disposal site, hence increases environmental impacts and reduces capping effectiveness.

Response: The overall site size is not affected signficantly by the material deposited from any single barge load of material, but is governed by the cumulative effect of many disposals. Disposal model data indicate that the vast majority of the material from each disposal will be deposited on an area approximately 1,000 feet in diameter, or about 20 acres. The overall size of the disposal site is governed by the amount of material being placed, sediment bulking factors, material characteristics that govern stable side slopes of the disposal mound, effects of bottom slopes, and settlement characteristics. Water depth affects only the initial area of deposition from an individual dump. This area would increase slightly with an increase in water depth, but this increase would not affect the overall site size. A sensitivity analysis indicates that, even if the deposition area for each disposal is doubled to 40 acres (1,400-foot diameter), the change in overall site area and the cap thickness would be negligible.

Category 1.3, Design and Monitoring. Port Gardner is subject to currents due to tides and river outflow that would distribute contaminated and cap material during disposal.

Response: Contaminated material will be clamshell dredged and disposed by bottom dump barge. Upon disposal, the material leaves the barge and descends through the water column at a high rate of speed, typically 10 feet per second. Therefore, the material spends little time near the surface and rapidly reaches the bottom area where tidal currents are extremely low and out the influence of the Snohomish River is no longer felt. Accurate placement of this capping material would require monitoring of current speeds in the vicinity of the disposal operation.

Category 1.3, Design and Monitoring. What would be the effect of earthquakes on CAD?

Response: Numerous earthquakes have occurred in the Puget Sound seismic province during historic times, the largest of which have recorded Richter magnitudes greater than 7.0. During a major earthquake there is potential for underwater landsliding of the deltaic sediments at the CAD disposal site. Underwater topography at the site suggests that some sliding has occurred in the past, probably due to the build up of an oversteepened base in the submarine delta. Sliding could take many forms; however, in a worst case scenario a liquifaction flow slide could involve the contaminated disposal materials.

Category 1.3, Design and Monitoring. Monitoring needs.

Response: Any contained disposal operation involving contaminated sediments must be considered a complex, somewhat inconventional activity due to the potential risks to the environment and public in the event of mistake or failure. Although there is greater familiarity with nearshore and upland confined disposal, the need for sound engineering and appropriate construction techniques applies equally to these options as for contained aquatic (CAD). Monitoring will be necessary during the dredging and disposal operations to determine the effectiveness of performance whether upland, nearshore, or CAD is used. Key parameters that would be monitored for the project if permitted have been identified in the draft EISS and appendixes. Final monitoring plans, based on final project designs, will be prepared and coordinated with appropriate state and Federal agencies.

Category 1.3, Design and Monitoring. Environmental impact of 5 percent or more mass loss would be critical concern.

Response. Mass contaminant loss has no direct correlation with environmental impact.

Category 1.3, Design and Monitoring. Mass loss may be higher than estimated, displacement during capping not considered, shallower capping operations have shown higher loss, and model is not field verified..

Response. Estimates of mass release have been made using the best available technical approaches. Further, in estimating the mass release, the most conservative approach and assumptions have been made. For example, the mass release estimate treats the entire volume of sediment "dredged as contaminated" as truly contaminated sediment. In reality, a significant portion of the "dredged as contaminated" sediment is clean native sediment. Estimates of mass contaminant rerlease are based on mass sediment release, and the estimated mass contaminant release is therefore conservative. Secondly, the mass release during dredging assumes that all sediment resuspended is released. This is a conservative assumption since a large portion of this material will resettle to the bottom with a short distance of the dredging operation and could be "redredged". Thirdly, the estimates of mass release during placement as determined by the disposal modeling assume that material remaining in suspension after 1,800 seconds is a release. In reality, a large portion of this material will later settle to the bottom within the disposal site and will be capped.

Displacement of the contaminated material on the bottom during cap placement will be insignificant because of the technique employed to place the cap. The capping material will be hydraulically dredged (or hydraulically off-loaded from barges) and will settle as discrete particles, gradually building up the cap. Since no "clumps" of cap material will impact the mound, no displacement due to impact will occur. Spreading of the contaminated mound due to buildup of the cap will be controlled by moving the discharge pipe for the capping material so as to spread the cap in thin lifts.

Category 1.3, Design and Monitoring. If capping is found to be ineffective, placement of additional cap material in isolating contaminats is uncertain.

Response. Application of technically appropriate testing protocols has determined the required cap thickness to isolate the contaminated material. The only way in which capping could be ineffective is an insufficient cap thickness. Application of additional material, although adding direct cost to the project, would prove an effective remedial action.

Category 1.3, Design and Monitoring. Cap thickness can vary, and availability of clean material would be a problem if spread is more than anticipated. .

Response. Cap thickness should be closely monitored during placement so that adjustments can be made using the available native sediments. If spreading is greater than anticipated, and available native sediment from the project is not sufficient to cap, the only option is to use additional cap material from other sources.

Category 1.3, Design and Monitoring. Effectiveness of monitoring is not known, and monitoring will be expensive.

Response. A monitoring plan for the CAD alternative has been proposed in the WES report. The accuracy of the techniques available for monitoring should be recognized. However, the available techniques should be sufficient to determine if cap placement is adequate. Use of REMOTS and other techniques to supplement hydrographic information has been proposed. The cost of monitoring will be significant.

The issue of long-term monitoring should be carefully considered. The sites proposed for CAD are generally in accretive areas. If the cap is shown to be effective initially, there may be little reason to continue monitoring for the long-term. In all cases, the anticipated use of data from any program should be established prior to the monitoring.

Category 1.3, Design and Monitoring. Additional capping is the only remedial option for CAD.

Response. Concur that placement of additional cap material is the only practical remedial measure for the CAD alternative.

Category 1.3, Design and Monitoring. Only long-term monitoring would confirm the accuracy of leachate preditions.

Response. Comment noted.

Category 1.3, Design and Monitoring. Ground water studies are required to evaluate the upland alternative and the need for a liner system must be determined.

Response: Ground water conditions must be determined for upland site design, especially if contaminated material is placed above the water table. However, a liner is only one of several control options which could be considered. A generic evaluation of leachate for upland alternatives based on recently completed testing is given in a recently comleted technical supplement to the WES studies.

Depending on the site selected and site conditions, contaminated dredged material may be placed in a upland site above or below the water table. If contaminated material is placed below the water table, the leachate characteristics may be estimated using anaerobic leaching test results. Leachate from material placed above the water table may be estimated using aerobic results. Results from the leachate tests are summarized in table 2.

Since anaerobic leaching data for Pb and Cr exceeded the drinking water water standards, a regional authority decision (RAD) may require some type of control to prevent any contaminant migration from material placed below the water table because of the possibility of deterioration to potential receptors. If the RAD determines that a control would be warrented, several control options are available. The site may be lined with a synthetic or natural liner. A capping system to prevent infiltration could also be installed in concert with the liner. Leachate collection and treatment in place of lining and capping could also be considered; however, Cu and Pb concentrations from the leaching tests are increasing over time which would necessitate long-term operation of a leachate collection and treatment system and the associated long-term expense of operation and maintenance. In-situ stabilization of the sediments after disposal could also be considered as a remedial measure should contaminant release increase in the future. Stabilization during disposal operations to fix the entire slurry mass or chemical admixing to contain specific contaminants are possible control options; however, any solidification/stabilization process would be expensive.

Aerobic leaching data indicate that Cd, Cr, and Pb exceed the drinking water standard by a much greater margin than the anaerobic test results. This may require a more extensive control measure for contaminated material placed above the water table than would be required for material placed below the water table. Again, site specific conditions would dictate which type of control measure would be necessary. The possibility of a ground water mixing zone to provide the necessary dilution may be possible. Also a shallow configuration for the containment area would make the installation of a liner a more viable control option.

Depending on the size of the containment area, the amount of material to be dredged, and the site conditions, a practical disposal scenario would be to place the contaminated material below the water table, where the material would remain anaerobic thereby releasing less contaminants. Cleaner material used as a surface cap could be placed above the water table.

TABLE 2

CONTAMINANT LEACHATE CONCENTRATIONS (mg/l) FOR FLUX ANALYSIS

Contaminant	Anaerobic	Aerobic
As	0.039	0.005
Cd	0.010	0.034
Cr	0.080	2.27
Cu	0.096	0.023
Ni	0.052	0.449
Pb	0.058	0.210
Zn	0.181	3.5
PCB	0.00036	0.00176

Category 1.3, Design and Monitoring. A complete discussion of control procedure should be added (for effluent and leachate).

Response. Discussions of effluent controls are given in Part IV of Appendix B of the draft EISS. Detailed discussions of settling test results and testing for addition of flocculents are presented in Appendix E and F of Appendix B of the draft EISS. These discussions generally apply to both upland and nearshore alternatives. Controls for leachate are also discussed in Part IV of Appendix B of the draft EISS and additional information will be available in a technical supplement to that document.

Category 1.3, Design and Monitoring. A standard for effluent discharge should be set and appropriate flows and controls to confined sites should be implemented to meet the standards.

Response. Comment noted. The intent of the information in Appendix B of the draft EISS was to determine the feasibility of using representative intertidal sites.

Category 1.3, Design and Monitoring. Appropriate monitoring plans and accuracy of monitoring should be agreed upon with all concerned agencies.

Response. Comment noted. Accuracy of the monitoring techniques will of course vary depending on the approaches used and site conditions. The limitations of monitoring should be recognized at the outset. What constitutes "failure" for any alternative should be carefully considered. For the CAD alternative, available monitoring techniques can determine if adequate cap thickness has been applied.

Category 1.3, Design and Monitoring. Why is Indiana Harbor sediment an atypical example for leachate testing and how do the results compare with Everett?

Response. Indiana Harbor sediment is highly contaminated with PCB's and contains an unusually high oil content. Results for the Indiana Harbor leaching tests will be available in 1987.

Category 1.3, Design and Monitoring. Discussion of sediment stabilization should be included under sections on surface runoff and leachate.

Response. Discussion of sediment stabilization for control of leachate is presented in Appendix B of the draft EISS. Similar approaches could likely be employed for control of surface runoff, although placement of clean surface cap would be more cost effective.

Category 1.3, Design and Monitoring. Separate release rates for confined sites with chemical clarification suggested.

Response. Separate release rates for chemical clarification would depend on the site-specific design of the chemical clarification system. Design of such a system can be accomplished once a given site configuration and dredge flowrate is selected.

Category 1.3, Design and Monitoring. Synergistic effects not considered in elutriate tests.

Response. The elutriates tests do not measure toxicity. They are used to predict water quality for various disposal conditions.

Category 1.3, Design and Monitoring. Monitoring programs have not been specifically proposed.

Response. Monitoring plans for both the CAD alternative and confined intertidal or upland alternatives are given in Appendix 1 of Appendix B of the draft EISS.

Category 1.3, Design and Monitoring. Water content of contaminated sediment cannot be related to parameters used in the dump model.

Response. The disposal model does account for the water content of the materail disposed. A conservative estimaste of 250 percent was used in the modeling runs, considered representative of the upper layers of the contaminated material. Since most of the material "dredged as contaminated" will be removed at much lower water content, the model runs are conservative estimates of behavior during disposal.

