A Preliminary Assessment of Wood Debris at Four Log Dumps on Douglas Channel, British Columbia: Comparison of Techniques

C.J. Williamson, C.D. Levings, J.S. Macdonald, E. White, K. Kopeck, and T. Pendray

Fisheries and Oceans Canada
Science Branch, Pacific Region
Simon Fraser University
School of Resource and Environmental Management
8888 University Drive
Burnaby, B.C. V5A 1S6

2000

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2539

Fisheries and Oceans Canada — Pêches et Océans Canada
Science — Sciences

Canada

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2539

2000

A PRELIMINARY ASSESSMENT OF WOOD DEBRIS AT FOUR LOG DUMPS ON DOUGLAS CHANNEL, BRITISH COLUMBIA: COMPARISON OF TECHNIQUES

by

C.J. Williamson, C.D. Levings[1], J.S. Macdonald, E. White[2], K. Kopeck[3], and T. Pendray[4]

Fisheries and Oceans Canada
Science Branch, Pacific Region
Simon Fraser University
School of Resource and Environmental Management
8888 University Drive
Burnaby, B.C. V5A 1S6

[1]Fisheries and Oceans Canada, Science Branch, West Vancouver Laboratory, 4160 Marine Drive, West Vancouver, B.C. V7V 1N6.
[2]3093 Heddle Road, R.R.1, S1, C10, Nelson, B.C. V1L 5P4.
[3]Terra Surveys Limited, Marine Division, 1962 Mills Road, Sidney, B.C. V8L 5Y3.
[4]Fisheries and Oceans Canada, Habitat and Enhancement Branch, Box 578, Smithers, B.C. V0J 1N0.

Cat. No. Fs 97-4/2539E ISSN 0706-6473

Correct citation for this publication:

Williamson, C.J., C.D. Levings, J.S. Macdonald, E. White, K. Kopeck, and T. Pendray. 2000. A preliminary assessment of wood debris at four log dumps on Douglas Channel, British Columbia: Comparison of techniques. Can. Manuscr. Rep. Fish. Aquat. Sci. 2539: 75 pp.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Williamson, C.J., C.D. Levings, J.S. Macdonald, E. White, K. Kopeck, and T. Pendray. 2000. A preliminary assessment of wood debris at four log dumps on Douglas Channel, British Columbia: Comparison of techniques. Can. Manuscr. Rep. Fish. Aquat. Sci. 2539: 75 pp.

Log dumping, sorting, and storage in nearshore marine waters can result in a considerable accumulation of wood and bark debris on the sea floor, with effects on benthic habitats. In our study, side-scan sonar and SCUBA were tested to determine their suitability for mapping wood and bark debris fields at four marine log dumps on the north coast of British Columbia. Bathymetric and video surveys were also tested. A variety of operational histories and site locations were used to compare results and develop a better understanding of factors contributing to debris persistence and dispersal for future studies. Side-scan sonar was effective at mapping deeper water and the distribution of a proportion of sunken logs at more recently used dump sites. Particulate wood and bark debris or logs that had been extensively colonized by wood boring organisms were less effectively observed using side-scan sonar. SCUBA was used to groundtruth the side-scan results at one location and was effective as a technique for mapping wood debris, bark, logs, and anthropogenic refuse in relatively shallow waters (< 20 m). Suggestions are made for extending the assessments to other locations (e.g., North Bentick Arm) and for using other hydroacoustic methods such as substrate classification.

RÉSUMÉ

Williamson, C.J., C.D. Levings, J.S. Macdonald, E. White, K. Kopeck, and T. Pendray. 2000. A preliminary assessment of wood debris at four log dumps on Douglas Channel, British Columbia: Comparison of techniques. Can. Manuscr. Rep. Fish. Aquat. Sci. 2539: 75 pp.

Le rejet, le tri et l'entreposage de billes de bois en milieu marin près des côtes peut entraîner une accumulation considérable de débris de bois et d'écorce sur le fond marin et ainsi affecter les habitats benthiques. Les auteurs ont évalué l'efficacité du sonar à faisceau latéral et de la plongée sous-marine pour la cartographie de la distribution des débris de bois et d'écorce à quatre décharges de billes en milieu marin le long de la partie nord de la côte de la Colombie-Britannique. Ils ont également fait l'essai de sondes bathymétriques et de dispositifs vidéo. Différents antécédents opérationnels et emplacements ont servi à la comparaison des résultats et à l'étude des facteurs de persistance et de dispersion des débris en vue d'études futures. Aux décharges dont l'utilisation était récente, le sonar à faisceau latéral était efficace pour la cartographie des eaux profondes et de la distribution d'une partie des billes immergées. Toutefois, ce moyen était moins efficace pour la détection des particules de bois et des débris d'écorce ou des billes fortement colonisés par des organismes qui percent le bois. La plongée sous-marine, à laquelle on a eu recours pour valider

les résultats de l'observation par sonar à faisceau latéral à un endroit, s'est révélée efficace pour la cartographie des débris de bois et d'écorce, des billes et des déchets d'origine anthropique en eaux relativement peu profondes, soit de moins de 20 m de profondeur. Les auteurs suggèrent que des évaluations soient effectuées à d'autres endroits, dans le bras Bentick nord par exemple, et que d'autres méthodes hydroacoustiques, telle que la classification du substrat, soient employées.

PREFACE

This report is a synthesis of information contained within three contract reports (White 1999; Terra Surveys Limited 1998, 1999) in addition to field notes collected by Department of Fisheries and Oceans staff while supervising the hydrographic survey. Sections of text as well as figures and tables were adapted from these contract reports and then supplemented with information collected by Department of Fisheries and Oceans staff to suit the format of this manuscript series. Each of the three contract reports is available through the Fisheries and Oceans Canada library system.

A. INTRODUCTION

Several authors have identified the need to study the biological impacts of log-handling activities on coastal waters in British Columbia (Duval 1980; Conlan and Ellis 1979; Pease 1974). However, very few comprehensive, quantitative field studies describing the effects of wood and bark have been published, and those that have, focussed on log handling and storage sites which handled high volumes (>1 million m^3) of wood over many years.

Most studies have suggested that thick bark and wood debris deposits resulting from log handling can cause substantial, long-term negative impacts to benthic ecosystems. Disturbances have been categorized as physical, chemical, or biological. Changes to the biota are varied and can range from subtle sub-lethal physiological effects on individual organisms to major changes in biological community structure (for reviews see Sedell and Duval 1985; Sedell *et al.* 1991; Duval 1980; and Faris and Vaughan 1985). Several studies have noted that deposition of a continuous carpet of wood and bark debris can virtually eliminate aerobic benthic infauna; Conlan and Ellis (1979); Pease (1974); Jackson (1986); and Vance *et al.* (1982). Walker (1974) noted that intermittent debris could result in an increase in faunal diversity. In these studies, negative biological impacts were localized, however, the cumulative effect of several hundred sites located on the B.C. coast is currently unknown. On the north and central coast of British Columbia where the topography is generally steep, SCUBA methodology, used in one of the earliest log debris studies in the Region (McDaniel 1973), is impractical because much of the likely impacted habitat is beyond diver range. The production of economically or socially important species can be concentrated in specific geographic locations in the deeper fjords, and changes to the total productive capacity of important habitats may be considerable.

Our goal in this study was to assess side-scan sonar and SCUBA diving as techniques to quantify and map the extent of wood debris and bark accumulation at four log dumps on the north coast of British Columbia, specifically on Douglas Channel, south of Kitimat. It is hoped that the data collected will be used to plan more comprehensive studies that aid in the development of compensation plans or mitigation strategies in addition to strengthening current management policy.

B. MANAGEMENT CONTEXT

Over the past decade with declines in the amount of readily available timber, forest companies have harvested areas where access is more difficult and cut-blocks are smaller. As a result, many smaller short-term (1 to 5 years) dumping locations have been developed or proposed for the B.C. coast. In some forest districts there has also been interest in re-opening old log dump sites that were originally located in ecologically productive or sensitive areas.

As part of the management process for new or lapsed foreshore leases, the Department of Fisheries and Oceans and the B.C. Ministry of Environment, Lands & Parks review plans for log dumps and other log handling facilities prior to their use. The objective of the review is to ensure that fisheries resources and overall fish production capability are not adversely affected by development of log handling facilities. Pre-siting reviews mainly focus on ensuring that sites which are selected for development for log handling facilities do not have sensitive fish habitats or fisheries resources (such as eelgrass beds or shellfish resources) which may be affected by the log handling activities. In most cases, much of the review focuses on physical alterations required to develop the site (such as foreshore fill). Assessment of operational impacts of log handling at individual sites is made difficult by the lack of available information on log dump impacts, particularly those from relatively short term, low wood volume sites in deeper water. These reviews generally take into account that some impacts from accumulation of debris will occur around the site, but there is little information available to predict the likely areal extent of impacts or whether negatively impacted habitat will recover over time.

C. METHODOLOGY

I. STUDY LOCATIONS

Four study sites located in Devastation Channel, Gardner Canal, and Kildala Arm near Kitimat, B.C. were chosen for the study (Figure 1). The local topography is typical of the steep walled 'U'-shaped glacial fjords on the B.C. central coast (Pickard 1961). Maximum channel depths in the study areas range up to 270 m (C.H.S. Chart 3745, Gardner Canal). The climate is typical of the temperate coastal marine environment with up to 2 m of average annual rainfall. Large freshwater discharges (e.g., 580 $m^3 \cdot s^1$ annual average into Gardner Canal) from glacially fed rivers, influence surface waters to approximately 20-m depth. During hydrographic surveys in summer, Pickard (1961) observed that surface salinity ranged from 0 to 20 ‰ and salinity at depths greater than 20 m ranged from 30.5 to 33.3 ‰. Pickard found that dissolved oxygen in Douglas Channel, near our survey sites, ranged from saturation at the surface to 5 $ml \cdot L^{-1}$ at 40-m depth. Secchi depths ranged from 0 to 5 m in Douglas Channel and Gardner Canal.

a. Site selection

After an initial reconnaissance survey by helicopter in March, 1997, four sites (Figure 1) were chosen from numerous potential study sites located in the Douglas Channel area (Appendix 1). The sites were selected to be representative of log dump activities on the north coast of British Columbia. Selection criteria included depth of water, duration of site operation, volume of wood processed, time since deactivation, aspect and exposure, as well as accessibility.

b. Site descriptions

i) Site 47 Dala River: The Dala dump site is situated on the north side of Kildala Arm at the head of the inlet (Figure 1). The Kildala River drains into the inlet just east of the log dump site in two channels forming a substantial estuarine area. The main river channel is at least 500 m from the landing dock used for the log dump. The dump site and most of the sorting area are situated over a subtidal shelf that is up to 40-m deep. The main portion of Kildala Arm beyond the dump drops quickly to depths up to 140 m. Immediately on both sides of the dump site there is an approximately 20- to 30-m wide intertidal area dominated by *Fucus sp.* and other common north coast macroalgae. A 70- to 100-m wide area of intertidal flats was present near the mouth of the Dala River. The sea floor at Dala River is generally uniform and slopes in a southerly direction from the shoreline (Figure 2). A slight ridge runs southwest from the dump skids to the 70-metre isobath. The steepest part of the survey area is on this ridge with a maximum slope of 45^0 in a localized area between the 20- and 70-m isobaths (Figure 2). The site is well exposed to east/west winds, however, Kildala Arm is relatively sheltered, and the wind and thus wave action may have had less influence on debris distribution compared with the other survey sites. At the time of the surveys Dala River log dump was not being used, although it was still considered an active dump site and was scheduled for use later in 1998. Between 1992 and 1997, 322,000 m^3 of wood had been dumped into the water.

ii) Site 44 Weewanie Hotsprings: Weewanie Hotsprings dump site is situated just north of the mouth of Weewanie Creek in a small cove that opens up into Devastation Channel (Figure 1). A beach at the head of the cove extends along a shallow grade to about 100 m off the high tide mark and then drops steeply beyond 70 m out into the main part of Douglas Channel. Douglas Channel reaches depths up to 280 m in this area. The deepest part of the survey area was in the southwest corner of the cove (Figure 2). Both the north and south sides of the cove drop steeply into the water; the southwest side is a natural drop whereas part of the north side is built from riprap that forms the seaward face of the most recent dumping area. Several very decayed crib logs on the southwest side of the cove appeared to form a much older log dumping area. The north dump/landing area was built along roughly two-thirds of the distance to the mouth of the cove. Steep bedrock outcrops converge underwater in a funnel shape at the cove entrance. Weewanie Hotsprings log dump was operated from 1965 to 1973, and approximately 550,000 m^3 of wood was dumped into water during that time.

iii) Site 26 Ochwe Bay (Paril River Dump): The Ochwe Bay log dump site is situated adjacent to the Paril River estuary in Gardner Canal (Figure 1). Most of the surveyed area is shallower than 40 m (Figure 4). Gardner Canal reaches a maximum depth of 130 m in the vicinity of Ochwe Bay. The log dump area was located on the west side of the bay and was constructed from bedrock cut out of the mountain. The south end of the bay is very shallow with a relatively large estuarine/intertidal area. A maximum depth of 60 m is reached in the north central portion of the Ochwe Bay site. The sea floor begins to ascend slightly towards the east edge of the survey area creating a north-south oriented underwater gully. Ochwe Bay is well exposed to waves and wind from the north and east. Ochwe Bay log dump was active between 1990 and 1994. During this period, 311,404 m^3 of wood was dumped in the bay. In 1996, a further 35,626 m^3 of wood was dumped by helicopter.

iv) Site 42 Collins Bay: The Collins Bay survey area (approximately 200 m^2) is situated in a small embayment at the north end of Collins Bay (Figure 1). A small creek at the head of the bay drains through a beach that grades seaward from gravel to fine sand. The beach extends into a shallow subtidal flat that has an area of about 160 m^2. The dump site (west side) is cut into bedrock with a landing area constructed from fill that was pushed into the water. The intertidal area in the east side of the bay is characterized by 20- to 50-cm rocks sloping into a sand/bark debris bottom. Fifty to eighty m from the beach at the head of the bay, the shallow bottom drops steeply to a depth of 30 m (Figure 5). The sea floor in the bay forms a 'valley' oriented in a north-south direction, descending to a maximum water depth of 35 to 40 m at the southern perimeter of the survey area. In the southwest corner of the survey area, the sea floor descends rapidly at an angle of ~35° from the shoreline. Collins Bay log dump was operated from 1989 to 1994, and 469,718 m^3 of wood was dumped into water during that time.

II. SIDE-SCAN SONAR SURVEY

Between March 21 and 25, 1998, Terra Surveys Limited completed surveys of sea floor features at the four log dumps. Survey data collected at the four sites included bathymetry, side-scan sonar imagery, photographs, sediment grabs, and video imagery. An 8-metre, aluminum hulled, jet-driven vessel was used for the side-scan surveys.

a. Data collection and instrumentation

i) Survey control and positioning: A real-time differential GPS navigation/positioning system was installed onboard the survey boat. This equipment consisted of a 12-channel Ashtech GPS receiver, computer/data logger, and survey line guidance display (NavLog and NavDisp navigation software packages).

Differential corrector signals were continuously logged using the B.C. Government's M-SAT link, a geostationary satellite network, transmitting GPS corrector signals from Williams Lake and Terrace, B.C. The Canadian Coast Guard 300-kHz beacon at Sandspit, Queen Charlotte Islands, was also utilized when necessary, due to nearshore topographic interference and/or heavy nearshore vegetation. Survey launch positions were continuously and automatically logged at 1-second intervals during all survey operations.

ii) Water level recording for bathymetric control: Prior to commencing survey operations, a digital water level recording station was installed by Terra Surveys Limited. This recorder was located at the south end of Moon Bay Marina (Kitimat, B.C.) near the marina entrance, on the edge of a man-made rock pier protruding from the shoreline.