Category 1.3, Design and Monitoring. Contaminated sediment resuspended during debris removal should be considered.

Response. If debris is removed during the dredging operation (i.e., large debris separated and placed into a separate barge), the resuspension is accounted for in the estimate for clamshell dredging (2 percent). If debris is removed as a separate operation it should be separately discussed.

Category 1.3, Design and Monitoring. Wood chip behavior not considered in model parameters.

Response. Wood chips were considered as a separate solids fraction in the modeling runs.

Category 1.3, Design and Monitoring. Differences in bottom areas impacted and influence of confining berm should be explained.

Response. The area impacted as quoted in the Appendix B of the draft EISS is intended as a conservative estimate assuming no confining berm. It was stated that other configurations for the CAD site were possible, to include use of a confining berm. The smaller area quoted in the draft EISS is based on an assessment by the Navy's A-E team and considers the influence of a confining berm. If a confining berm is constructed using clamshell dredging and bottom-dump from barges, the overall effect of the berm will be to reduce the area of impact, not increase it. The reference to a June 1986 statement by the Corps that the berm would increase the area impacted is either a misinterepretation or possibly a typographical error.

Category 1.3, Design and Monitoring. How can cap thickness and determinations of irregularities be monitored?

Response: Coring of the completed CAD in a number of locations, using piston or vibracore, will provide adequate information. This technique has been successfully employed at other CAD sites (e.g. Duwamish).

Category 1.3, Design and Monitoring. The justification for eliminating the downpipe is questionable since the elutriate tests used questionable reference water sample.

Response: Elimination of the downpipe was not based on a strict comparison to reference water. The purpose of the downpipe was: (1) to isolate the descending material from the the surrounding water column and thereby limit water quality impacts, and (2) to increase accuracy of placement of the material on the bottom. Comparison of elutriate results to Federal Water Quality criteria showed that very little release of contaminants in dissolved form occurs. Greater than 90 percent of the contaminants remained bound to the sediments. The low releases would be diluted at least to the reference background within a very short distance of the disposal site. Such dilution could be expected within a normal mixing zone typically stipulated by the resource agencies and which would be necessary for conventional water quality parameters (e.g. dissolved oxygen). Additionally, while the dump model indicated accurate delivery of the material was possible, other analyses indicated that the material, in descending through the downpipe, would arrive at the bottom in a slurried state that would not possess the structural properties to support the cap. This defeats the whole purpose of the CAD.

Category 1.3, Design and Monitoring. What confidence is there that the barges will actually be point dumped?

Response: Point dumping from a stationary barge will likely be a regulatory requirement as well as a design requirement. Tautline bouys or electronic positioning are two methods of assurring accurate disposal. CAD, it must be emphasized, is not equivalent to the more common open-water disposal operation, but is an engineered construction project. Careful monitoring will be needed throughout the construction to assure performance. Construction inspection by regulatory agencies is also anticipated.

Category 1.3, Design and Monitoring. Ability to place an even cap thickness is questioned.

Response. The approach proposed for the Everett project (hydraulic placement in thin layers to gradually build up the cap) is the best method for uniform placement. It is true that tides and winds act at the Everett site, but they are also present in all marine environments. Dredging and disposal equipment is available which can operate safely and effectively for this project.

Category 1.3, Design and Monitoring. Additional cap material may not be effective if the original cap fails.

Response. The only identifiable reason for cap failure is insufficient cap thickness. For this condition, additional cap material is an appropriate remedial measure.

Issue 1.4, Smith Island. Additional ground water studies are needed to determine site acceptability.

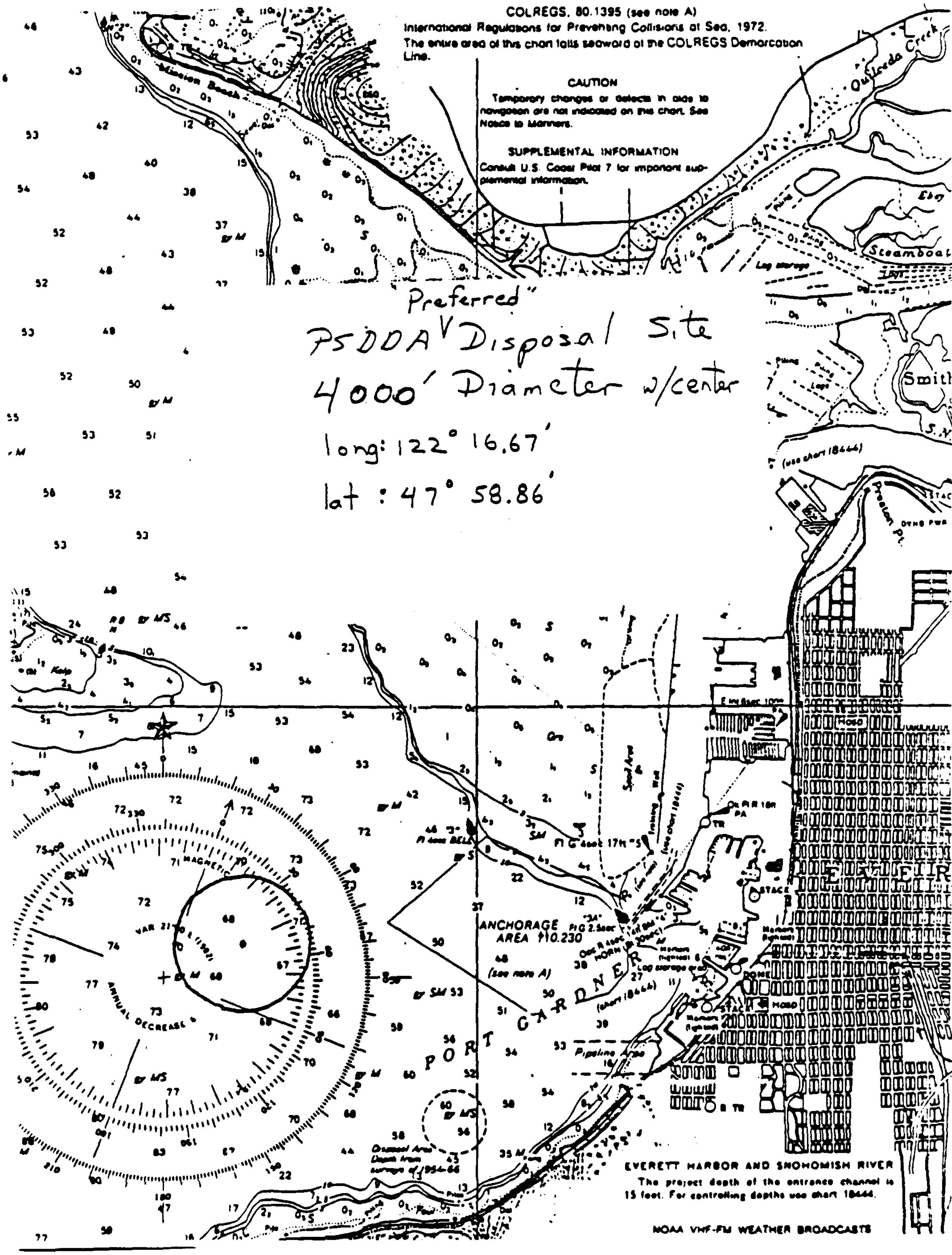
Response: Studies would be required to determine ground water levels as well as directions and velocities of underground flow. Ideally, this would require the installation of numerous open tube-type piezometers around the perimeter, and within the site, and monitoring through at least a full year prior to dredge disposal in order to determine background condition, followed by long-term monitoring. Ground water samples would be periodically taken from piezometers and tested for contaminants. There might also be a need for pumping tests and/or tracer studies to aid in determination of permeabilities and flow directions.

Category 1.4, Smith Island. Potential flood zone hazards need to be evaluated.

Response: Smith Island has been evaluated under the National Flood Insurance Program as part of the Snohomish County Flood Insurance Study, dated September 5, 1983, and is identified as a flood hazard area. The 100-year flood elevation at Smith Island is 9 feet above National Geodetic Vertical Datum (NGVD). Existing levees at Smith Island are inadequate to protect against seepage and overtopping during a 100-year frequency flood. A new levee system must be designed and constructed to protect the contaminated fill from flooding. Adequate freeboard should be included in the levee design.

Category 1.4, Smith Island. Smith Island appears to be the best disposal alternative.

Response. There is insufficient technical data available on the Smith Island site to determine if its use is feasible.


COLREGS, 80.1395 (see note A)
International Regulations for Preventing Collisions at Sea, 1972.
The entire area of this chart falls seaward of the COLREGS Demarcation Line.
CAUTION
Temporary changes or defects in aids to navigation are not indicated on this chart. See Notice to Mariners.
SUPPLEMENTAL INFORMATION
Consult U.S. Coast Pilot 7 for important supplemental information.
"Preferred"
PSDDA Disposal Site
4000' Diameter w/center
long: 122° 16.67'
lat : 47° 58.86'
Mission Beach
Steamboat
Smith
Preston Pt.
ANCHORAGE AREA 110.230
(see note A)
PORT GARDNER
Pipeline Area
Disposal Area
EVERETT HARBOR AND SNOHOMISH RIVER
The project depth of the entrance channel is 15 feet. For controlling depths use chart 18444.
NOAA VHF-FM WEATHER BROADCASTS

APPENDIX F

FALL CRUISE REPORT

U.S. NAVY HOMEPORT DISPOSAL SITE INVESTIGATIONS

Fall Cruise Report

by

Paul Dinnel, David Armstrong, Bruce Miller and Robert Donnelly
School of Fisheries and Fisheries' Research Institute
University of Washington, Seattle

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For

Seattle District, U.S. Army Corps of Engineers
Seattle, Washington

Introduction

The East Waterway within the Port Gardner region of Puget Sound has tentatively been selected as a new homeport by the U.S. Navy. Construction of the facility will require dredging of the East Waterway and the possible disposal of dredged materials at a deep-water site in Port Gardner.

The U.S. Navy in conjunction with the U.S. Army Corps of Engineers (COE) has provided funds to the University of Washington School of Fisheries to conduct trawling studies of the proposed disposal site with special emphasis on Dungeness crabs, Cancer magister, commercial shrimp and bottomfish resources.

This report summarizes the preliminary findings of the fourth set of trawl cruises conducted in Port Gardner during September, 1986 and compares these data to that collected during the February, April, and June 1986 cruises.

Methods

The methods, trawl gear and sample stations were described in detail in the winter, spring and summer cruise reports (Dinnel et al. 1986a, b, c) and remain the same except for the following three additions: 1) two additional beam trawl stations (E and F; Figure 1) were added southwest of the original proposed Navy Disposal Site to increase the sampling coverage in this region; 2) two beam trawl stations (G and H; Figure 1) were added just east of Control Site 2 for increased sample coverage; and 3) seven trawls were made south of Port Gardner between Mukilteo and Picnic Point (see Figure 7 in the Results section for station locations) to help define the southward range of the female Dungeness crab concentrations observed in Port Gardner.

Briefly, crab and shrimp were sampled at 63 stations in Port Gardner with

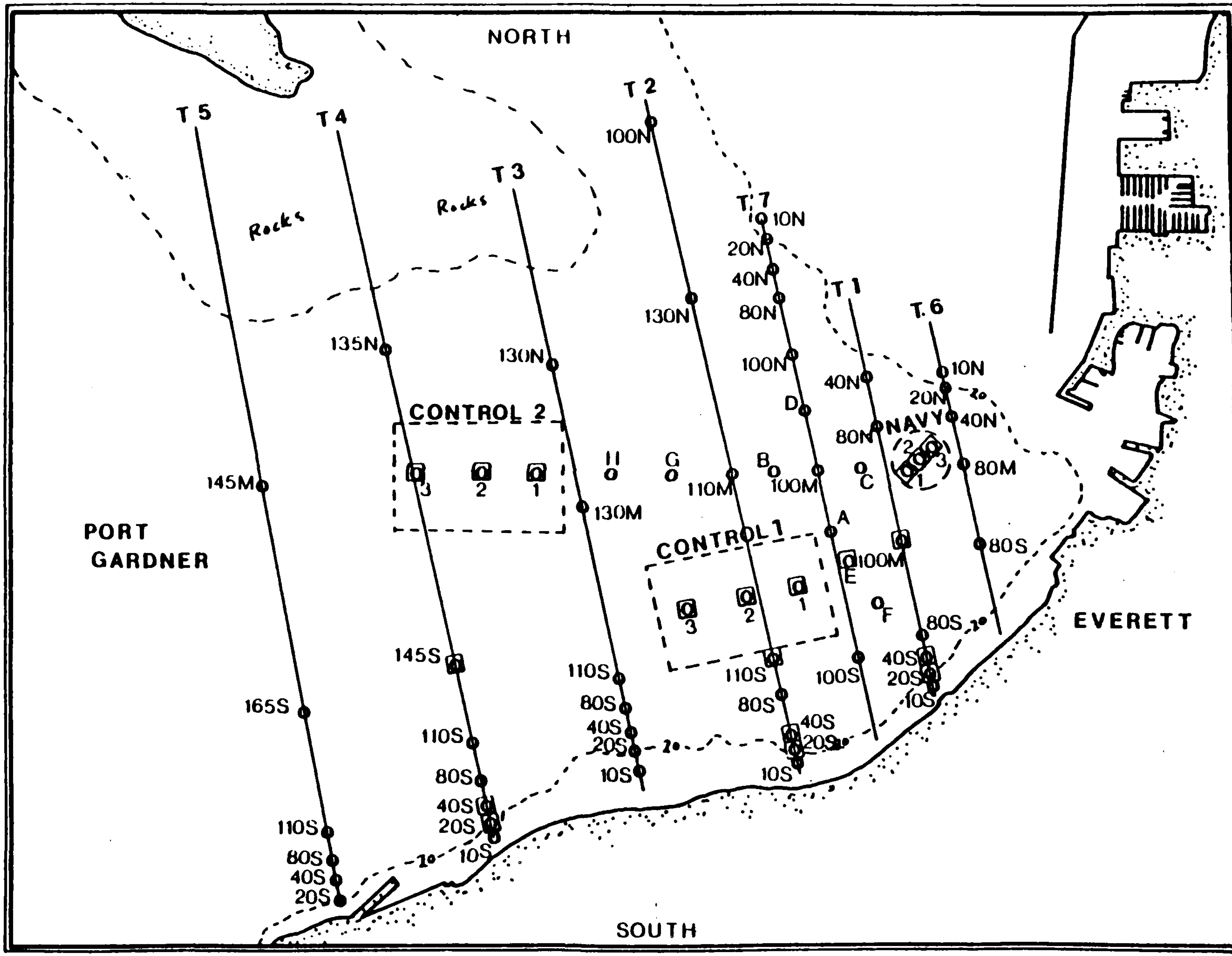

Figure 1. Beam trawl (O) and otter trawl (□) sample stations in Port Gardner. Depths in meters. N = North, M = Middle, S = South.

a 3-m beam trawl (Figure 2, top). A subset of 19 of the beam trawl stations (Figure 1) were also sampled for bottomfish with a 7.6 m otter trawl (Figure 2, bottom).

The term "density" (e.g., crabs/ha) as used in this report and previous cruise reports (Dinnel et al. 1986a, b, c) specifically refers to index or estimated densities as calculated from the beam or otter trawl catches with the assumption of 100% catching efficiency. Trawl gear rarely catches 100% of the animals in its path, which means the actual faunal densities are nearly always underestimated. Nonetheless, the two types of trawl gear, especially when used together as in this study, do give good relative estimates of the variety of resources present and the trends in relative abundances between areas and between seasons.

Results

Dungeness Crab

The average estimated density of Dungeness crab calculated from all (excluding Stations A-H) beam trawl stations in Port Gardner during September (n = 55) was 100 crabs/hectare (ha), a value in good agreement with average densities found during the past three seasons (e.g., 126, 85 and 114 crabs/ha for February, April and June, 1986, respectively). Individual station densities ranged from 0 to 572 crabs/ha (Appendix Table 1). Average crab densities (crabs/ha ±1 standard deviation; n = 3 in each case) at the Navy and control sites in Port Gardner in September, 1986 were:

Navy Disposal Site = 76 ± 51

Control Site 1 = 13 ± 11

Control Site 2 = 25 ± 29

The four highest average crab densities (267 to 572 crab/ha) occurred at

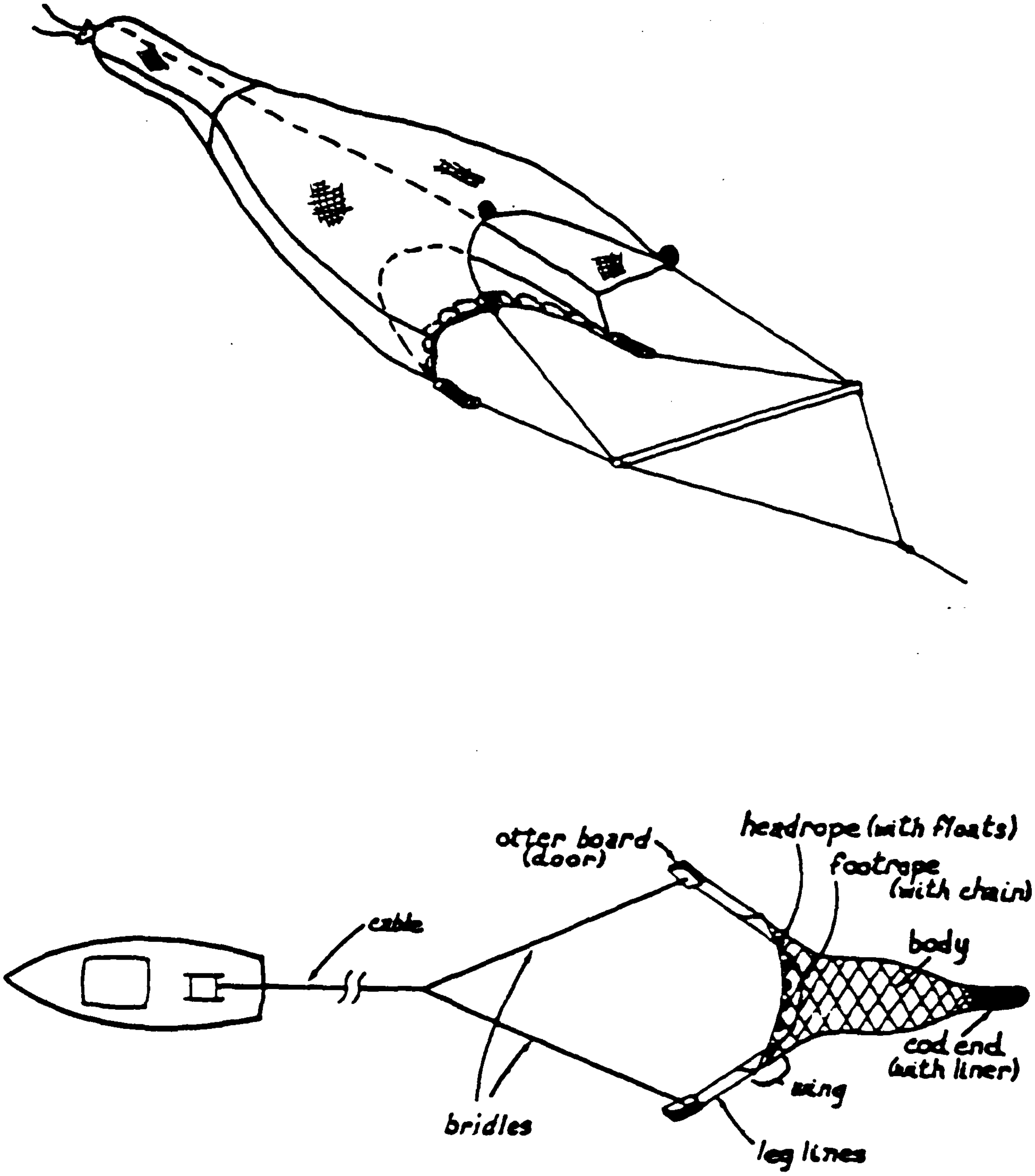

Figure 2. Diagrams of the beam trawl (top) and otter trawl (bottom) used in this study.

the 40 to 80 m deep stations between Everett and Mukilteo (Appendix Table 1) and are essentially a reflection of the deep female aggregations along this slope and the Snohomish River Delta slope north of Everett (Figure 3). The female crab also continued to prefer the region of the original Navy Disposal Site but at concentrations reduced from the previous sampling periods (Dinnel et al. 1986a, b, c). The general pattern of female crab distribution shown in Figure 3 is very similar to the distributions shown during the past three seasons in 1986 with the exception that crabs were found in greater abundances in the central area of Port Gardner (i.e., beyond the inshore slope area at depths >100 m). The average density of all crabs in this central area was 39 crabs/ha versus average densities of <5 crabs/ha during the last three seasons. All but one of the crabs caught at or below 100 m depth were females.

Male Dungeness crabs remained as scarce (only 8% of the total) in the beam trawl samples as in the previous seasons. The spatial distribution of the males also remained quite similar with almost all males occurring along shore in relatively shallow water (Figure 4).

Six new beam trawl stations (A-H; Figure 1) have recently been added to increase the coverage of the area west of the original Navy Disposal Site. This deeper (90 to 110 m) area is now being proposed as the preferred disposal site in an effort to minimize disposal-related impacts on female crabs. The average density of crabs at these seven stations in September was 22 crabs/ha, an average density three to four times less than that at the original Navy Disposal Site (Appendix Tables 1 and 2). Two additional new stations (G and H) were also sampled by beam trawl just east of Control Site 2. The crab densities at these two stations were also low (19 and 0 crabs/ha for Stations G and H, respectively; Appendix Table 2).