Tidal data were logged at 15-minute intervals, with each data sample being the average water level present over the previous 60-second interval. These observations were referenced to CHS benchmark "BM3, 1977", ID Number 77C9513, located in the northwest corner of the concrete foundation for the No. 2 or northernmost cement silo, west of the southwest corner of the RivTow wharf approach, about 0.6 m above ground level.

Tidal data was compared to the published (Canadian Tide and Current Tables, 1998) data for the secondary port at Kitimat. For the four survey sites, bathymetric data was corrected to Chart Datum, halfway between the secondary ports of Hartley Bay and Kitimat.

iii) Bathymetry and side-scan sonar: Bathymetric data was collected at each site to help determine the influence that sea floor topography has on log dump debris distribution. At each site a grid of bathymetric survey lines was laid out within the boundaries of the survey with nominal spacings of 20 m. These were supplemented by survey cross lines at approximately 50-m spacings. Additional bathymetric data was collected during the side-scan sonar survey.

Bathymetric data was collected using a Raytheon 719-C survey echo sounder (S/N 9946) with a 200-kHz, 3° beamwidth transducer mounted on the port side of the "Doppler" as shown in Figure 6. The echo sounder was calibrated for speed of sound daily to water depth of 35 m. The echo sounder calibration line was checked throughout the day. Data was collected on a X-2 scale with timed fixes marked automatically by the navigation computer every 30 seconds. A total of 27 survey lines of bathymetric data were collected at Collins Bay, 24 at Ochwe Bay, 24 at Weewanie Hotsprings, and 33 at Dala River. Analog echo sounder records were manually digitized and then corrected for velocity-of-sound, vessel draft, and adjustments to chart datum using the electronically logged tide gauge data.

Side-scan sonar track lines were laid out with 35-m spacing parallel to the shore. Each line was started in shallow water and spacing of 35 m was used to allow for overlap in side-scan sea floor coverage in addition to collecting more bathymetric data.

Surficial sea floor features data were collected using an EG&G Model 272-TD dual frequency (100/500-kHz) side-scan towfish (S/N 0011581) running on 500 kHz, at 50-m horizontal scan range, and recorded on an EG&G Side-scan Recorder Model 260 (S/N 0011233). Time was annotated automatically by the navigation computer at 30-second intervals. The results obtained by the side-scan were generally satisfactory with the exception of bottom interference in very shallow waters (< 2 m) and while turning, where the towfish proximity to the jet drive wash produced minor interference on the port channel data. The geo-referenced position of sea floor features was interpreted from side-scan sonar records. The relative position of each feature was calculated and positioned by: 1) measuring the feature's horizontal offset (port or starboard) from the survey track line, 2) calculating the layback (horizontal distance behind boat) of the towfish using water depths and length of tow cable out, and 3) manually plotting the sonar feature on survey track maps. These plots were then digitized and plotted onto a sea floor features map sheet. With a 50- to 75-m horizontal scan range, the chosen track line spacing of approximately 35 m allowed more than 100% overlapping coverage between tracks, yielding good confirmation of sonar sea floor features.

Side-scan and bathymetric survey data coverage of intertidal areas was not possible during this survey due to the timing of low tide. As a result, the bathymetric and side-scan survey lines could not be fully extended into intertidal areas, with the exception of Collins Bay. Bathymetric data for Collins Bay was collected early on the morning of March 24 before low tide.

iv) Sea floor video: A black and white video survey was used as one of two groundtruthing tools during the side-scan survey. Sea floor features were recorded using a black and white Fisher-DV-1 Drop Video Camera with 100 m of umbilical cord, a SONY DA Pro 4 Head VCR, and a black and white 10-inch monitor. The camera was towed approximately 1 to 2 m above the sea floor, along a few pre-selected survey lines at each survey site. The video data, although slightly unclear, was useful in defining areas of organic debris, confirming sunken logs as sonar targets, identifying organisms using the site, and defining areas of biological activity. Video data were not analyzed for the Weewanie Hotsprings and Dala River sites. However, observational field notes collected during the surveys were used to comment on the video and sediment samples for the Weewanie and Dala sites.

For the video tow, the elapsed recording time on the VCR clock was used to reference the video images to GPS time. Video image features were hand-plotted on a track map and were then manually digitized. A layback correction was applied for the camera position relative to the GPS receiver. Layback is the horizontal distance of recording instrument behind the GPS receiver. Layback increases with boat speed and the depth of the recording instrument.

Video transects (exaggerated width 5X) were plotted on maps that included features interpreted from the side-scan record. The actual video track is centred on the exaggerated, plotted track. Sea floor materials observed in the video tow were pooled into three categories: 1) shell fragments and coarse sand; 2) twigs and organic debris; and, 3) fine sand and mud. Where bottom materials had patchy distributions, the dominant material was indicated on the video track plot.

v) Sediment sampling: A Dietz La-Fond sediment sampler was used to further groundtruth the study sites. Twenty-one sample attempts were made at the four dump sites. Sample sites were generally chosen in water depths not likely to be examined by SCUBA investigators (i.e., > 20 m). However, some samples were collected in shallow areas for comparison. Photos and a description of the samples are available from Terra Surveys Limited (1998). Ochwe Bay and Collins Bay were examined visually to estimate the amount of wood debris present. The samples collected at Dala River and Weewanie Hotsprings log dumps were not analyzed.

III. DIVE SURVEY

A dive survey of Ochwe Bay was completed between March 20 and 22, 1999, to groundtruth the results of the side-scan survey in shallow water and to investigate the level and nature of biological impacts related to log dumping and wood debris accumulation. The Ochwe Bay site was chosen for the dive survey because most of the impacted area (as observed from side-scan) was located in relatively shallow water and allowed more SCUBA coverage than the other sites. The survey included an observational transect of the intertidal shoreline as well as 12 dive transects perpendicular to the shoreline in front of the log dump. Habitats in depths > 20 m were not assessed in this survey because 20 m is considered the safe limit for repetitive SCUBA diving. The shoreline at high and low tide, the log dump landing perimeter, log dump skid locations, and transect start points at the high tide line were recorded using a handheld GPS unit (Trimble ProXL). Buoys anchored to the end of three transects were used to mark the transect endpoints at the surface using GPS. GPS points for the dive survey were differentially corrected using a continuously recording base station in Houston, B.C. Transects were spaced at 10-m intervals using a hip chain. The middle of three crib logs located on the log dump shoreline was used as a zero point. Transects to the north of the centre crib log were designated with a '+' and transects south of the centre crib log were designated with a '-' (Figure 7).

The approximate numbers and positions of biological and anthropogenic features were recorded relative to slope distance and depth along each transect. Only data on macroinvertebrates that were easily visible at or above the substrate water interface were recorded. The depth, areal extent, and nature of bark and wood debris were also recorded. The substrate was hand probed to approximate the depth of bark deposits. The compass orientation, relative position, and sizes of large features such as logs and boulders were also recorded. Depth was collected from measurements taken with a SCUBAPRO DC 12 dive computer. All depths were corrected to chart datum.

D. RESULTS

I. DALA RIVER

a. Side-scan sonar survey

Little organic debris was observed at the Dala River site and few identifiable features were observed using side-scan sonar (Figures 8, 9). Several unidentified sonar targets were located and were thought to be anchor blocks for the dock and sorting booms. Some of these features may have been rocks or boulders.

Very little bark or log debris was observed during the video tow. The only substantial debris accumulation observed was immediately around the base of the dump skidway. From the limited data collected in the video survey (Figures 8, 9), it was observed that the sea floor was relatively uniform and had a fine-grained substrate with little biota or organic debris. Squat lobsters (*Munida quadraspina*) appeared frequently in deeper water on the subtidal shelf. Very few other organisms were observed.

II. WEEWANIE HOTSPRINGS

a. Side-scan sonar survey

Large volumes of wood debris were observed on the sea floor at Weewanie Hotsprings log dump. Many targets observed in the side-scan sonar data were identified as logs (Figures 9, 10) that ranged in length from 2 to 15 m. Based on video images, it appeared that the logs on the sea floor were very decomposed and had been in place for a long time. Only one sonar target, 70 m from the beachhead, was interpreted as a sunken log. Other targets that were thought to be logs were located closer to the entrance of the bay in the area bounded by rock outcrops (Figures 3, 9). A number of sonar targets displaying reflective characteristics of small boulders were located along the north and south bedrock perimeters. Two sonar targets were located near fix points 1 and 2 and were likely anchor blocks that were attached to two buoys floating at the surface.

III. OCHWE BAY

a. Side-scan sonar survey

Fifty to sixty logs ranging in length from 2 to 20 m were observed from the side-scan sonar data at Ochwe Bay (Figures 11, 12, 13). The logs were mainly oriented lengthwise north to south and were positioned east and north of the three crib logs, labelled 'dump site railings' in Figure 11. Side-scan records indicated that an acoustically absorbent sea floor material was present over most of the site. A gradual transition of riprap-sized material from the high water line to soft organic material and twigs 25 to 30 m east into deeper water was observed in the side-scan data. Man-made features, possibly chain or anchor scars were located on the sea floor in two places. A linear, acoustically reflective material appearing to be an outcrop of either bedrock or coarse gravel/boulders was observed from the side-scan record in 45 m of water in the northeast corner survey.

Video data indicated that twigs and organic debris dominated the area extending from the dump site railings, approximately 90 m east, 120 m north, and 30 m south. To the east of the visible organic debris field, the sea floor made a transition to fine and then coarse sand (possibly mixed with silt) as the sea floor rose. South of the debris field the sea floor appeared to be comprised of mainly coarse sand and bivalve shell fragments. It was inferred from the video and side-scan data that large sections of the survey area were likely covered with soft organic or muddy substrate. Several rocks (up to 0.5-m dia.) were observed in the video data approximately 20 m northeast of the northern most crib log (Figure 11). Video data referenced to GPS time confirmed that several targets in the sonar data were logs.

In summary, the majority of the log debris was concentrated north and east of the crib logs, with organic debris made up of primarily small (< 5-cm length) twigs extending in the same directions but terminating 100 to 120 m east of the high water line. It appears that by the nature of the sea floor in this area, small twigs and finer organic debris has been carried and deposited in a northerly direction, and may therefore extend further north than the area surveyed and quite possibly in waters in excess of 60 m in depth.

b. <u>Dive survey</u>

The results of the dive survey were in general agreement with the results of the video survey, however, there was some disagreement with the numbers and positions of logs from the side-scan data. Depth profiles were constructed for transects, +50, 0, -20, -30, and –50, and show the distribution of wood debris and organisms observed in the dive survey as well as logs observed in both surveys (Appendix 2).

For the purposes of this investigation the dive survey area was divided into five intertidal and subtidal habitats. The intertidal zone was classed as boulder/rip-rap shore or intertidal flats and the subtidal zone was classed as rock, sand/silt slope, or subtidal flats.

In the impacted areas, accumulations of bark debris up to 40 cm deep (Figure 15), cables (wire rope and chokers), forestry camp refuse, and logs were common. Logs were well colonized by shipworms (*Bankia setacea*). Cables and rocks provided substrate for filter feeders such as feather duster worms (*Eudistylia vancouveri*), sea peaches (*Halocynthia aurantia*), and plumose anemones (*Metridium senile*). Dungeness (*Cancer magister*) and decorator crabs (*Oregonia gracilis*), coon striped shrimp (*Pandulus danae)*, stubby squid (*Rosia pacifica*), California sea cucumbers (*Parastichopus californicus*), and sunstars (*Pycnopodia helianthoides*) were observed on top of the debris. Infaunal filter feeders were conspicuously absent from the bark impacted areas. Large mobile predators and epifaunal deposit feeders were the only organisms observed on top of the wood debris substrate.

Continuous fine wood debris up to 40-cm deep covered approximately 0.13 ha (estimated from SCUBA transects), in an area 50-m wide along the seaward face of the dump that extended toward deeper water to a distance of 20 to 30 m (Figure 15). Intermittent wood debris up to 10-cm deep covered at least 0.42 ha and was found in an area 65 m along the dump face and at least 65-m offshore (Figure 15). The intermittent debris field continued beyond the depth at which safe repetitive SCUBA diving is possible. Areas of scour and deposition of bark debris and sand substrate were apparent around rocks and logs on the bottom, indicating that underwater currents may play a substantial role in the distribution of wood debris and sediments at Ochwe Bay. A white substance was found in and on the surface of the debris, which may be magnesium or calcium sulphate precipitates and/or a bacterial mat comprised of a common mixotrophic marine bacteria such as species from the genus *Beggiatoa* (e.g., Gray and Head 1999). Sulphate precipitates can be found within anoxic sediments and *Beggiatoa sp.* commonly occur on the surface of anoxic sediments. Some species of *Beggiatoa* utilize both oxygen and sulphide for respiration and are commonly seen as white macroscopic colonies (bacterial mats) at the sediment water interface. White deposits were observed in areas with thick bark deposits greater than 10 cm within the continuous debris mat as well as areas with intermittent debris (Appendix 2).

The rocky intertidal area on the face of the site was well colonized with an assemblage of intertidal animals and algae typical of Gardner Canal, including: barnacles (*Balanus sp.*), limpets (*Collissella digitalis*), isopods (*Idotea sp.*), amphipods, hermit (*Pagurus sp.*) and shore crabs (*Hemigrapsus sp.*), rockweed (*Fucus distichus*), sea lettuce (*Ulva lactuca*), and red and green filamentous algae (*Enteromorpha intestinalis* and *Odenthalia washingtoniensis*). Wood debris present on the rocky shore was in the form of drift logs as well as logs and stumps that were buried when the site was constructed.

The intertidal flats were surfaced with cobble and small boulders interspersed with patches of sand. Barnacles, mussels (*Mytilus edulis*), young clams, amphipods, periwinkles, and *Fucus sp.* were common in this area. Wood debris was present at the mouth of a small creek on the western margin of the flats.

The subtidal rock habitat formed the seaward face of the dump site and was thickly colonized with red filamentous algae, sea lettuce, diatoms, laminarian kelp (*Laminaria saccharhina*), and sargassum weed (*Sargassum muticum*). Ochre and false ochre starfish (*Evasterias troschellii*), the fish-eating star (*Stylasterias forreri*), the short spined seastar (*Pisaster brevispinus*), sunstars (*Pycnopodia helianthoides*), California and orange sea cucumbers (*Parastichopus californicus* and *Cucumaria miniata*), Dungeness (*Cancer magister*) and decorator crabs (*Oregonia gracilis*), and coon striped shrimp (*Pandalus danae*) were observed. Fish included walleye pollock

(*Theraga chalcogramma*) and Pacific snake pricklebacks (*Lumpenus sagitta*). An apparent octopus den was also located among the rocks. A large pile of broken log bundle cables and strapping was located immediately in front of the dump face (Figure 15).

The sand-silt habitat generally started at 7- to 9-m depth and was located in the north part of the survey area as well as downslope of the subtidal rock habitat. A transition area of sand and scattered rocks separates the sand/silt slope from the rocky subtidal. Sunstars, Dungeness, decorator, and hermit crabs as well as brittle stars (*Ophiopterus papillosa*) were observed. Laminarian kelp was found on any suitable hard substrate (e.g., rocks and logs). Horse clam (*Tresus capax*) beds with densities of 5 to 10 individuals per square metre were observed. The sparse wood debris found in this habitat was typically in the form of logs or larger pieces of wood greater than 1.5-m long.

The subtidal flats sustained a relatively diverse set of fauna in the unimpacted areas. Fish observed included sand sole (*Psettichthys melanostictus*), speckled sanddab (*Citharichthys stigmaeus*), starry flounders (*Platichthys stellatus*), black fin poachers (*Bathyagonus nigripinnis*), Pacific snake pricklebacks, and sculpins. Other organisms included hermit crabs, Dungeness crabs, a king crab (*Paralithodes camtschaticus*), decorator crabs, sunstars, a rose star (*Crossaster pappossus*), and leather stars (*Dermasterias imbricata*). Bivalve shells were very common on the seabed; the species observed included butter clams (*Saxidomus giganteus*), cockles (*Clinocardium nuttallii*), truncated softshell clams (*Mya truncata*), horse clams, and jingle shells (*Pododesmus cepio*). Horse clams were the only live clams observed; they were found in densities of 15 to 20 per square metre. Moon snail (*Euspira pallida*) presence was inferred from egg casings in addition to snail predation holes in butter clam shells.

IV. COLLINS BAY

a. <u>Side-scan sonar survey</u>

Approximately 95 linear sonar targets (identified as logs) ranging in length from 1 to 20 m were observed scattered throughout the site. Most of the logs were within 60 and 160 m of the log dump landing area (Figures 16, 17). Linear features representative of chain, cable, or anchor drag scars were also observed on the side-scan record. In the very shallow waters and on shore at the north end of the site, there were a number of logs and stumps that were not visible on the side-scan records. Much of this debris had cut ends and may be debris left over from dumping operations. It was difficult to distinguish between the different types of sediments and debris on the side-scan records due to the acoustically absorbent and soft nature of the material over much of the sea floor within the survey area.

Videographic data was collected along two corridors (Figures 16, 17). A patchy distribution of organic debris, fine sand, and mud dominates the sea floor of the site, although twigs and other organic debris become less concentrated approximately 150 m east of the landing site. The sea floor within 150-m radius of the site made a transition from small organic debris to fine sand, then to coarse sand and shell fragments. Many of the logs visible on the video were confirmed sonar targets although there were some smaller branches (< 5-cm diameter), which did not show up on the sonar records.

Six sediment samples were retrieved in twelve attempts from the sea floor at various locations within the survey area (Figure 16). With the exception of one sample, which contained coarse sand, all of the samples were predominantly organic in nature, containing twigs, bivalve shell fragments, small pieces of bark, and mud. There was a strong hydrogen sulphide odour in all but one (42-1) of the samples, indicating reductive decomposition. Live macroscopic organisms were not observed in the sediment samples.

Larger pieces of sea floor debris (logs) appeared to become sparser towards the southern perimeter of the survey area; additional video or side-scan data is needed to confirm this. Areas of sea floor debris containing twigs and small branches were more concentrated within 170 m east and south of the landing site, but without further video coverage the full extent of debris coverage could not be accurately determined.

E. DISCUSSION

The dumping of logs into water down skids can result in the generation of a considerable amount of bark and wood debris. The abrasive action of boom boats and waves during the sorting and storage of bundles can also generate quantities of wood debris. Bark and wood lost during dumping often forms thick, continuous, anoxic fibre mats extended from the base of the dump skids. The debris mat tends to dissipate with distance from the entry point; however, wood debris can often be observed substantial distances from the dump skids as seen at all four of the sites sampled. Debris deposits can also be generated as logs resting on the sea floor decay. Wood boring organisms (e.g., *Toredo* spp.) quickly reduce the wood fibre content of logs, but the bark of some species (e.g., western red cedar (*Thuja plicata*) which has a high lignin content) is left relatively untouched. The amount of wood debris generated during handling and storage can be different depending on tree species, tidal levels, and dumping methods. Debris accumulation, distribution, and the resulting biological impacts are affected by physical factors including depth, sea floor slope, dump site aspect, water currents, and wind or wave exposure (Sedell *et. al.* 1991; Duval 1980).

In this study, we used side-scan sonar as a tool to identify the areal extent of impacts caused by log dumping and handling activities. Side-scan sonar was able to discern the orientation and position of some but not all the logs (as verified by the video survey). Side-scan was not useful for mapping accumulations of small pieces of wood debris and bark.

The position and orientation of sunken logs can be used to delineate a portion of a log dump debris field, which may include small wood debris, however, bark and fine wood fibre may be easily redistributed by currents as was observed in this study. Logs may also require more time to become waterlogged and sink compared to smaller pieces of wood debris, and may travel longer distances before sinking.

The results of several studies suggest that the major impacts to benthic organisms at log dump sites occur as the result of thick anoxic bark or wood fibre deposits (Conlan and Ellis (1979); Pease (1974); Jackson (1986); McDaniel (1973)). In the short term, logs may not cause any impacts. However, at Ochwe Bay, fine wood debris deposits were thicker in areas with more sunken logs. Some studies have indicated that large pieces of wood debris can, for a time, increase faunal diversity by providing suitable substrates for attachment for some filter feeders as well as food and cover for epifauna and wood boring organisms (e.g., Conlan and Ellis 1979). In this study several species not normally found in sand-bed environments were associated with logs and rock debris. Logs do decay, however, and the wood and bark left behind can contribute to the wood debris accumulation.

Results of the dive survey indicated that side-scan sonar was unable to discern a number of important targets, including several large logs and boulders (Figure 18). Changes in the density of logs over time due to decomposition, burial, and colonization by wood boring organisms may reduce the visibility of the logs with respect to side-scan sonar. The Ochwe Bay site was last used for helicopter dumping operations in 1996; any logs that may have settled in the survey area would have had a minimum of a year and a half to absorb water and to be colonized by wood-boring organisms. Groundtruthing using video or other methods must be completed before side-scan sonar can be used as a tool to define log dump debris fields. However, side-scan sonar may be useful in initial broad scale surveys to locate abandoned log dump sites before focusing on specific areas.

Substrate classification methods such as RoxAnn and QTC are additional remote sensing techniques, which could be used to classify bottom sediments. These techniques use data derived from reflected hydro acoustic signals to assess seabed roughness and hardness, and are not dependent on the 'relief' of features on the bottom. RoxAnn and QTC have been used as an experimental technique for geoduck and sea cucumber stock assessment (Cripps 1996), general 'biotope' surveys (Foster-Smith *et al.* 1998), and for mapping juvenile Atlantic cod habitat (Collins *et al.* 1996). However, there is no information on whether RoxAnn or QTC will be effective for mapping wood debris such as bark mulch. If they are, these techniques would be useful for mapping the dispersion of wood debris from log storage in deepwater areas, below SCUBA range.

Video camera surveys also hold promise as both groundtruthing and remote sensing methods for deeper water. Useful data could be obtained by video-drop work (present study), still camera methods used in previous studies (McDaniel *et al.* 1977), and new technology such as the Seabed Imaging and Mapping System (SIMS) (Harper *et al.* 1998) or remotely operated vehicles. Each technique has advantages and limitations. For example, the SIMS method is limited to 20-m depth but can survey a much greater area of the bottom in a shorter period of time relative to SCUBA.

SCUBA diving can be a productive method for the assessment of log dump debris fields (e.g., Pease 1974; and Jackson 1986). Unfortunately, due to current technological and physiological constraints, a 20-m depth has been set as a standard safety limit for repetitive research or vocational diving, and therefore the majority of recent log dumps cannot be completely surveyed by divers. New log dumps are typically located with a minimum of 3- to 4-m depth below the dumping skids at low tide (B. Koroluk, Department of Fisheries and Oceans, pers. comm.). Where possible, embayments and areas with shallow slopes are also avoided such that many log dumps are now located in areas adjacent to very deep waters. Despite the 20-m limit, the dive survey provided valuable biological data for mapping log dump effects and physical data for groundtruthing side-scan results.

In our study, the intermittent bark layer could not be completely surveyed by divers, and video data suggests that bark has settled over a larger area than observed in the dive survey. The level of the biological impact in the section of the debris field with intermittent coverage is unknown. Some studies (e.g., Walker 1974) have observed that intermittent wood debris deposits can actually increase faunal biomass and diversity.

The most severely impacted portion of the sea floor assessed in the dive survey at Ochwe Bay was located above the 20-m isobath where bark deposits were thickest. Infaunal organisms, some of which are considered valuable food resources (e.g., horse clams) were conspicuously absent from this area. In contrast, large mobile predators and scavengers such as crabs and starfish were observed on the surface of the bark cover. The presence of these organisms on the debris does not, however, preclude biological impacts. For example, O'Clair and Freese (1985) found that crabs avoided bark deposits when given a choice but when they were forced to use bark deposits as a substrate, they were less fecund, had lower feeding rates, and had a decreased survivorship. O'Clair and Freese hypothesized that these effects were caused by hydrogen sulphide in combination with ammonia and other unmeasured toxicants. In another study, O'Clair and Freese (1988) found that a population of Dungeness crabs, living at a log dump in Alaska with elevated hydrogen sulphide and ammonia concentrations in the bark debris, had less than half as many ovigerous females that were less than half as fecund as a control population.

Other studies have noted sublethal and behavioural effects on biota caused by wood debris. Chang and Levings (1976), used ten mobile invertebrates in a laboratory experiment to study substrate preferences; they found that nine of the ten organisms avoided wood debris and preferred substrates where burrowing was easier. Stanhope *et al.* (1987) found that the production of an estuarine isopod, *Gnorimosphaeroma* *insulare,* was reduced in wood debris compared with *Fucus* or bank habitats. They observed that the lack of production was most likely the result of a relative paucity of food microbes, particularly fungi. Similarly, Stanhope and Levings (1985) and Stanhope (1983) found that the amphipods *Eogammarus confericolus* and *Corophium spinicorne* from wood debris habitats had lower production (also caused by the reduced availability of food microbes) as well as higher mortality rates in the wood debris habitat. Behavioural effects have been noted in early life stages of organisms with planktonic larvae. Menzie (1984) hypothesized that the recruitment potential for organisms with planktonic larvae may be diminished because the larvae will not settle on unsuitable substrates. In field studies this was confirmed by McGreer *et al.* (1985) and Kathman *et al.* (1984), who observed that the sediments with high concentrations of wood were less colonized by planktonic marine organisms. Our preliminary results are generally consistent with the current body of literature in that wood wastes, particularly thick bark deposits, have an obvious impact on natural marine assemblages.

The areal extent of impact at Ochwe Bay was similar to that of several sites in Alaska (Pease 1974) and four sites in British Columbia (White 1999). Areas impacted by wood debris ranged from 0.05 to 0.8 ha (Tables 1 and 2). Although these areas are small, the combined effect on economically or socially important species may be larger and is currently unknown. As stated earlier, in steep-walled fjords, the total productive area for species with high fisheries value are often located in relatively shallow habitats. This may be particularly true on North Bentinck Arm near Bella Coola, B.C., where many of the log dumps are located adjacent to very deep fjord waters (Appendix 3). Caution must be used before locating dump sites to deep waters, since there are no data that suggest habitats of certain organisms (e.g., prawn and shrimp) using deepwater sites will not be impacted in some way. Furthermore, cleanup of deepwater sites is likely to be expensive and difficult if impacts to deepwater habitats are deemed unacceptable.

The recovery rates of impacted sediments at log dumps are also a management concern, however, very little attention has been directed at studying the subject. Most of the available information suggests that thick bark deposits persist for long periods of time. For example, in Pease (1974), the Nakwisina Sound log dump in Alaska had been inactive for 11 years and still had 0.8 ha of bark debris. In our study, Weewanie Hotsprings dump site was last used around 1973 and large deposits (unquantified) of wood were observed on the sea floor. In the past, logs at most dump sites were dumped unbundled into the water and a small portion of the logs sank almost immediately (especially, hemlock (*Tsuga* spp.)). In British Columbia, since the early 1980's, most logs have been bundled prior to dumping and the loss to sinking has been reduced. Weewanie Hotsprings log dump operated before this time and most certainly experienced a substantial loss of log due to sinkage. In our side-scan survey, a dense accumulation of logs was observed on the sea floor nearly 30 years after the last log was dumped. Cleanup of large quantities of debris at older sites like Weewanie Hotsprings dump may become more of an issue in the future. For more recent log dumps like Ochwe where the accumulation of debris is less substantial, the impacts to the sea floor habitats of marine biota are still obvious and need to be minimized where possible.

Additional information on such factors as the expected areal extent of debris accumulation, the recovery rate of the affected habitat, the physical site conditions which may contribute to minimize impacts, and the value/feasibility of possible cleanup and assessment techniques, would all improve the defensibility of management decisions related to log handling siting and related habitat management. Further detailed studies are necessary to collect information to address these management concerns.

F. ACKNOWLEDGEMENTS

Funding for this project was provided by the following Pacific Region units of the Department of Fisheries and Oceans: Science Branch, Habitat and Enhancement Branch, and the Oceans Directorate. The Canadian Ocean Frontiers Research Initiative also supported this work. We are grateful to West Fraser Timber Co. Limited for allowing access to their field camp at Triumph Bay. Eero Karanka, Department of Fisheries and Oceans Habitat and Enhancement Branch, provided valuable guidance for study site locations in Douglas Channel. Thanks are owing to Beth Piercey, Ann Thompson, and Margaret Mattson for their invaluable help in proof-reading and formatting this document.

G. LITERATURE CITED

Chang, B.D., and C.D. Levings. 1976. Laboratory experiments on the effects of ocean dumping on benthic invertebrates. I. Choice tests with solid wastes. Fish. Can. & Mar. Serv. Tech. Rep. 637: 74 pp.

Collins, W., R. Gregory, and J. Anderson. 1996. A digital approach to seabed classification. Sea Technol. 37, 8: 83-88.

Conlan, K.E., and D.V. Ellis. 1979. Effects of wood waste on sand-bed benthos. Mar. Pollut. Bull.10: 262-267.

Cripps, K. 1996. Geoduck and sea cucumber surveys using Roxann (1994-1995). *In* Proceedings of the Ocean Feature Classification Workshop, Sidney, B.C. *Edited by* T.C. Curran. Canadian Hydrographic Service, Sidney, B.C. pp. 9-15.

Duval, W.S. (Technical Director). 1980. A review of the impacts of log handling on coastal marine environments and resources. Prepared for the Environmental Review Panel of the COFI/Government Estuary, Foreshore and Water Log Handling and Transportation Study, by ESL Environmental Sciences Limited, and F. F. Slaney & Company Limited, Vancouver, B.C. 224 pp.

Faris, T.L., and K.D. Vaughan. 1985. Log transfer and storage facilities in southeast Alaska: a review. Gen. Tech. Rep. PNW-174. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 24 p., plus map.

Foster-Smith, R., J. Davies, I. Sotheran, and R. Walton. 1998. Is the RoxAnn ground discrimination system a useful tool for remote sensing and mapping of subtidal benthic marine biotopes? *In* Proceedings Canadian Hydrographic Conference, Victoria, B.C., March 10-12, 1998. pp. 404-21.

Gray, N., and I. Head. 1999. New insights on old bacteria: diversity and function of morphologically conspicuous sulfur bacteria in aquatic systems. Hydrobiologia 401: 97-112.

Harper, J.R., B. Bornhold, D. McCullough, and B. Emmett. 1998. Seabed imaging and mapping system - seabed classification of substrate, epiflora, and epifauna. *In* Proceedings Canadian Hydrographic Conference, Victoria , B.C., March 10-12, 1998. pp. 382-393.

Jackson, R.G. 1986. Effects of bark accumulation on benthic infauna at a log transfer facility in S.E. Alaska. Mar. Pollut. Bull. 17: 258-262.

Kathman, R.D., S.F. Cross, and M. Waldichuk. 1984. Effects of wood waste on the recruitment potential of marine benthic communities. Can. Tech. Rep. Fish. Aquat. Sci. 1284: 50 pp.

McDaniel, N.G. 1973. A survey of the benthic macroinvertebrate fauna and solid pollutants in Howe Sound. Fish. Res. Board. Can. Tech. Rep. 385: 64 pp.

McDaniel, N.G., R.D. Macdonald, J.J. Dobrocky, and C.D. Levings. 1977. Biological surveys using in-water photography at three ocean disposal sites in the Strait of Georgia, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 713: 41 pp.

McGreer, E.R., D.R. Munday, and M. Waldichuk. 1985. Effects of wood waste for ocean disposal on the recruitment of marine macrobenthic communities. Can. Tech. Rep. Fish. Aquat. Sci. 1398: 29 pp.

Menzie, C.A. 1984. Diminishment of recruitment: a hypothesis concerning impacts on benthic communities. Mar. Pollut. Bull. 15: 127-128.