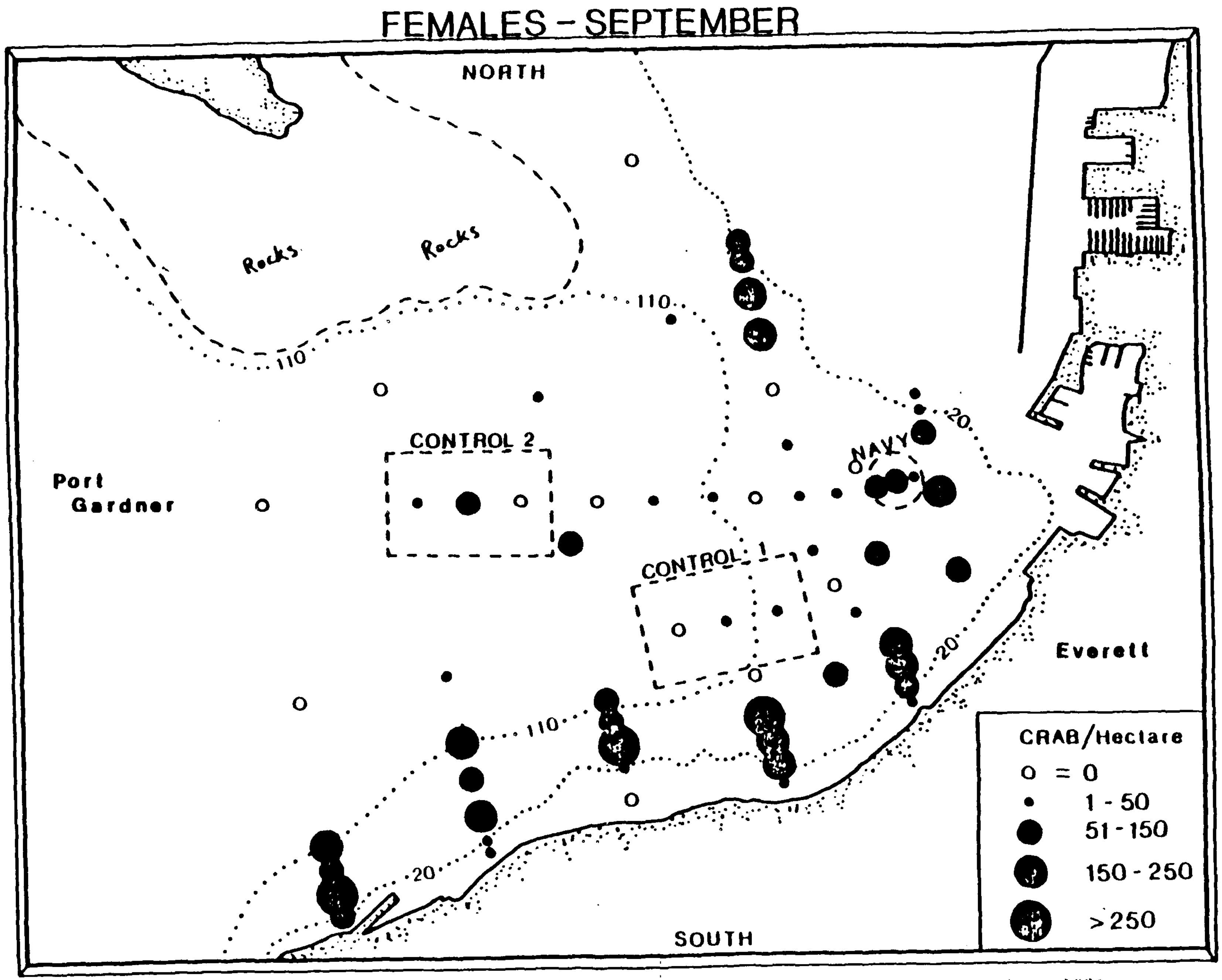

Figure 3. Map of Port Gardner showing distribution of female Dungeness crab during September, 1986 at the beam trawl stations. The depth contours are in meters.

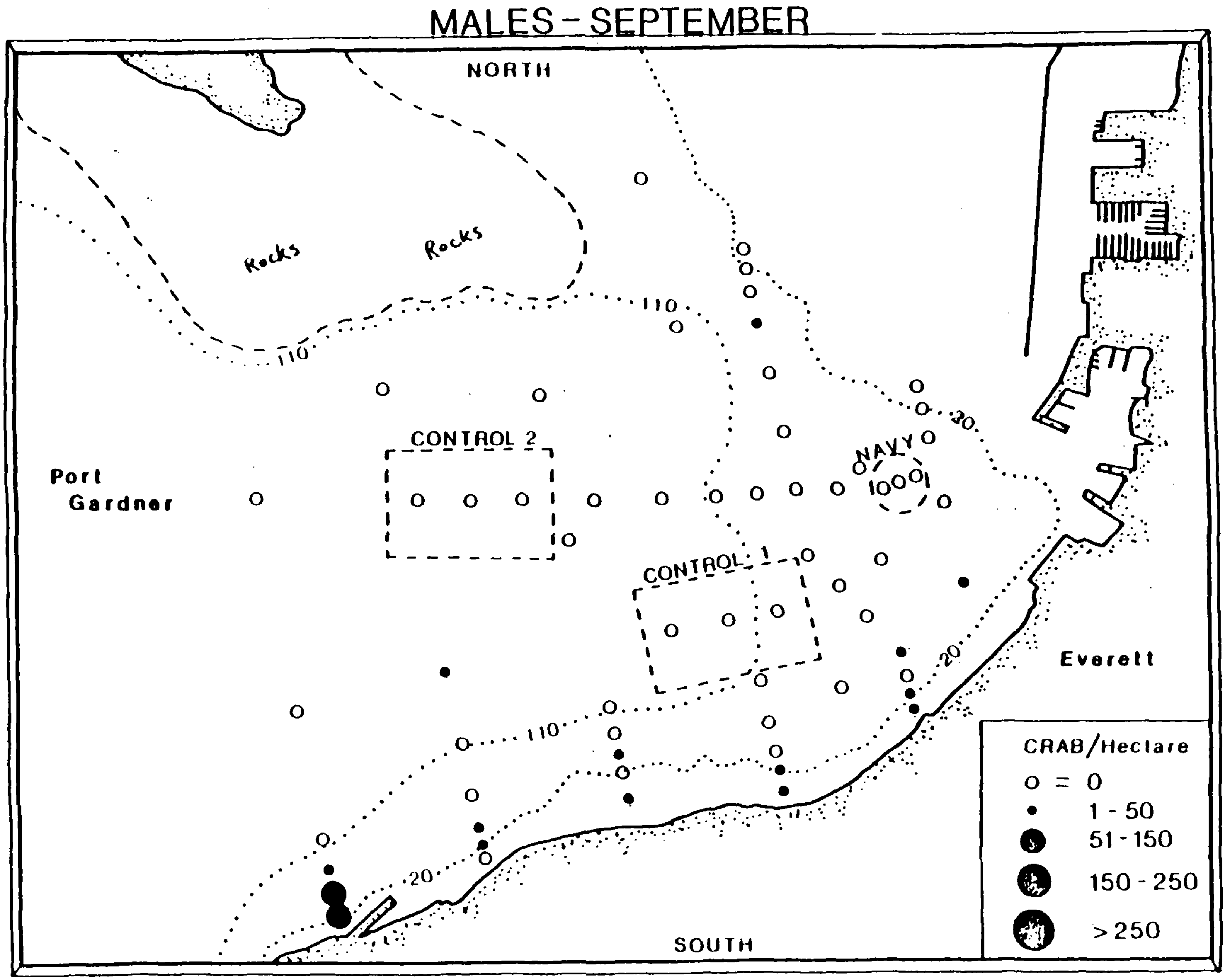

Figure 4. Map of Port Gardner showing distribution of male Dungeness crab during September, 1986 at the beam trawl stations. The depth contours are in meters.

The distribution of all crabs by depth illustrated in Figure 5 (top) shows that the crabs have "spread out" from their previous peak concentrations at 80 m and are now most dense at 40 m with higher relative densities at the deepest stations as well. Figure 5 (bottom) shows that the depth distribution for the females is essentially the same as for all crabs (Figure 5, top), since 92% of the total crabs are female. The male crabs continued, as in the past, to be most frequent at depths $\leq$40 m.

Comparison of the average crab densities at the Navy Disposal Site and the two control sites shows that crab density at the Navy Site has dropped substantially from the other three seasons (Figure 6). This same figure also illustrates the low but increased densities at the two deeper control sites as compared to the three past seasons.

Seven additional beam trawls conducted south of Port Gardner between Mukilteo and Picnic Point found very few crabs (Figure 7, Appendix Table 2), a very marked contrast to the crab densities found along the slope between Everett and Mukilteo.

The otter trawl caught crab at most of the otter trawl sampling locations in September, but once again at a rate much less than the beam trawl (Appendix Table 3). Comparison of the catches per unit of area swept for both gear types showed that the otter trawl efficiency for crabs was less than 5% of the beam trawl in September. It is interesting to note that the beam trawl catches of crab were four times higher in the Navy Disposal Site than the combined catches in the control site. The otter trawl, however, caught several times more crab at the control sites than the Navy Site. This difference in crab catches between the two gear types suggests that crab were buried in the Navy Site (hence, sampled only by the beam trawl which "digs in" as it fishes) and not buried in the control sites (thus, available to capture