O'Clair, C.E., and L. Freese. 1985. Responses of Dungeness crabs, *Cancer magister*, exposed to bark debris from benthic deposits at log transfer facilities: survival, feeding and reproduction. *In* B.R. Melteff (Symp. Coord.). Proceedings of the Symposium on Dungeness Crab Biology and Management. Alaska Sea Grant Report No. 85-3, Fairbanks, Alaska. pp. 227-229. (abstract only).

O'Clair, C.E., and L. Freese. 1988. Reproductive condition of Dungeness crabs, *Cancer magister* at or near log transfer facilities in Southeastern Alaska. Mar. Environ. Res. 26: 57-91.

Pease, B.C. 1974. Effects of log dumping and rafting on the marine environment of southeast Alaska. USDA Gen. Tech. Rep. PNW-22. 58 pp.

Pickard, G.L. 1961. Oceanographic features of inlets in the British Columbia mainland coast. J. Fish. Res. Board. Can. 18: 907-999.

Sedell, J.R., and W.S. Duval. 1985. Influence of Forest and Rangeland Management on anadromous fish habitat in Western North America. 5: Water transportation and storage of logs. USDA Gen. Tech. Rep. PNW-186. 67 pp.

Sedell, J.R., F.N. Leone, and W.S. Duval. 1991. Water Transportation of Logs, p.325-367. *Edited by* W.R. Mehan. *In* Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. Amer. Fish. Soc. Spec. Publ. 19. Bethesda, Maryland, U.S.A.

Stanhope, M.J. 1983. The effect of estuarine log debris on the population characteristics and parameters of the benthic salmon food organisms in the Squamish Estuary, B.C. Report available from Woodlands Services Division, MacMillan Bloedel Ltd., 65 Front St. Nanaimo, B.C., Canada. V9R 5H9.

Stanhope, M.J., and C.D. Levings. 1985. Growth and production of *Eogammarus confervicolus* (Amphipoda: Anisogammaridae) at a log storage site and in areas of undisturbed habitat within the Squamish Estuary, British Columbia. Can. J. Fish. Aquat. Sci. 42: 1733-1740.

Stanhope, M.J., D.W. Powell, and E.B. Hartwick. 1987. Population characteristics of the estuarine isopod *Gnorimosphaeroma insulare* in three contrasting habitats: sedge marsh, algal bed, and wood debris. Can. J. Zool. 65: 2097-2104.

Terra Surveys Limited. 1998. Hydrographic and substrate survey of selected log handling sites: Douglas Channel and Gardner Canal (Kitimat, B.C.). Terra Surveys Limited, Sidney, B.C. Report 72-363. Prepared and submitted to Fisheries and Oceans Canada, West Vancouver, B.C.

Terra Surveys Limited. 1999. Hydrographic and substrate survey of selected log handling sites: Douglas Channel and Kildala Arm (Kitimat, B.C.). Terra Surveys Limited, Sidney, B.C. Report 72-382. Prepared and submitted to Fisheries and Oceans Canada, West Vancouver, B.C.

Vance, I., S.O. Stanley, and C.M. Brown. 1982. The Loch Eil Project: cellulose-degrading bacteria in the sediments of Loch Eil and the Lynn of Lorne. J. Exp. Mar. Bio. Ecol. 56: 267-278.

Walker, J.D. 1974. Effects of bark debris on benthic macrofauna of Yaquina Bay, Oregon. M. Sc. Thesis. Oregon State University, Corvallis. 94 pp.

White, E. 1999. Biological survey: Ochwe Bay log dump, Gardner Canal, March, 1999. Report prepared for Fisheries and Oceans Canada, West Vancouver, B.C. 44 pp.

H. TABLES

Table 1. Summary of log dumping from Southeast Alaska (adapted from Pease 1974).

Site	Years of use	Years of inactivity before study	Volume dumped (m^3)	Depth of wood debris (cm)	Approximate area affected (ha)
Thorne Bay	10	0	1 297 083	60 to 90	0.57
Mud Bay	7	0	495 250	30 to 60	0.57
Hanus bay	1	0	18 867	5 to 8	0.08
Starrigan Bay	3	1	16 508	—	0.14
Eagle Bay	1	2	63 675	30 to 60	0.04
Rodman Bay	7	5	382 050	—	0.04
Katlian Bay	6	7	266 492	—	0.04
Nakwisina Sound	2	11	87 258	—	0.08

Table 2. Summary of log dumping from the north coast of British Columbia (adapted from White 1999).

Site	Years of use	Volume dumped (m^3)	Depth of wood debris (cm)	Total area affected (ha)
Steamer Passage	3	41 000	0 to 20	0.2
Marion Creek	2	30 000	0 to 15	0.05
Kitkiata Inlet	5	327 022	0 to 20	0.15
Chambers Creek	3	88 000	5 to 50	0.25

I. FIGURES

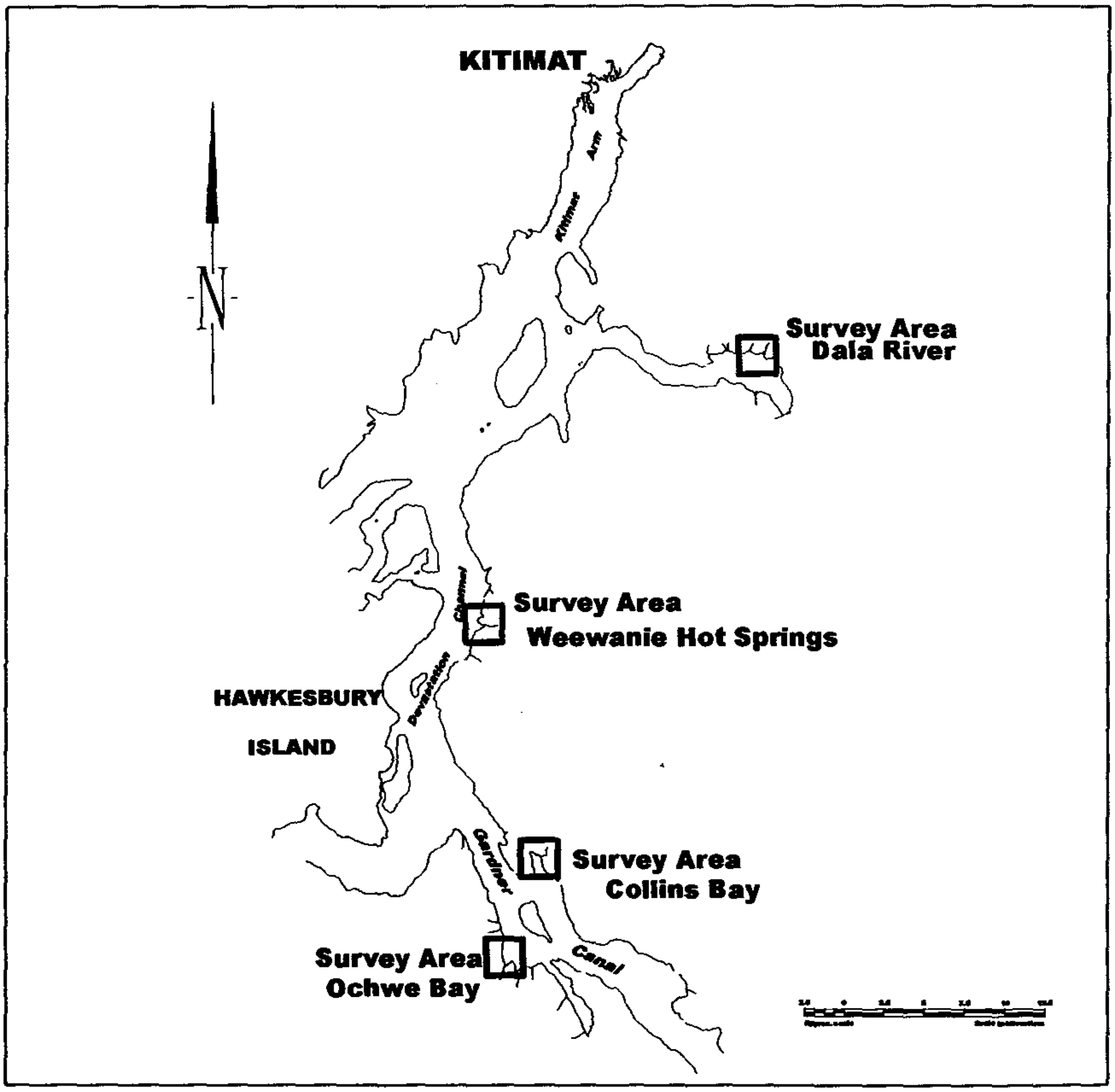


Figure 1. Map of Gardner Canal showing the four log dump survey sites (adapted from Terra Surveys Limited 1998, 1999).

Figure 2. Map of the Dala River log dump showing contoured bathymetry data (Terra Surveys Limited 1999).

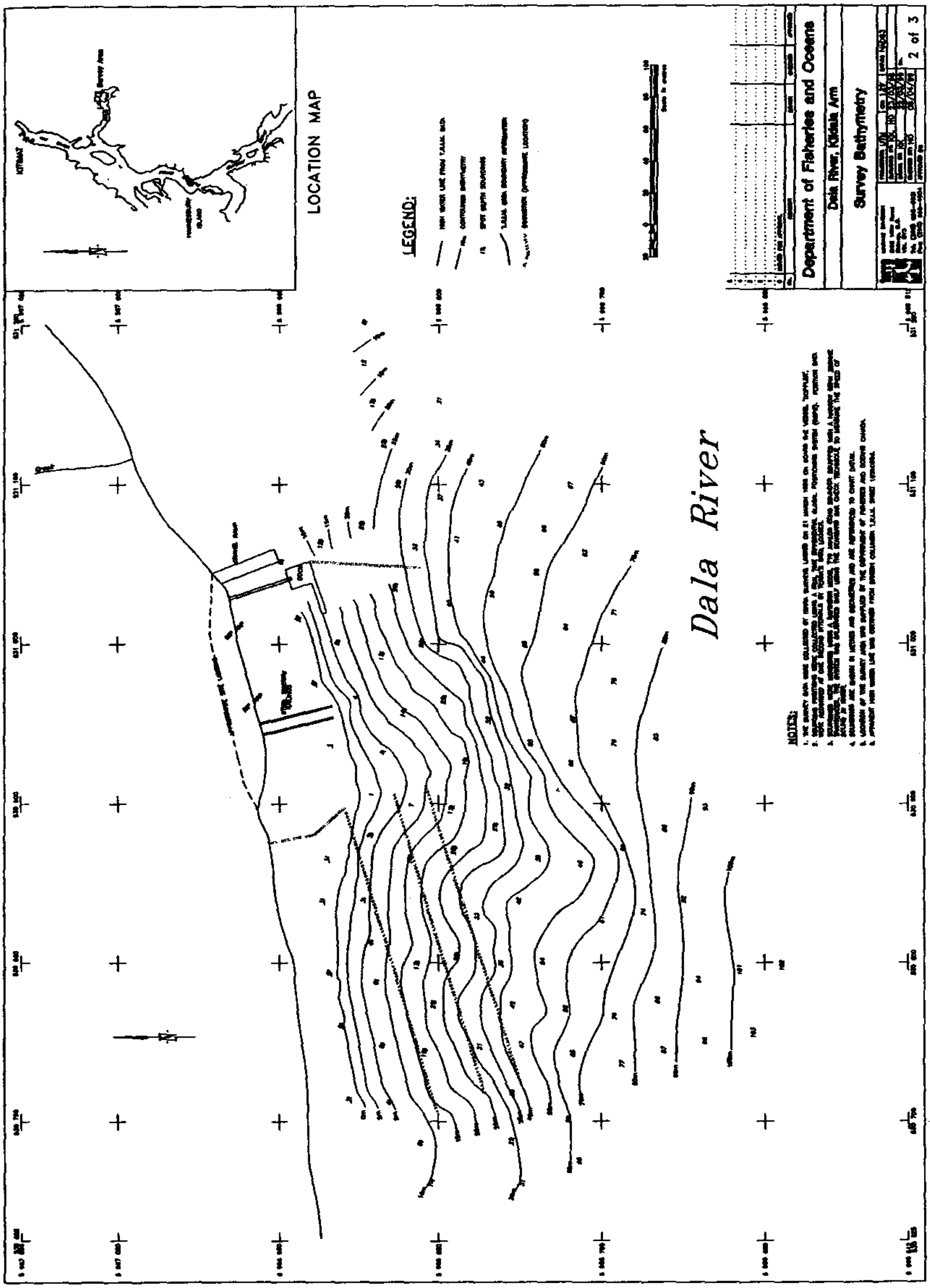

LOCATION MAP
LEGEND:
NOTES:
Dala River
Department of Fisheries and Oceans
Dala River, Kildala Arm
Survey Bathymetry
2 of 3

Figure 3. Map of the Weewanie Hotsprings log dump showing contoured bathymetry data (Terra Surveys Limited 1999).

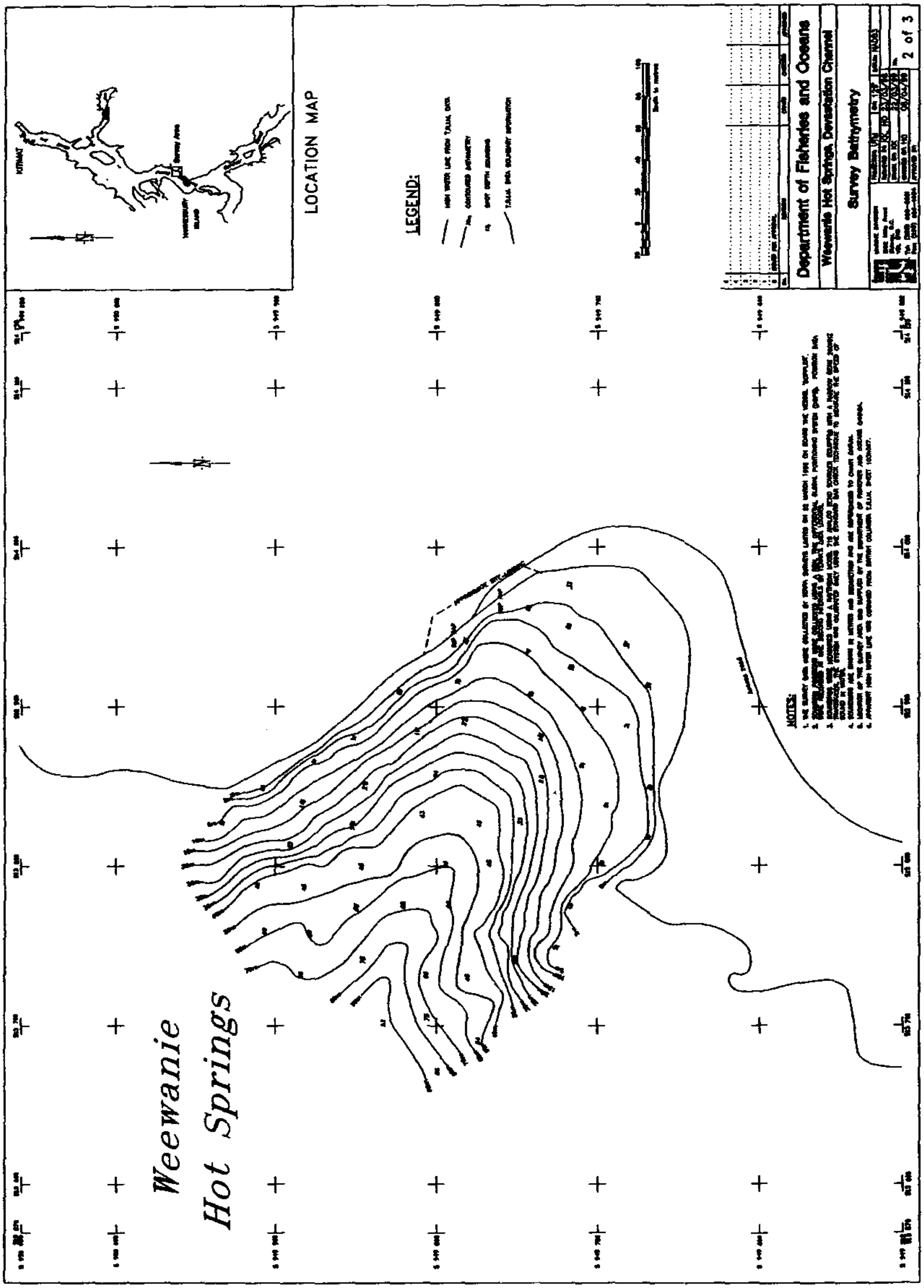

Weewanie
Hot Springs
LOCATION MAP
LEGEND:
NOTES:
Department of Fisheries and Oceans
Weewanie Hot Springs, Devastation Channel
Survey Bathymetry
2 of 3

Figure 4. Map of the Ochwe Bay log dump showing hand-contoured bathymetry overlaid onto the original spot bathymetry map from Terra Surveys Limited (1998).

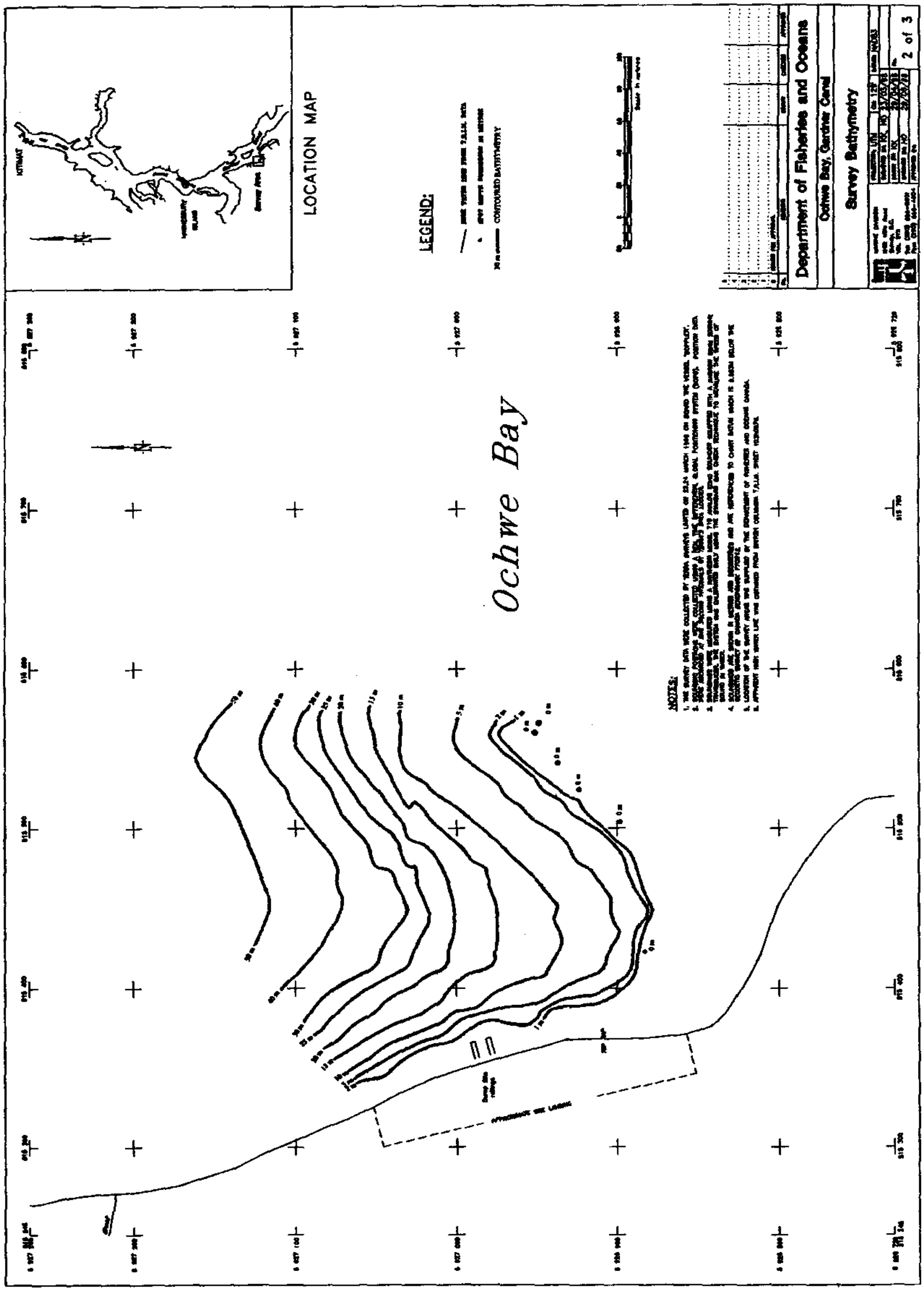
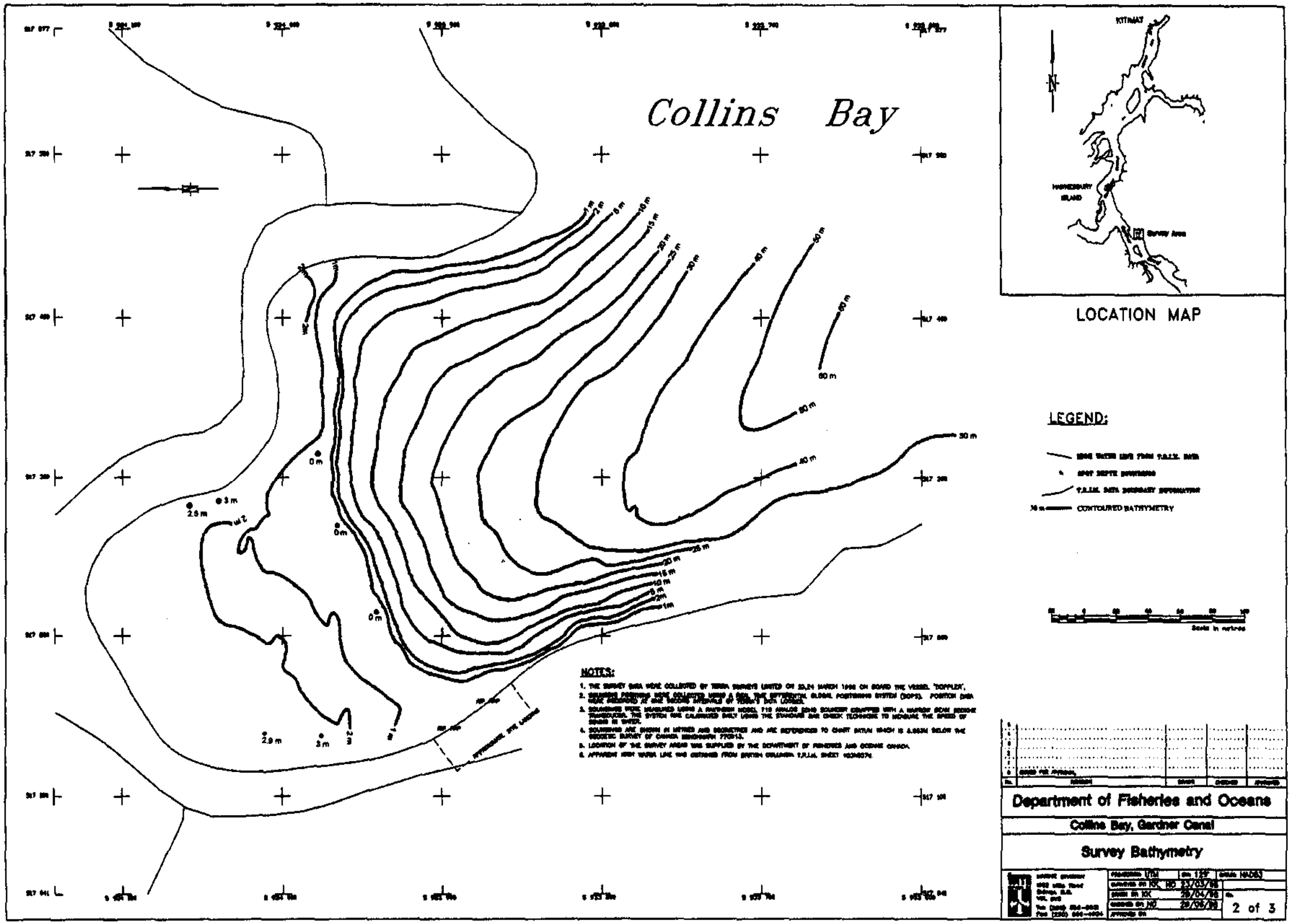

LOCATION MAP
LEGEND:
Ochwe Bay
NOTES:
Department of Fisheries and Oceans
Ochwe Bay, Gardner Canal
Survey Bathymetry
2 of 3

Figure 5. Map of the Collins Bay log dump hand-contoured bathymetry overlaid onto the original spot bathmetry map from Terra Surveys Limited (1998).


Collins Bay
LOCATION MAP
KITIMAT
LEGEND:
CONTOURED BATHYMETRY
NOTES:
Department of Fisheries and Oceans
Collins Bay, Gardner Canal
Survey Bathymetry
2 of 3

This page left blank purposely

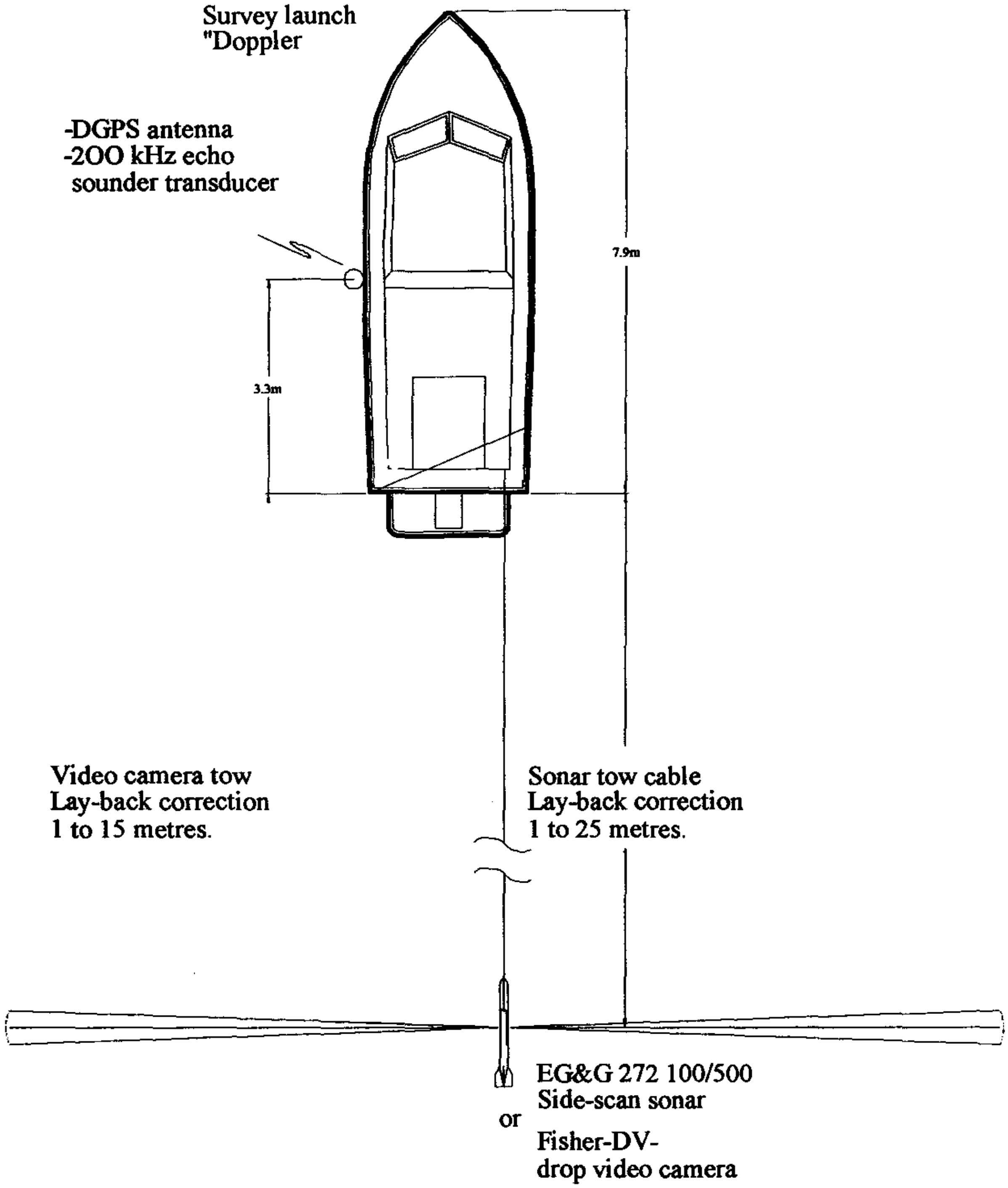


Figure 6. Survey boat and equipment configuration for the hydrographic survey (adapted from Terra Surveys Limited 1998, 1999).

This page left blank purposely

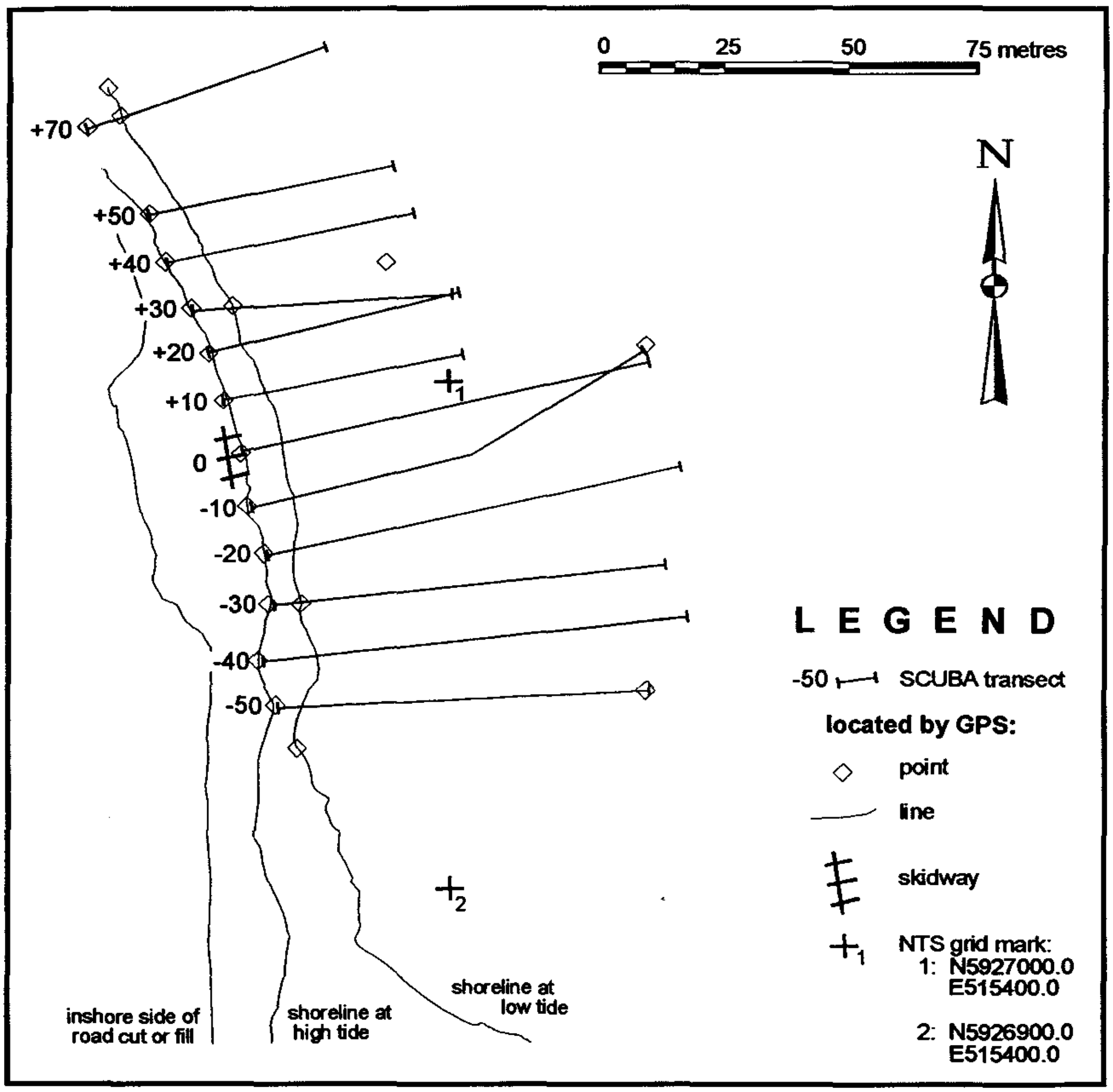


Figure 7. Scuba survey transects at Ochwe Bay for observations made in March, 1999 (White 1999).