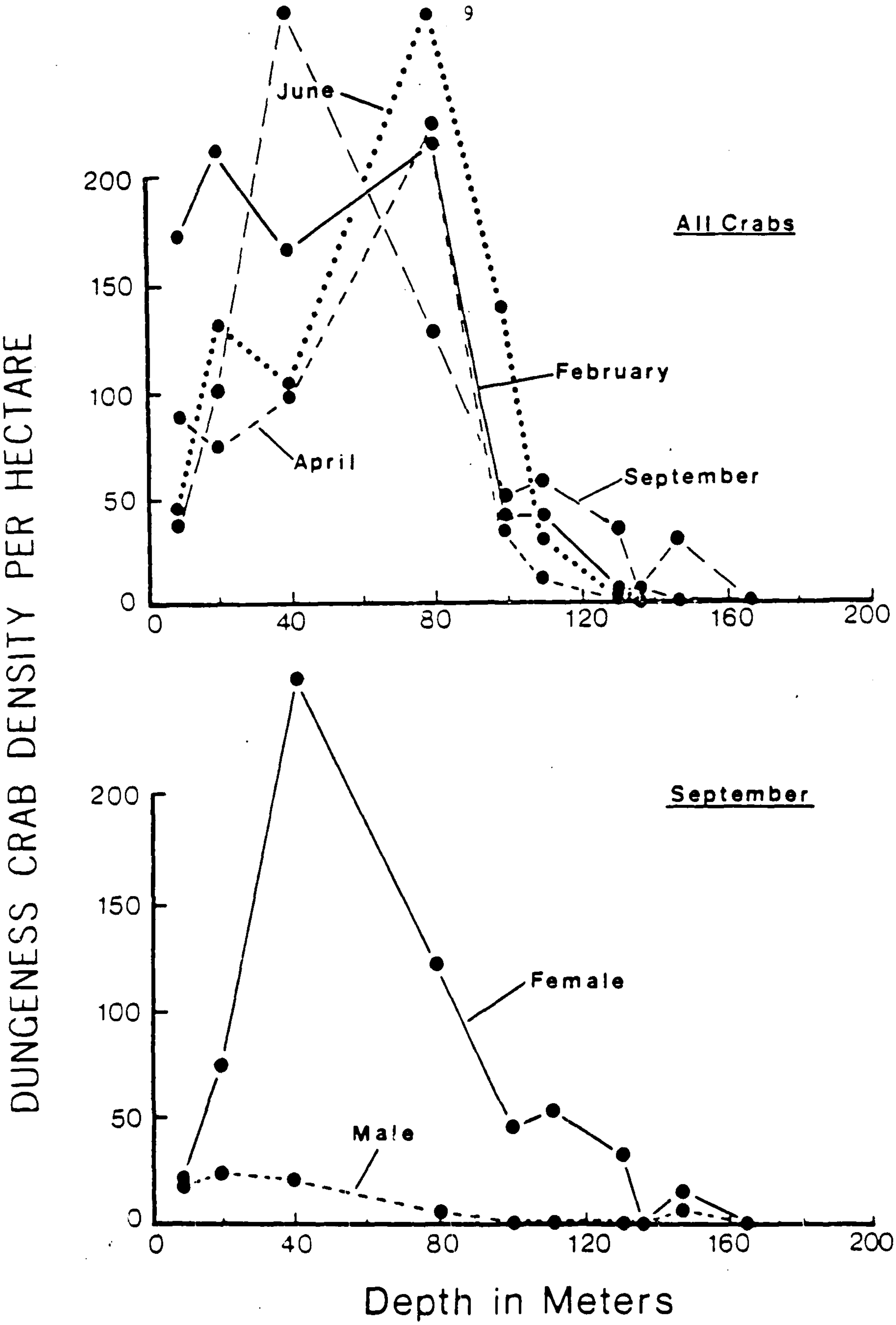

Figure 5. Average estimated crabs/hectare for all Dungeness crab in Port Gardner during four sampling seasons (top) and average crabs/hectare of males and females by depth in September (bottom).

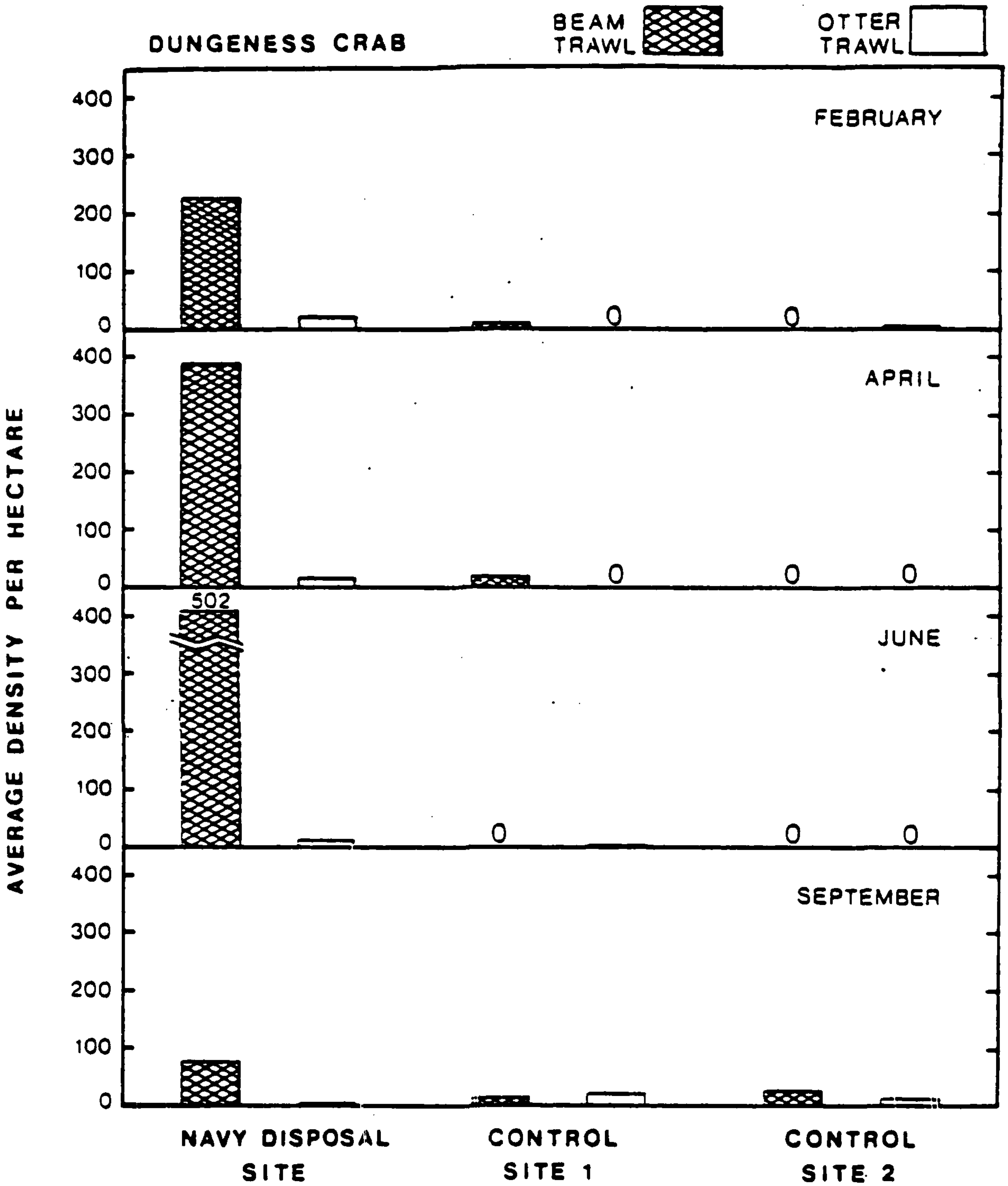

Figure 6. Comparative average densities of Dungeness crab at the Navy Disposal Site and the two control sites in Port Gardner by season and by trawl type.

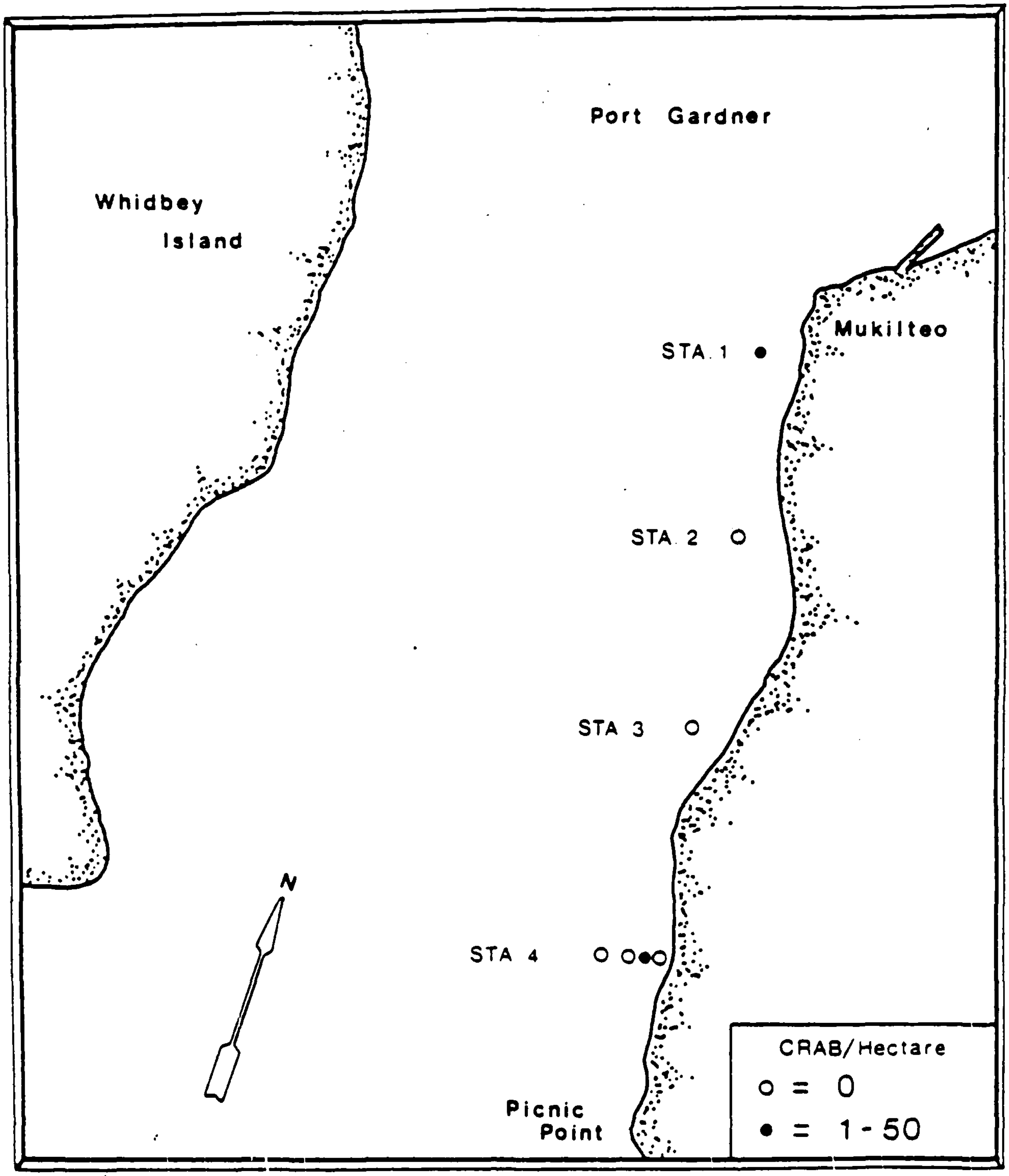

Figure 7. Estimated densities of Dungeness crab from single trawls at seven beam trawl stations sampled in September, 1986 between Mukilteo and Picnic Point.

by both gear types).

Shrimp

The average estimated density of shrimp (all commercial species combined) calculated from all (excluding Stations A-H) beam trawl stations in Port Gardner in September was 269 shrimp/ha, up substantially from past densities of 123, 19 and 30 shrimp/ha in February, April and June, respectively. Shrimp sampled by beam trawl in September were generally most abundant in the inner Port Gardner area and least abundant in the middle, deep area (Figure 8, Appendix Table 3). Indeed, the four largest catches were at the 40 to 80 m depths along the eastern Transects 1, 6 and 7. The average shrimp density within the Navy Disposal Site (294 shrimp/ha) was 15 times greater than the average of the combined densities of the Control 1 (6 shrimp/ha) and Control 2 (32 shrimp/ha) sites (Figure 9). Average shrimp densities by depth in September were greatest at the 40 m to 80 m depth range as they were in two of the last three sampling periods (Figure 10). Shrimp catches in this region are generally composed of a mixed variety of shrimp species including spot prawn, Pandalus platyceros, side-stripe shrimp, Pandalopsis dispar and several species of pink shrimp, Pandalus spp. Shrimp catches along the inshore slope area also contained juvenile shrimp of several of these species suggesting that this zone may be a nursery area for shrimp.

Beam trawl samples at the new Port Gardner stations (A-H) in September showed generally low densities (<100 shrimp/ha) at all stations. No shrimp were caught south of Port Gardner at the stations between Mukilteo and Picnic Point (Appendix Table 4). As in previous seasons, spot prawn were most plentiful at the 40 to 80 m depth off Mukilteo (Transect 5).

Otter trawl sampling at the Navy and two control sites showed the same

SHRIMP – SEPTEMBER

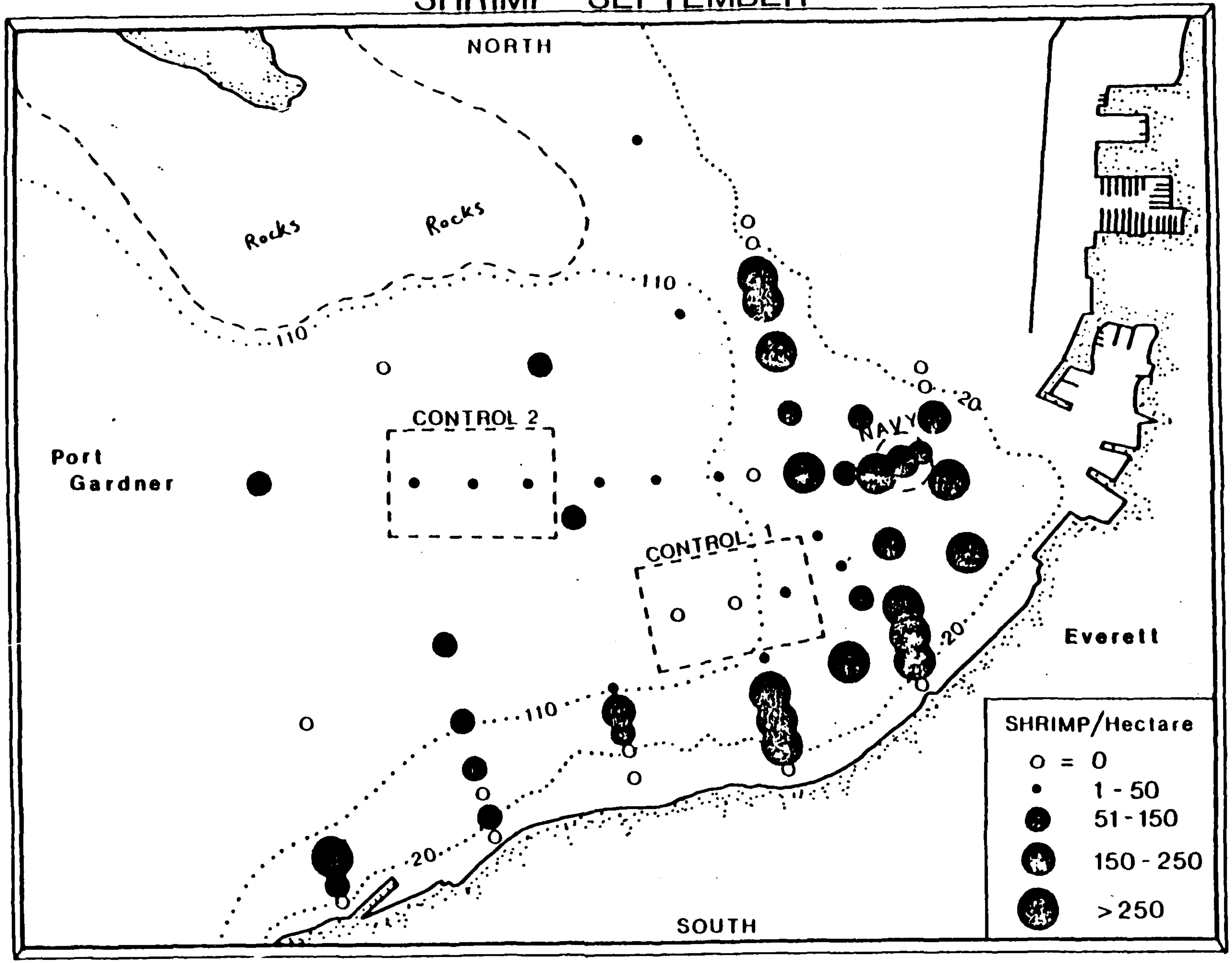

Figure 8. Estimated commercial shrimp densities at the beam trawl stations in Port Gardner during September, 1986. The depth contours are in meters.

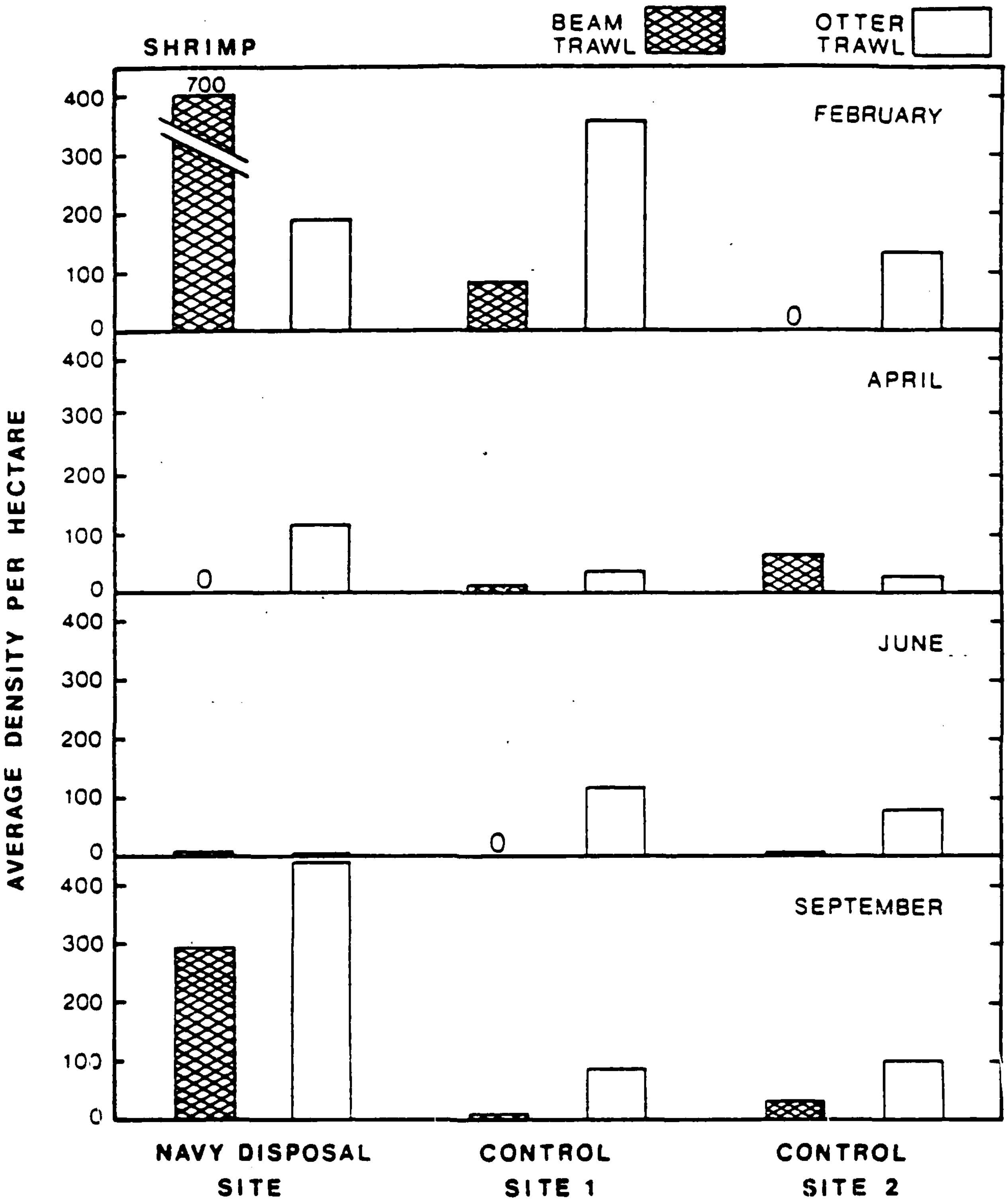

Figure 9. Average commercial shrimp densities at the Navy Disposal Site and the two control sites in Port Gardner by season and by trawl gear type.

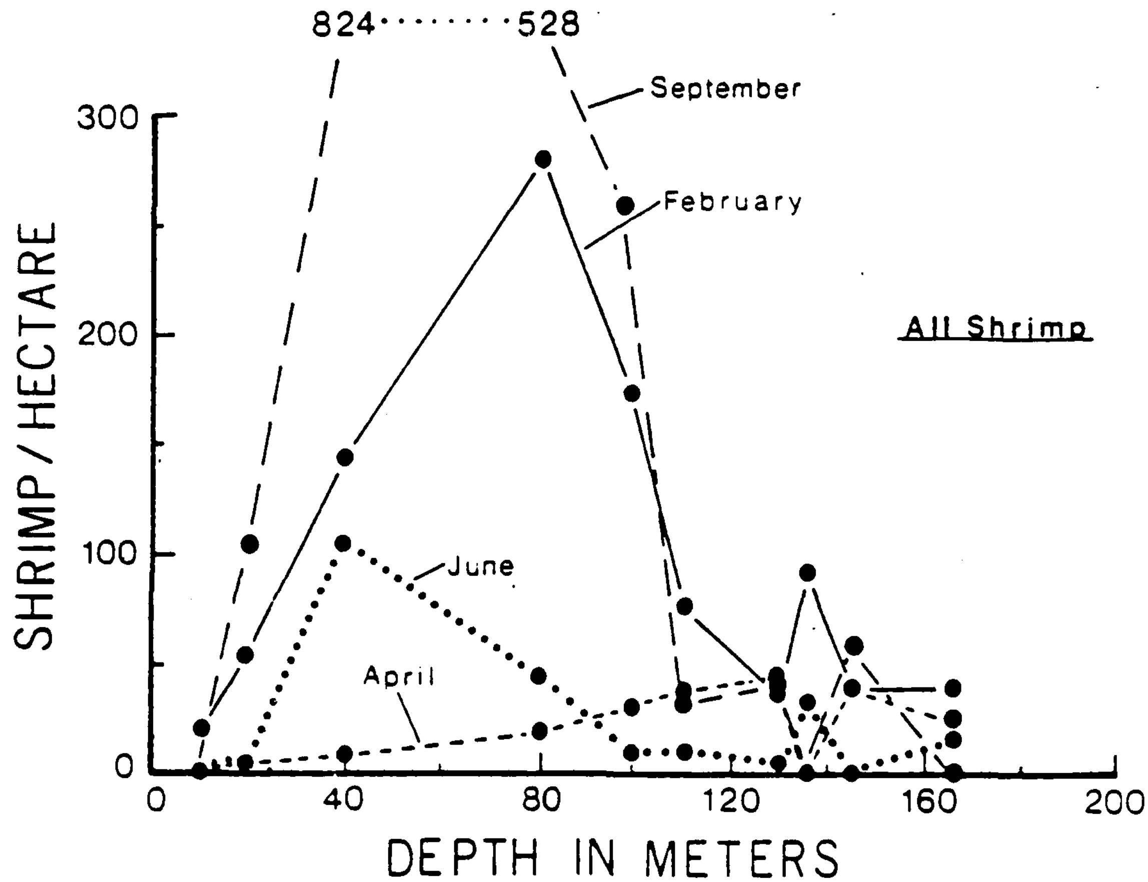

Figure 10. Average commercial shrimp densities by depth and by season in Port Gardner.

basic pattern of shrimp densities as the beam trawl: approximately four times the average density of shrimp at the Navy Site (443 shrimp/ha) as compared to the control sites (56 and 101 shrimp/ha for Sites 1 and 2 respectively; Figure 9, Appendix Table 3).