Figure 8. Map of the Dala River log dump showing sea floor features that were interpreted from side-scan sonar (Terra Surveys Limited 1999).

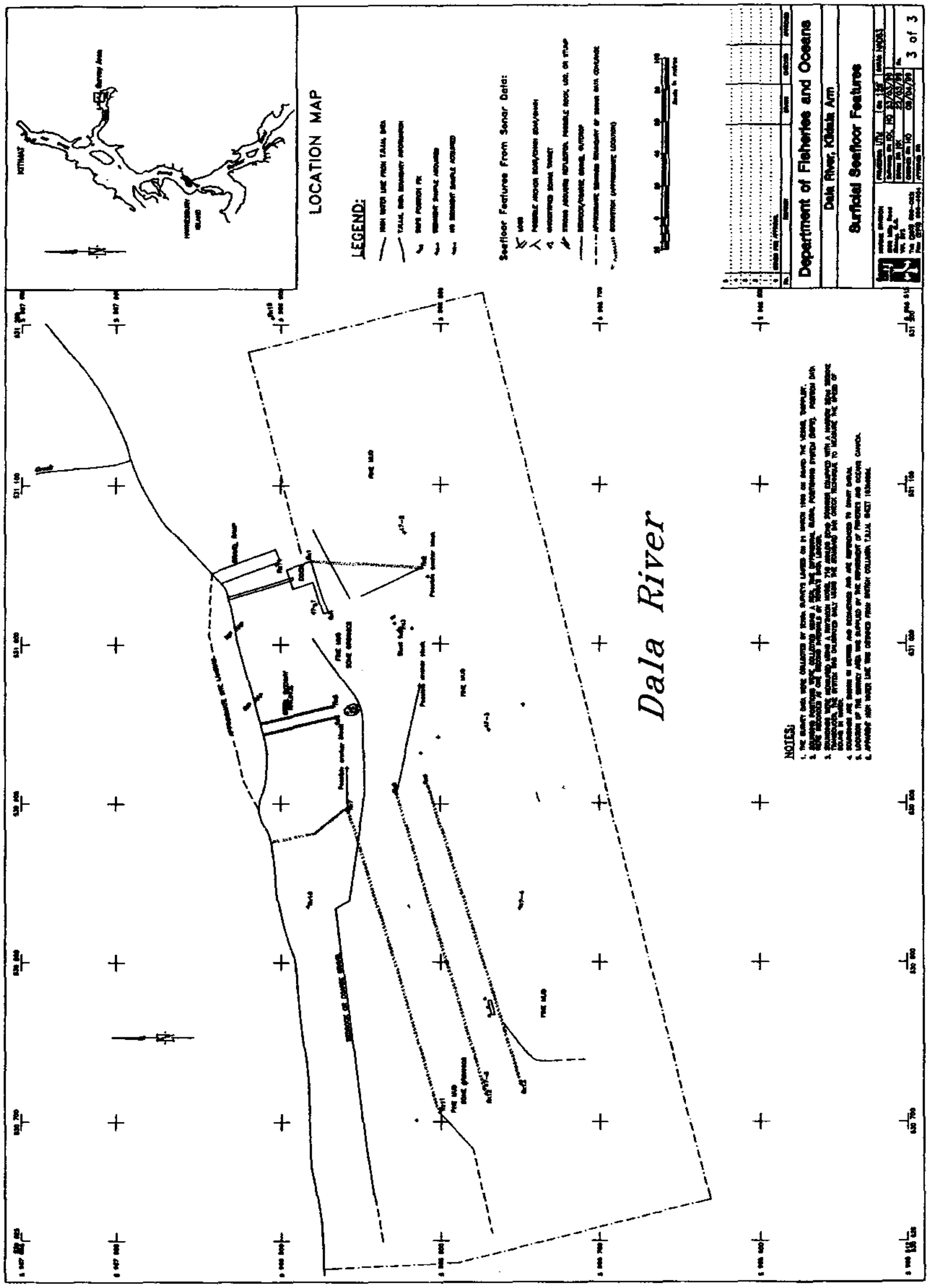

LOCATION MAP
LEGEND:
Seafloor Features From Sonar Data:
Dala River
NOTES:
Department of Fisheries and Oceans
Dala River, Kildala Arm
Surficial Seafloor Features
3 of 3

Figure 9. Map of the Dala River log dump showing the survey lines for the side-scan, echo sounding, and video surveys (Terra Surveys Limited 1999).

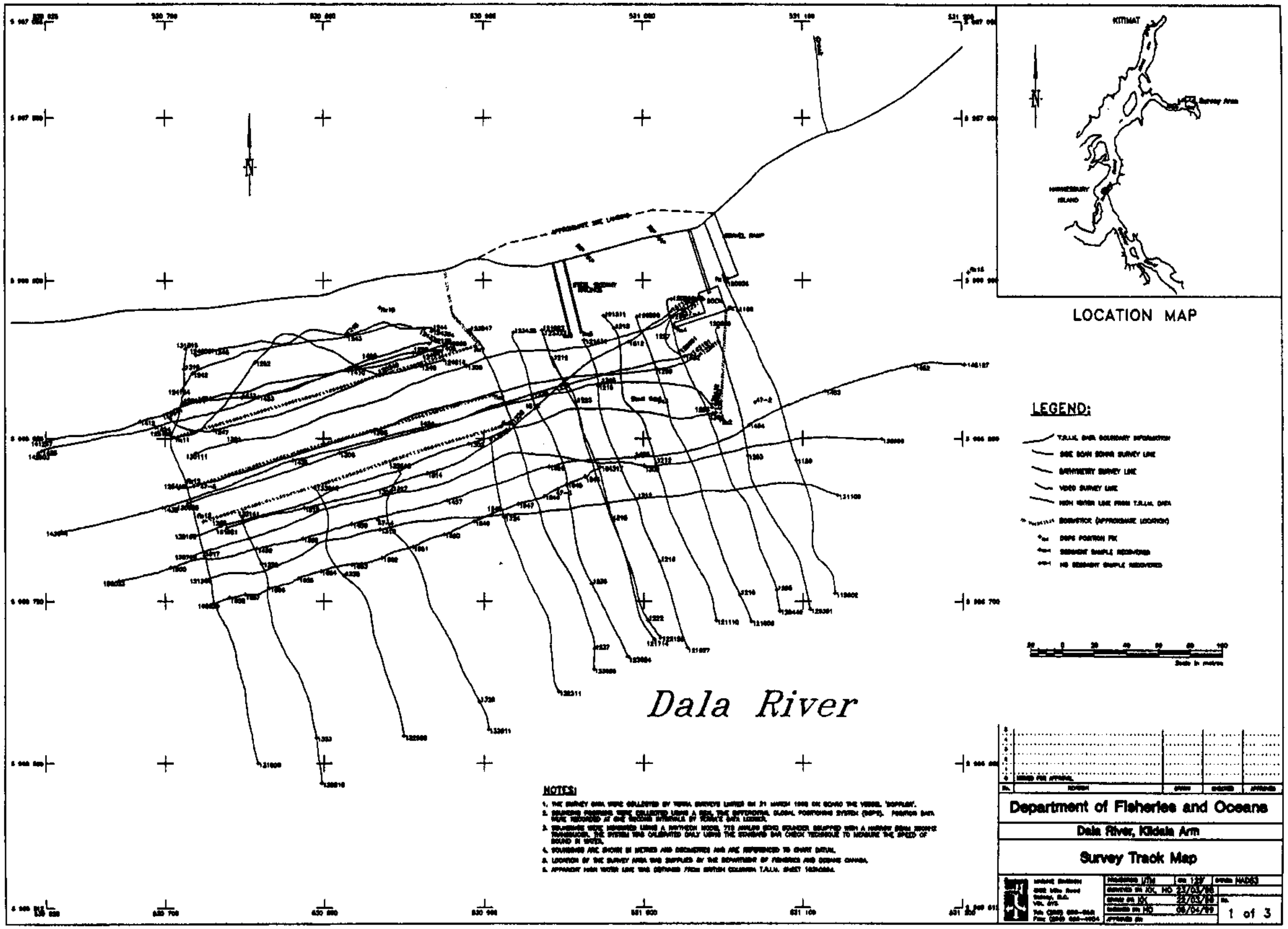

KITIMAT
LOCATION MAP
LEGEND:
Dala River
NOTES:
Department of Fisheries and Oceans
Dala River, Kildala Arm
Survey Track Map
1 of 3

Figure 10. Map of the Weewanie Hotsprings log dump showing sea floor features that were interpreted from side-scan sonar (Terra Surveys Limited 1999).

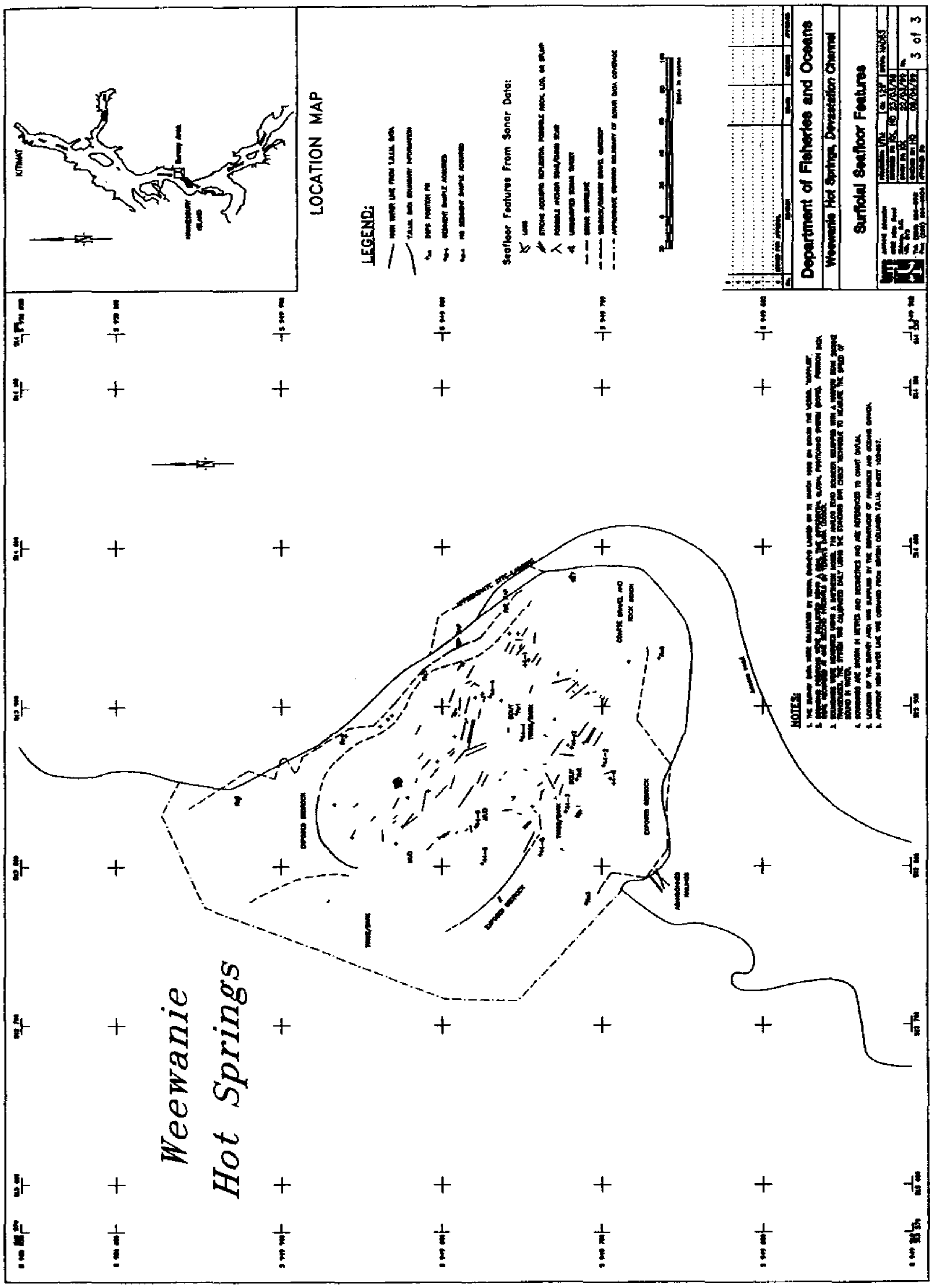

Weewanie
Hot Springs
LOCATION MAP
LEGEND:
Seafloor Features From Sonar Data:
NOTES:
Department of Fisheries and Oceans
Weewanie Hot Springs, Devastation Channel
Surficial Seafloor Features
3 of 3

Figure 11. Map of the Weewanie Hotsprings log dump showing the survey lines for the side-scan, echo sounding, and video surveys (Terra Surveys Limited 1999).