Although preliminary comparisons indicate the otter trawl was relatively more efficient than the beam trawl for sampling shrimp, a carefully controlled and quantitative experiment has not been conducted to specifically address this question.

Bottomfish

The average number of bottomfish caught at the Navy Disposal Site and the two control sites in September was 244 fish/ha, compared with 170 fish/ha in July, 202 fish/ha in April and 773 fish/ha in February. The average biomass shows a slightly different pattern with 29 kg/ha in September compared to 28 kg/ha in July, 22 kg/ha in April, and 101 kg/ha in February. The Navy Disposal Site had the largest number of fish caught (543 fish/ha contrasted with 295 fish/ha in July, 434 fish/ha in April, and 1541 fish/ha in February) when compared with the two control sites (Fig. 11). A comparison of September, June, April and February sampling showed that Control Site 1 had 81, 156, 102 and 401 fish/ha, while Control Site 2 had 108, 60, 68 and 403 fish/ha, respectively (Fig. 11; Appendix Table 5). The number of species caught at the Navy Disposal Site declined from 14 for both February and April to 10 and 11 in June and September; however, Control Sites 1 and 2, which showed marked reductions from February to April and July (11 and 16 in February, down to 7 for both in April and 6 for both in July) rose in September to 11 and 10 respectively.

Biomass generally followed the same pattern as abundances. The Navy

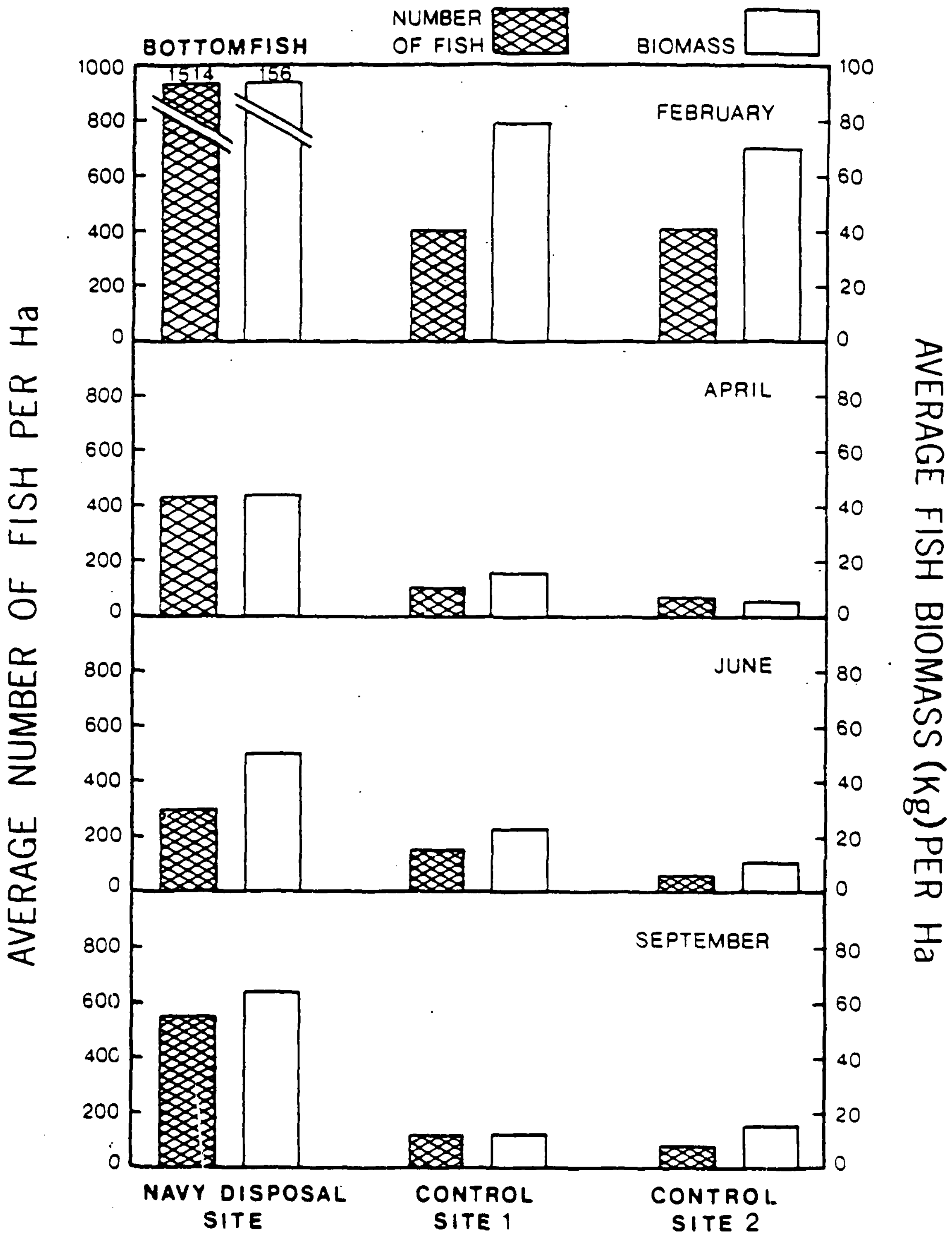

Figure 11. Average estimated bottomfish abundances and biomass by season calculated from otter trawls at the Navy and Control sites in Port Gardner.

Disposal Site was highest (63 kg/ha) followed by Control Site 1 (15 kg/ha) and Control Site 2 (11 kg/ha; Fig. 11; Appendix Table 6). This was the same pattern exhibited previously except that absolute biomass fell during April and July, then rose slightly in September.

Comparison sampling of the otter trawl and beam trawl indicated that the otter trawl was clearly a better sampler of bottomfish than the beam trawl as measured by species diversity, abundance, biomass and range of size categories sampled. However, the beam trawl provides good complementary data on juvenile fishes. Additional analysis of the otter trawl-beam trawl comparison experiment is presently underway.

Internal and external gross examination of flatfishes for fin erosion, tumors, parasites and liver abnormalities indicated insignificant indices of these conditions.

Discussion

Dungeness Crab

Dungeness crab continued to be plentiful along the inshore slope areas of Port Gardner. The males remained shallow (<40 m) while females were most plentiful between 40 and 80 m. The one major finding in September was that crabs had dispersed somewhat, with low densities of crabs being found in the central, deeper (100-130 m) portion of Port Gardner. This increase came at the same time that a marked reduction of crabs occurred in the area of the original Navy Disposal Site suggesting that crabs may move outward from the nearshore area during the summer months. The reason(s) for this apparent movement is presently unknown although increased feeding activity during this period (prior to egg extrusion and incubation) is a plausible reason.

A major concern in Port Gardner is the location of an acceptable

Contained Aquatic Disposal (CAD) Site for disposal of contaminated sediments followed by capping to isolate the contaminants. The original proposed Navy CAD Site at about 80 m depth was clearly in a zone of high female crab abundance. Relocation of the CAD site further downslope at about 90 to 110 m depth has been proposed as a means to minimize crab impacts (COE 1986). Figure 5 (top) illustrates that there are rapidly decreasing densities of Dungeness crab as depth increases from 80 to 110 m and slowly decreasing densities below 110 m. Thus, relocation of the CAD site downslope to the 100 to 110 m depth range should greatly reduce, but not eliminate, direct crab impacts. A few crabs still occur in this area and the September sampling suggests that migration of crabs takes place through this "bottom of the slope" zone out to deeper water, and, we suspect, back again prior to egg extrusion and incubation. Present unknowns relating to crabs and CAD include 1) the degree of direct impacts to crab in the disposal site, 2) crab use of the CAD site during and after disposal and capping, and 3) effects of toxicants on crab eggs if capping does not completely isolate the toxicants.

Shrimp

Shrimp densities were substantially higher in September than during the three previous seasons, probably due to summertime recruitment of young post-larval shrimp. Shrimp densities show a pattern very similar to crabs; the highest densities are along the inshore slope between depths of 40 to 100 m with substantially reduced densities at or below 110 m (Figure 10). Thus, relocation of the CAD site to the 100 to 110 m zone should also reduce impacts to shrimp resources and their favored habitat.

Bottomfish

Bottomfish were most abundant at the Navy Disposal Site, and least abundant at the control sites. The same pattern was true of biomass. These patterns were similar to the previous sampling periods except biomass continued to increase from July to September.

The most abundant fishes (English sole, Parophrys vetulus; Dover sole, Microstomus pacificus; slender sole, Lyopsetta exilis; Pacific hake, Merluccius productus; and ratfish, Hydrolagus colliei) remained the same during all four sampling periods; however, abundances fell from February to April and rose in some cases in July and September (Appendix Table 5). English sole dominated all sampling periods at the Navy Disposal Site. The relative abundance of Pacific hake was high for all four sample periods, but the biomass declined markedly from February to April and rose only slightly in July and again in September. Thus, only smaller (possibly young-of-the-year) individuals were present during April, July and September. A nearby area (Port Susan) is known to be a spawning ground for Pacific hake and supports a commercial hake fishery.

The new proposed location for the Navy Disposal Site is near Control Site 1. This appears to be a much better choice for deposition of dredged materials considering the available bottomfish resources. However, present unknowns relating to bottomfish in the CAD Site are 1) the degree of direct impact to possible spawning fish at the disposal site (it may be insignificant), 2) fish use of the CAD Site during and after disposal and capping, and 3) present incidence and potential change in incidence of diseases and abnormalities of flatfish.

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Appendix Table 1. Dungeness crab densities per hectare calculated from beam trawl catches in Port Gardner during September, 1986. Station numbers for the transects indicate depth in meters plus location where N=North, M=Middle, and S=South. The averages are means ± 1 standard deviation.

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Navy Disposal Site (80m)				
Station 1	95	0	95	20 gal. wood, debris
Station 2	115	0	115	10 gal. wood, debris
Station 3	19	0	19	15 gal. wood, debris
Average	76 ± 51	0	76 ± 51	
Control Site (110m)				
Station 1	19	0	19	15 gal. wood
Station 2	19	0	19	1 gal. worm tubes wood chips
Station 3	0	0	0	2 gal. wood, shell
Average	13 ± 11	0	13 ± 11	
Control Site 2 (130m)				
Station 1	0	0	0	1 gal. worm tubes, shell
Station 2	57	0	57	1 gal. worm tubes, shell
Station 3	19	0	19	0.5 gal. worm tubes, wood
Average	25 ± 29	0	25 ± 29	
Transect #1				
10-S	19	38	57	3 gal. algae, wood, detritus
20-S	57	19	76	
40-S	191	0	191	30 gal. algae, wood
80-S	248	19	267	15 gal. wood, algae
100-M	95	0	95	20 gal. wood, debris
80-N	0	0	0	5 gal. wood, debris
40-N	-	not sampled	-	
Average	102 ± 99	13 ± 16	114 ± 97	

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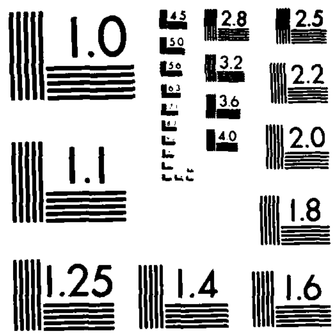

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Appendix Table 1 (continued)

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Transect #2				
10-S	19	19	38	1 gal. algae, detritus
20-S	210	19	249*	15 gal. algae, shell
40-S	153	0	153	15 gal. algae, wood
80-S	305	0	305	25 gal. wood, algae, clay balls
110-S	0	0	0	3 gal. detritus, algae wood
110-M	38	0	38	1 gal. worm tubes, wood chips
130-N	38	0	38	1 gal. detritus, shell
100-N	0	0	0	2 gal. wood chips
Average	95 ± 114	5 ± 9	103 ± 119	
Transect #3				
10-S	0	19	19	6 gal. algae, shell
20-S	38	0	38	50 gal. wood, algae
40-S	553	19	572	30 gal. bark
80-S	95	0	95	8 gal. rock, algae, detritus
110-S	57	0	57	3 gal. wood, algae
130-M	76	0	76	1 gal. worm tubes, wood, shell
130-N	19	0	19	1 gal. worm tubes
Average	120 ± 194	5 ± 9	125 ± 199	
Transect #4				
10-S	19	0	19	1 gal. algae, shell
20-S	38	38	76	6 gal. algae, wood, shell
40-S	172	38	210	30 gal. wood chips, bottles
80-S	115	0	115	4 gal. wood, algae, cans
110-S	153	0	153	4 gal. detritus, wood, gravel
145-S	38	19	57	2 gal. algae, worm tubes
135-N	0	0	0	1 gal. worm tubes, wood chips
Average	76 ± 69	14 ± 18	90 ± 75	

Appendix Table 1 (continued)

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Transect #5				
20-S	76	57	133	20 gal. algae, gravel, wood, shell
40-S	496	57	553	30 gal. wood, rock, algae
80-S	95	19	114	40 gal. wood, algae, rock, debris
110-S	153	0	153	3 gal. wood, detritus
165-S	0	0	0	1 gal. worm tubes
145-M	0	0	0	1 gal. worm tubes
Average	137 ± 186	22 ± 28	159 ± 204	
Transect #6				
80-S	76	19	95	50 gal. algae, wood, cans
80-M	191	0	191	20 gal. wood, debris, cans
40-N	76	0	76	10 gal. wood, debris
20-N	19	0	19	2 gal. wood, detritus
10-N	38	0	38	1 gal. detritus, wood
Average	80 ± 67	4 ± 8	84 ± 67	

Appendix Table 1 (continued)

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
Transect #7				
100-S	76	0	76	40 gal. wood chips, bottles, cans
100-M	38	0	38	2 gal. wood chips
100-N	0	0	0	2 gal. wood, detritus
80-N	210	19	229	3 gal. wood, cans
40-N	229	0	229	1 gal. wood, detritus, shell
20-N	95	0	95	4 gal. wood, shell
10-N	76	0	76	0.5 gal. detritus, shell
Average	103 ± 85	3 ± 7	106 ± 89	
GRAND AVERAGE	92 ± 113	8 ± 15	100 ± 119	

*Includes 1 young-of-the-year (unsexed) crab, 9.0mm carapace width.

Appendix Table 2. Dungeness crab densities per hectare calculated from beam trawl catches at extra stations in Port Gardner during September, 1986. The averages are means ± 1 standard deviation.

Station	Density/Hectare Females	Males	All Crabs	Substrate Comments
West of Navy Site				
Station A (105m)	19	0	19	8 gal. wood chips
Station B (110m)	0	0	0	1 gal. worm tubes, wood
Station C (90m)	38	0	38	1 gal. detritus, wood chips
Station D (105m)	38	0	38	1 gal. detritus, wood chips
Station E (115m)	0	0	0	1 gal. worm tubes, wood
Station F (110m)	38	0	38	7 gal. wood, debris
Average	22 ± 19	0	22 ± 19	
East of Control Site 2				
Station G (130m)	19	0	19	3 gal. wood, shell
Station H (130m)	0	0	0	4 gal. wood, shell
Between Mukilteo and Picnic Point				
Station 1 - 40m	19	0	19	3 gal. wood, detritus
Station 2 - 40m	0	0	0	5 gal. wood, algae
Station 3 - 40m	0	0	0	5 gal. wood, algae, bottles
Station 4 - 10m	0	0	0	10 gal. sand, algae
Station 4 - 20m	38	0	38	3 gal. algae
Station 4 - 40m	0	0	0	5 gal. clay balls, algae
Station 4 - 80m	0	0	0	20 gal. clay balls, algae
Average	8 ± 15	0	8 ± 15	

Appendix Table 3. Shrimp densities per hectare calculated from both beam and otter trawl catches in Port Gardner during September, 1986. Station numbers for the transects indicate depths in meters and location where N = North, S = South, E = East, and W = West. The averages are means ± 1 standard deviation. N.S. = not sampled. Estimated crab densities are also given for the otter trawl.

	Beam Trawl	Otter Trawl	
Station	Shrimp/hectare	Shrimp/hectare	Crab/hectare
Navy Disposal Site (80 m)			
Station 1	581	387	5
Station 2	169	536	0
Station 3	131	405	0
Average	294 ± 250	443 ± 81	2 ± 3
Control Site 1 (110 m)			
Station 1	19	77	14
Station 2	0	72	18
Station 3	0	108	27
Average	6 ± 11	86 ± 20	20 ± 7
Control Site 2 (130 m)			
Station 1	19	81	9
Station 2	38	104	14
Station 3	38	117	5
Average	32 ± 11	101 ± 18	12 ± 4
Transect #1			
10-S	0	N.S.	N.S.
20-S	375	0	0
40-S	1760	5	9
80-S	375	N.S.	N.S.
100-M	187	198	0
80-N	131	N.S.	N.S.
40-N	N.S.	N.S.	N.S.
Average	471 ± 648	68 ± 113	3 ± 5

Appendix Table 3. (cont.)

Station	Beam Trawl	Otter Trawl	
	Shrimp/hectare	Shrimp/hectare	Crab/hectare
Transect #2			
10-S	0	N.S.	N.S.
20-S	300	0	18
40-S	356	0	18
80-S	730	N.S.	N.S.
110-S	38	68	5
110-M	19	N.S.	N.S.
130-N	38	N.S.	N.S.
100-N	38	N.S.	N.S.
Average	190 ± 258	23 ± 39	14 ± 8
Transect #3			
10-S	0	N.S.	N.S.
20-S	0	N.S.	N.S.
40-S	131	N.S.	N.S.
80-S	206	N.S.	N.S.
110-S	38	N.S.	N.S.
130-M	75	N.S.	N.S.
130-N	56	N.S.	N.S.
Average	72 ± 74		
Transect #4			
10-S	0	N.S.	N.S.
20-S	56	0	9
40-S	0	5	5
80-S	75	N.S.	N.S.
110-S	56	N.S.	N.S.
145-S	56	45	0
135-N	0	N.S.	N.S.
Average	35 ± 33	17 ± 25	5 ± 5
Transect #5			
20-S	0	N.S.	N.S.
40-S	150	N.S.	N.S.
80-S	936	N.S.	N.S.
110-S	131	N.S.	N.S.
165-S	0	N.S.	N.S.
145-M	75	N.S.	N.S.
Average	215 ± 359		

Appendix Table 3. (cont.)

Station	Beam Trawl Shrimp/hectare	Otter Trawl Shrimp/hectare	Otter Trawl Crab/hectare
Transect #6			
80-S	655	N.S.	N.S.
80-M	1292	N.S.	N.S.
40-N	243	N.S.	N.S.
20-N	0	N.S.	N.S.
10-N	0	N.S.	N.S.
Average	438 ± 547		
Transect #7			
100-S	262	N.S.	N.S.
100-M	412	N.S.	N.S.
100-N	393	N.S.	N.S.
80-N	1049	N.S.	N.S.
40-N	3127	N.S.	N.S.
20-N	0	N.S.	N.S.
10-N	0	N.S.	N.S.
Average	749 ± 1106		
Port Gardner Average	269 ± 527	123 ± 159	9 ± 8

Appendix Table 4. Shrimp densities/hectare calculated from both beam and otter trawl catches at extra stations in Port Gardner during September, 1986. The averages are means ± 1 standard deviation. N.S. = not sampled.

Station	Shrimp Density/Hectare	
	Beam trawl	Otter trawl
West of Navy Site		
Station A (105 m)	19	N.S.
Station B (110 m)	0	N.S.
Station C (90 m)	94	N.S.
Station D (105 m)	75	N.S.
Station E (115 m)	38	68
Station F (110 m)	94	N.S.
Average	53 ± 40	68 ± 0
East of Control Site 2		
Station G (130 m)	38	N.S.
Station H (130 m)	19	N.S.
Average	28 ± 13	
Between Mukilteo and Picnic Point		
Station 1 (40 m)	0	N.S.
Station 2 (40 m)	0	N.S.
Station 3 (40 m)	0	N.S.
Station 4 (10 m)	0	N.S.
Station 4 (20 m)	0	N.S.
Station 4 (40 m)	0	N.S.
Station 4 (80 m)	0	N.S.
Average	0	

Appendix Table 5. Average catch by otter trawl (number of individuals per hectare) at each of the proposed disposal sites in Port Gardner during September 1986.

	Navy Site	Control Site 1	Control Site 2
English sole	253	13	13
Dover sole	4	9	9
Slender sole	99	36	36
Rex sole		4	
Flathead sole	4		
Quillback rockfish	4	4	4
Ratfish	122	4	5
Blacktip poacher	4		
Pacific hake	45	4	27
Blackbelly eelpout	4		
Cod	2		
Tom cod			4
Dogfish		4	
Spinyhead sculpin		3	
Blackfin poacher	4	4	9
Blackfin eelpout			5
Red brotula			
Pallid eelpout		3	4
Soft sculpin			

Appendix Table 6. Average catch by otter trawl (kilograms per hectare) at each of the proposed disposal sites in Port Gardner during September 1986.

	Navy Site	Control Site 1	Control Site 2
English sole	40.50	3.02	3.43
Dover sole	0.92	2.08	2.55
Slender sole	5.16	2.12	1.59
Rex sole		0.37	
Flathead sole	0.29		
Quillback rockfish	1.73	1.09	0.46
Ratfish	6.85	2.77	2.24
Blacktip poacher	0.04		
Pacific hake	2.90	1.76	0.04
Blackbelly eelpout	0.10		
Cod	4.45		
Tom cod			0.02
Dogfish		1.34	
Spinyhead sculpin		0.10	
Blackfin poacher	0.04	0.05	0.12
Blackfin eelpout			0.11
Red brotula			
Pallid eelpout		0.01	0.03
Soft sculpin			

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