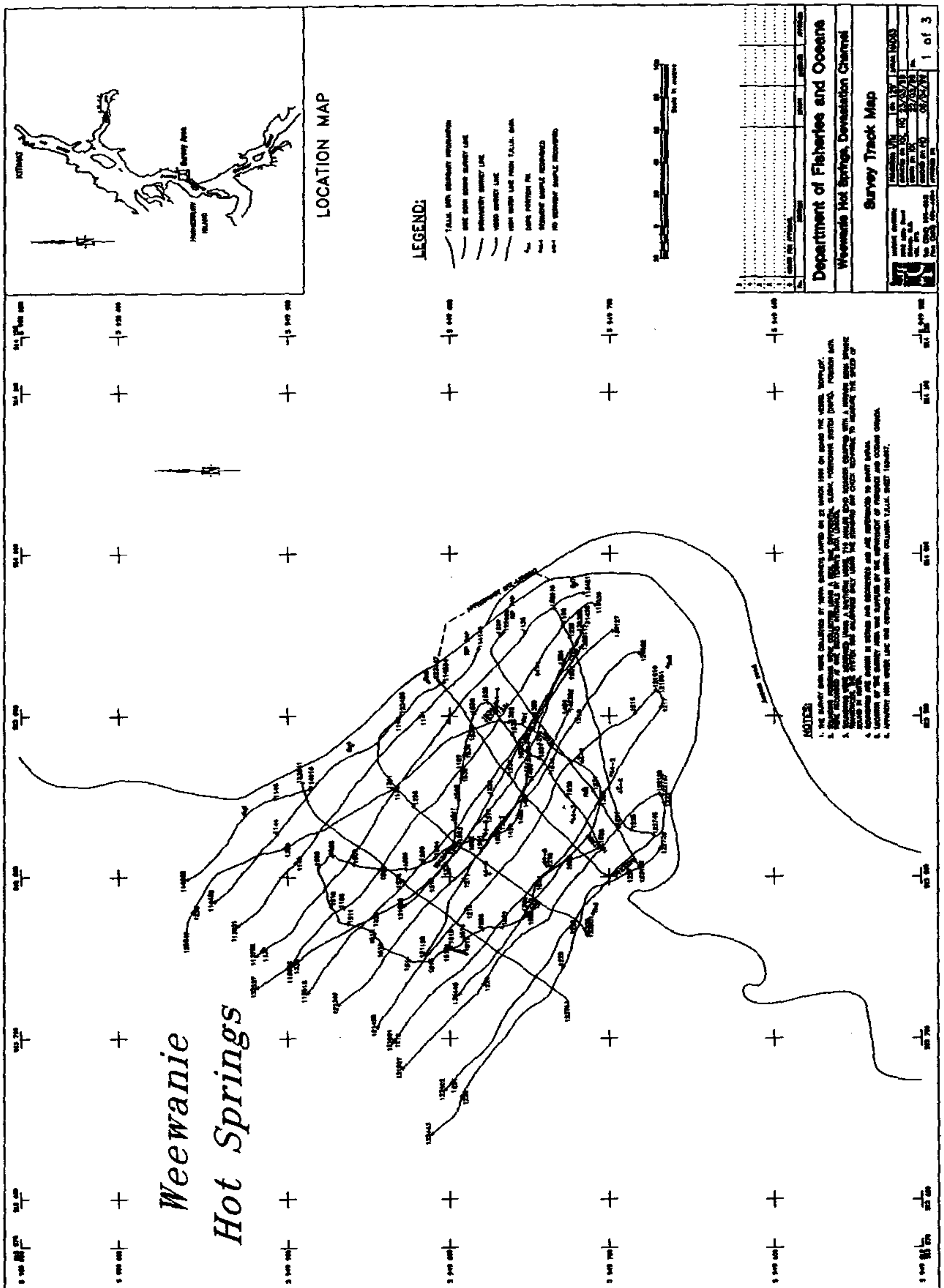
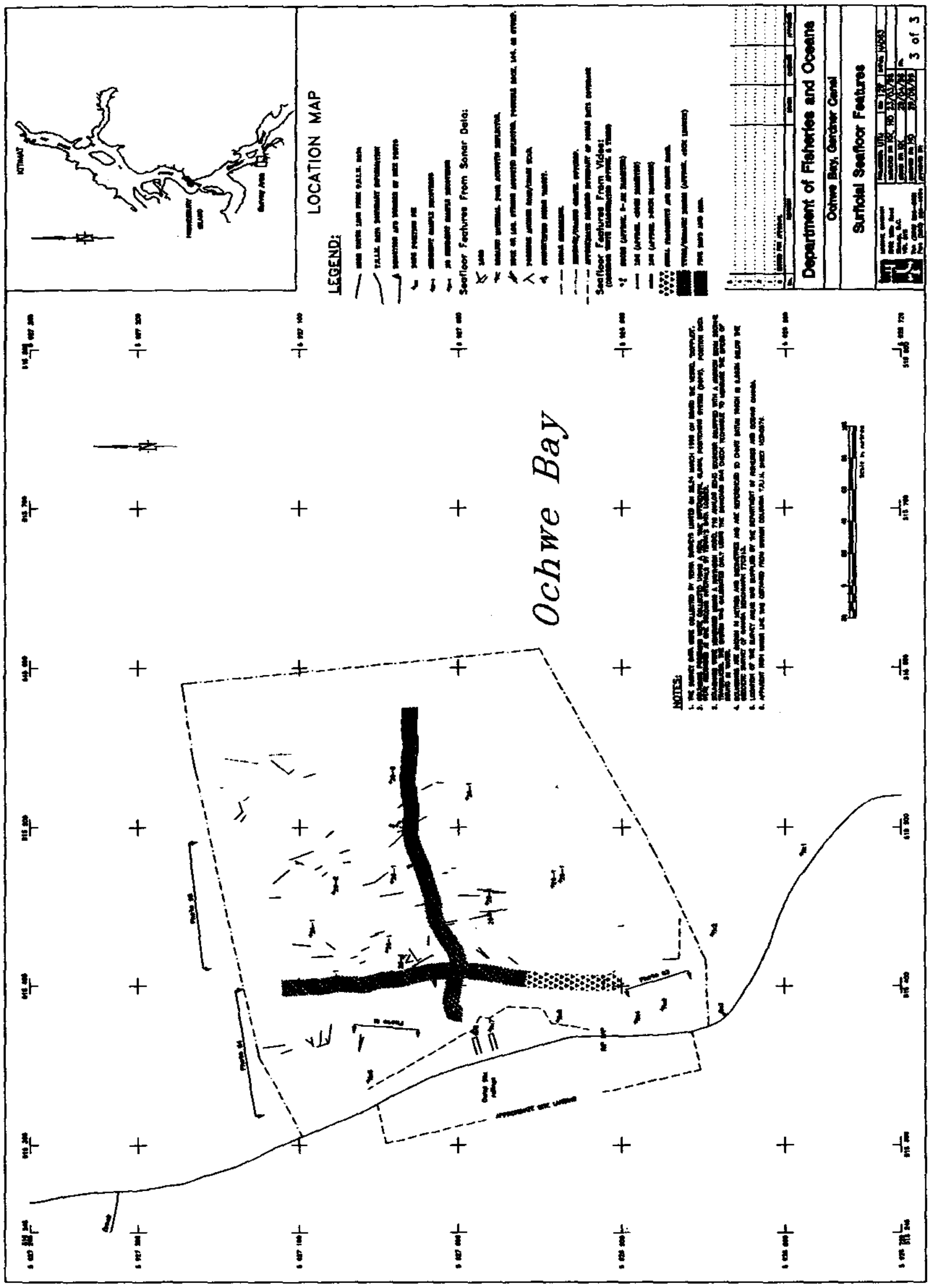

Weewanie
Hot Springs
LOCATION MAP
LEGEND:
NOTES:
Department of Fisheries and Oceans
Weewanie Hot Springs, Devastation Channel
Survey Track Map
1 of 3

Figure 12. Map of the Ochwe Bay log dump showing sea floor features that were interpreted from side-scan sonar (Terra Surveys Limited 1998).



Ochwe Bay
LOCATION MAP
LEGEND:
Seafloor Features From Sonar Data:
Seafloor Features From Video:
NOTES:
Department of Fisheries and Oceans
Ochwe Bay, Gardner Canal
Surficial Seafloor Features
3 of 3

Figure 13. Map of the Ochwe Bay log dump showing the survey lines for the side-scan, echo sounding, and video surveys (Terra Surveys Limited 1998).

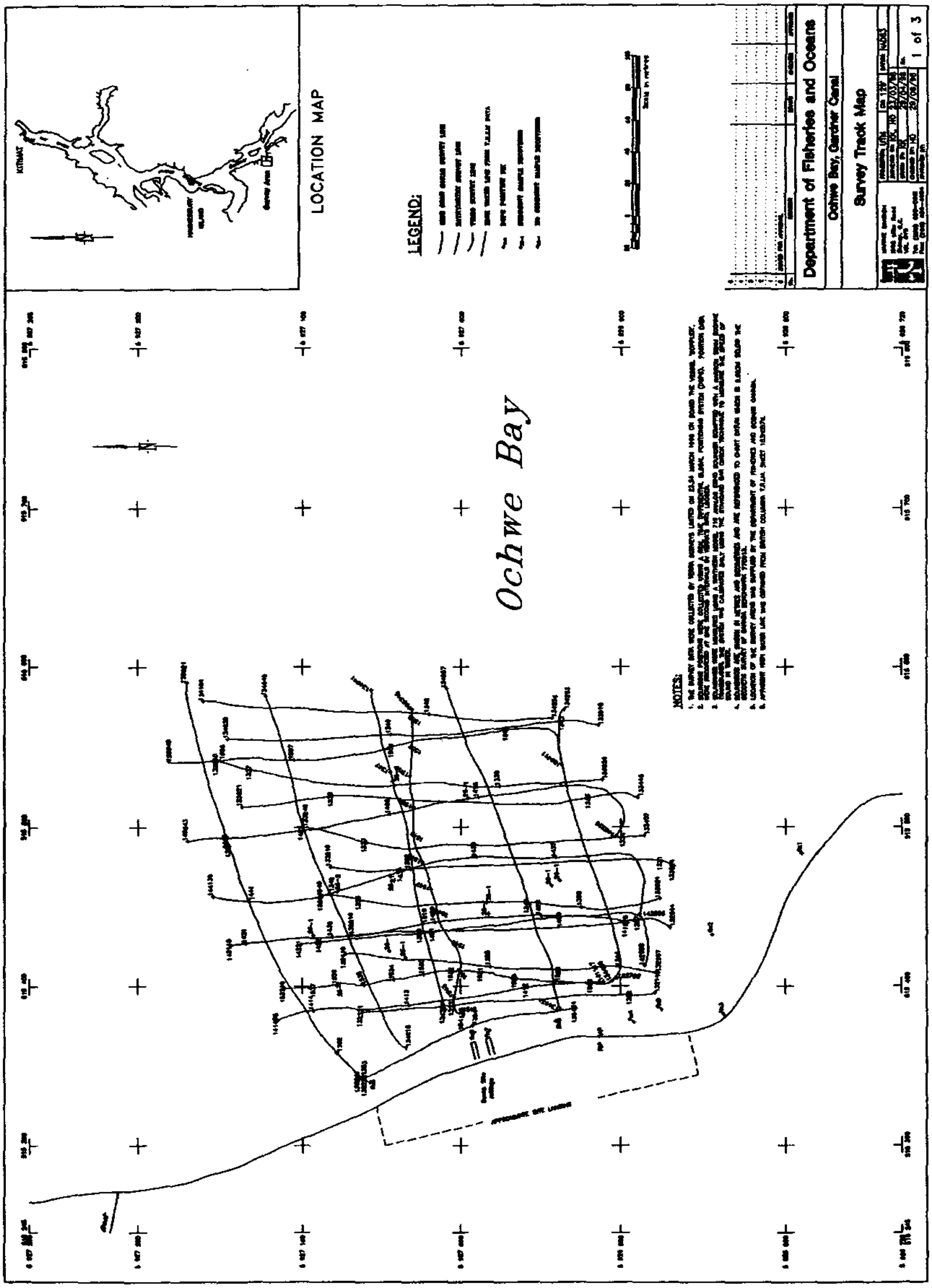
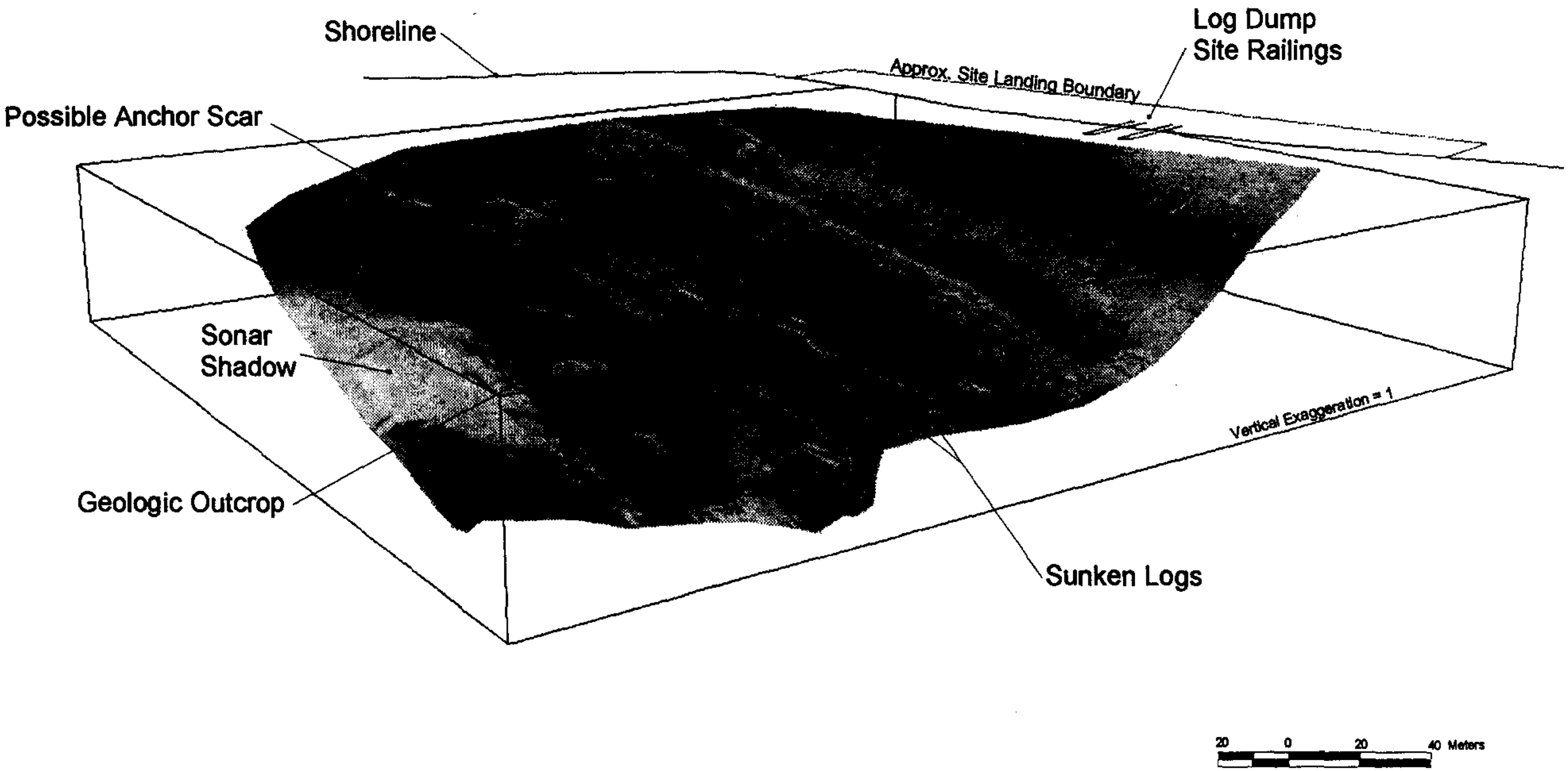

LOCATION MAP
LEGEND:
Ochwe Bay
NOTES:
Department of Fisheries and Oceans
Ochwe Bay, Gardner Canal
Survey Track Map
1 of 3

Figure 14. Three-dimensional mosaic of sea floor features at Ochwe Bay, developed from side-scan sonar (Terra Surveys Limited 1998).

Sea Floor Mapping

3-D Representation



terra surveys ltd
MARINE DIVISION
1962 Mills Road
Sidney, B.C. Canada V8L 5Y3
Phone: (250) 656-0931
Fax: (250) 656-4604
Email: terra@ sidney.terrasurveys.com

Funding provided by Department of Fisheries and Oceans Branch,
Department of Fisheries and Oceans Habitat and Enhancement Branch,
and the Canadian Ocean Frontiers Initiative.
Scientific Authority: Colin Levings, Science Branch, West Vancouver Laboratory

NOTES:
Sidescan sonar and bathymetric data was used to create this georeferenced product for the purpose of studying the impacts of coastal log dumping grounds on marine habitat.

This page left blank purposely

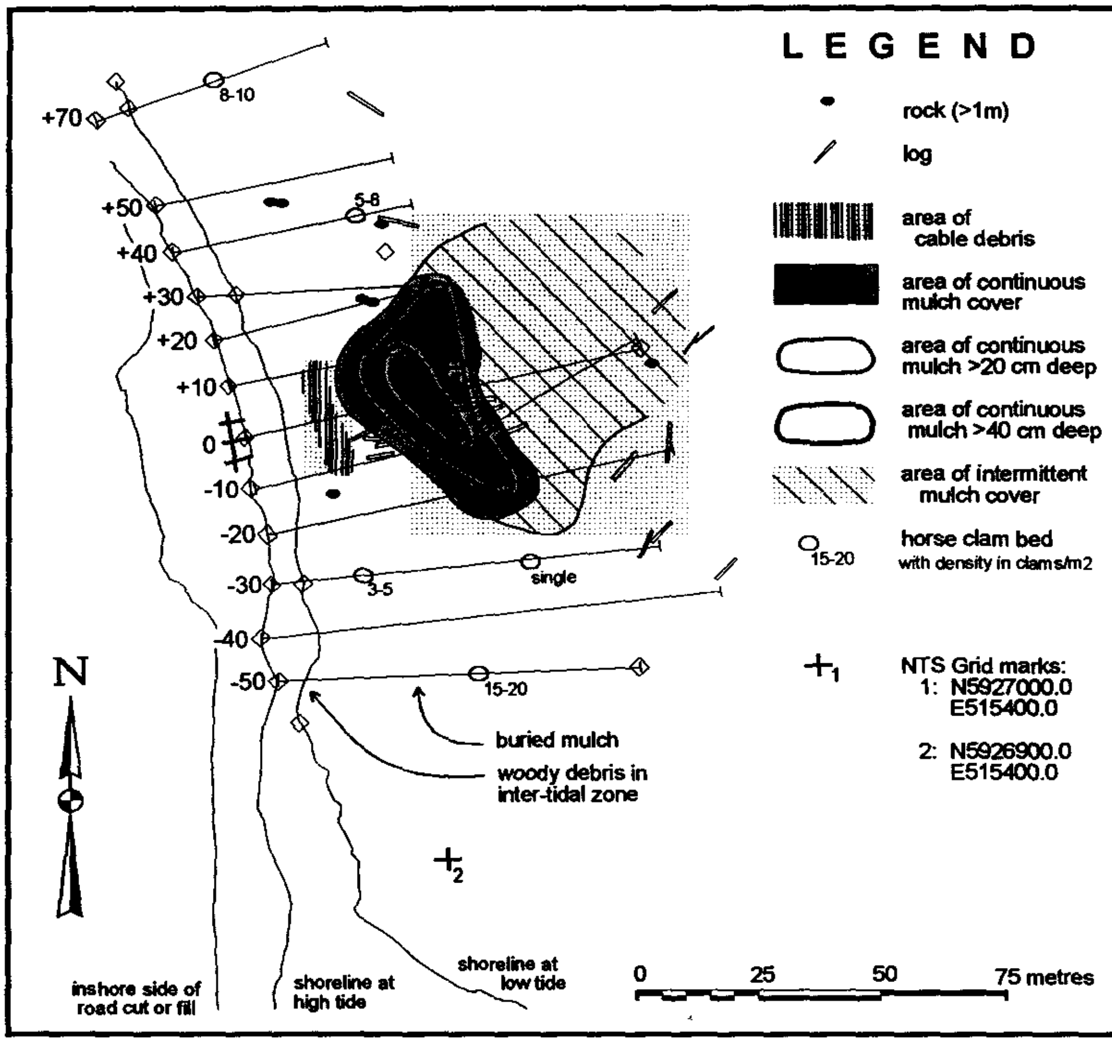


Figure 15. Map of the areal extent of sea floor debris observed at Ochwe Bay during the SCUBA survey (White 1999).

Figure 16. Map of the Collins Bay log dump showing sea floor features that were interpreted from side-scan sonar (Terra Surveys Limited 1998).

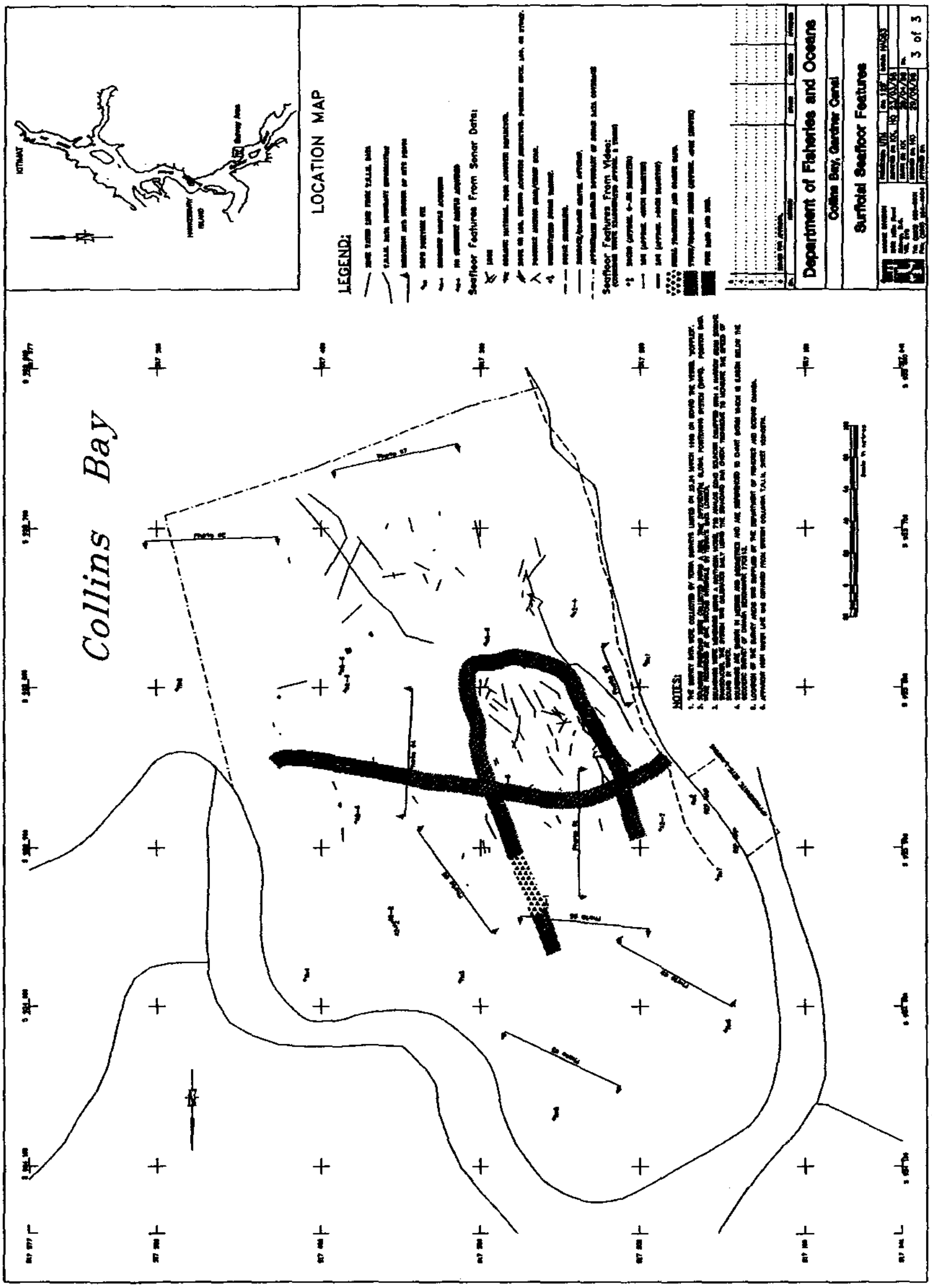
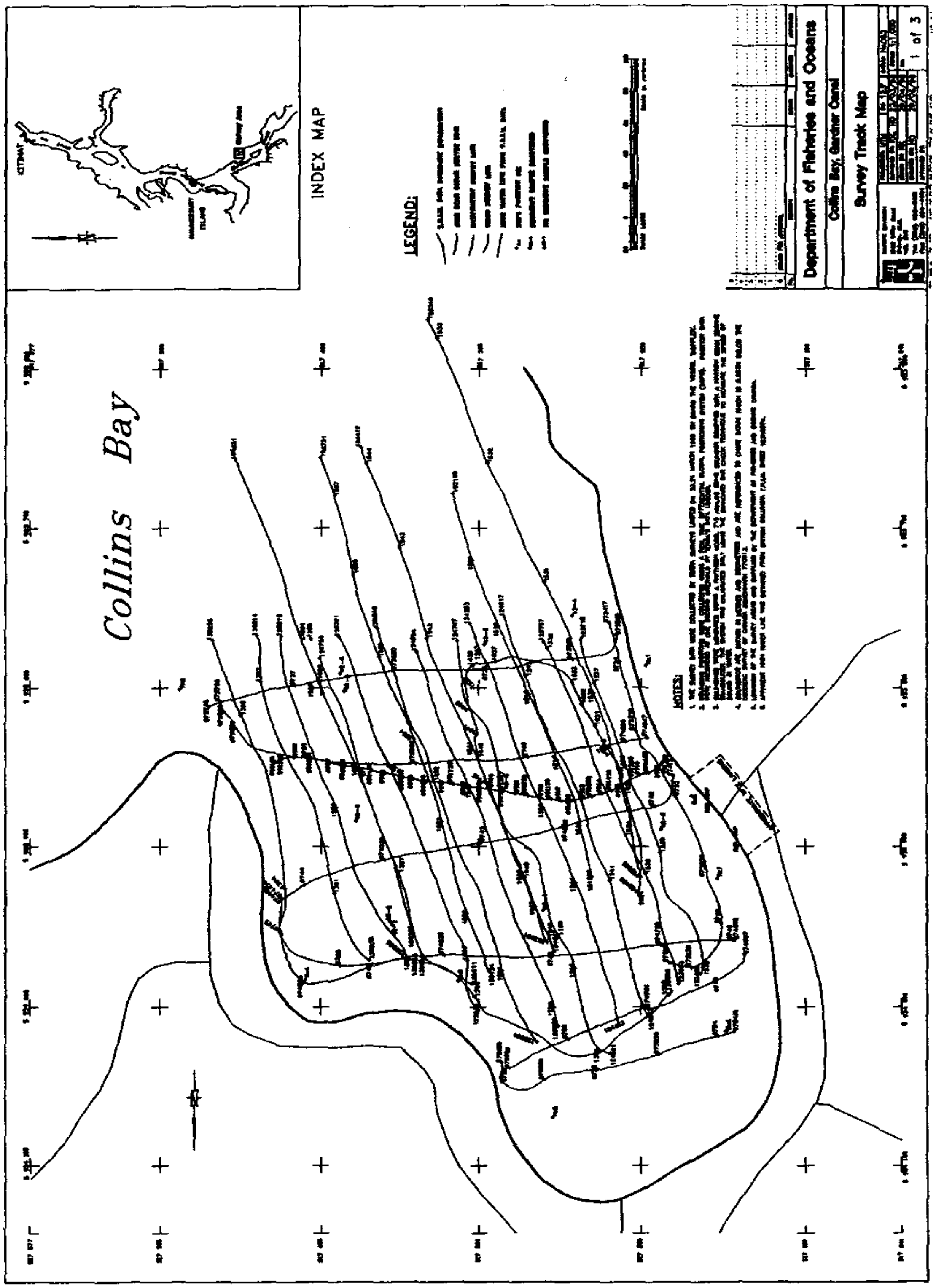

Collins Bay
LOCATION MAP
LEGEND:
Seafloor Features From Sonar Data:
Seafloor Features From Video:
NOTES:
Department of Fisheries and Oceans
Collins Bay, Gardner Canal
Surficial Seafloor Features
3 of 3

Figure 17. Map of the Collins Bay log dump showing the survey lines for the side-scan, echo sounding, and video surveys (Terra Surveys Limited 1998).


Collins Bay
INDEX MAP
LEGEND:
NOTES:
Department of Fisheries and Oceans
Collins Bay, Gardner Canal
Survey Track Map
1 of 3

This page left blank purposely

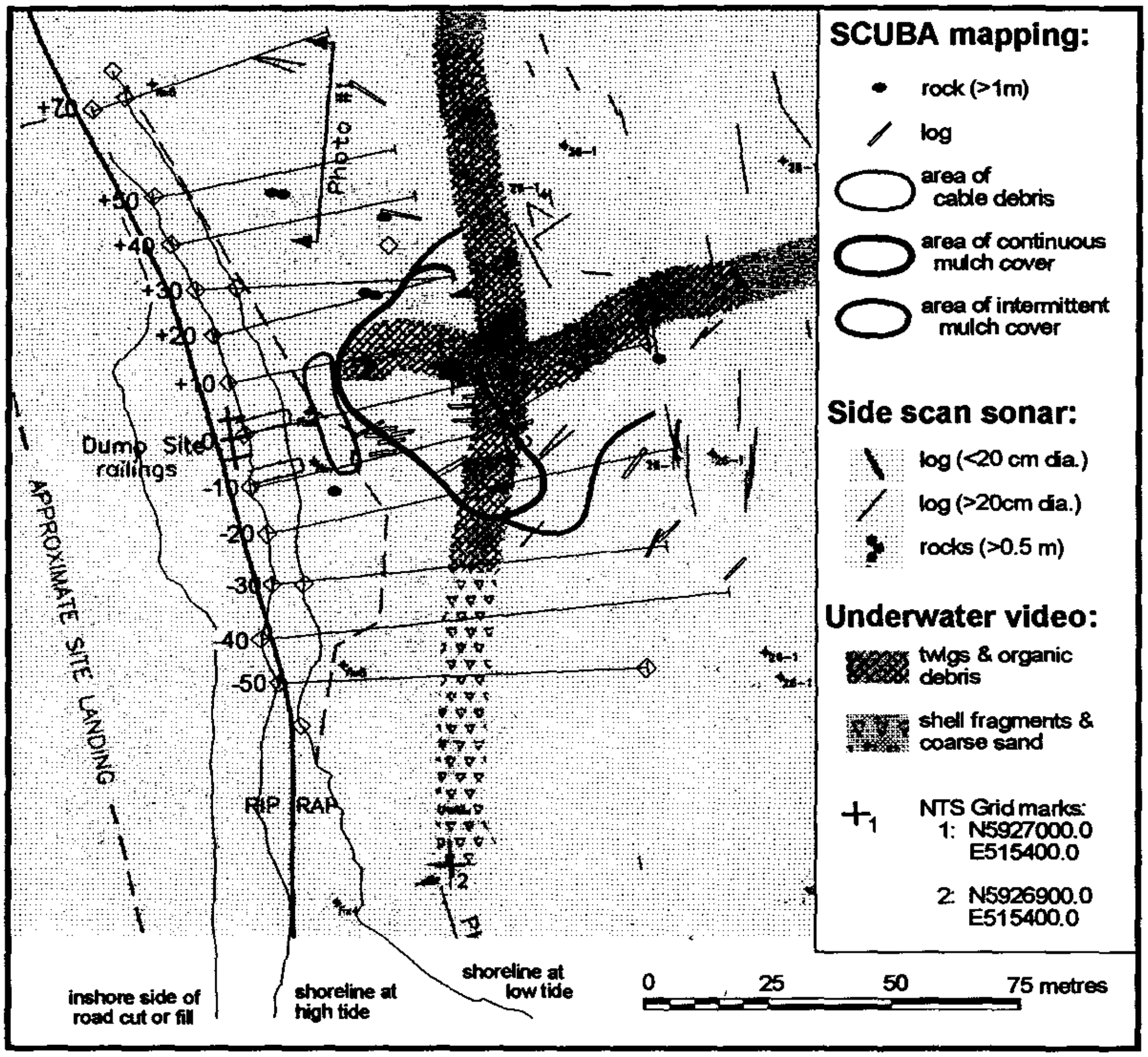


Figure 18. Comparison of the physical results of the SCUBA and side-scan surveys at Ochwe Bay (White 1999).

This page left blank purposely

J. APPENDICES

Appendix 1. Log dumps or proposed sites in the Douglas Channel area that were considered as potential study sites (from Department of Fisheries and Oceans, unpublished files, 1997). The survey data are available from Department of Fisheries and Oceans, North Coast Division, Prince Rupert, B.C.

ID	Location	Annual Activity	Volume (m^3)	Surveys
1	Chettleburgh Pt.	1983	B	None
2	Kiln Bay	1994-1995	70,000-90,000	Archipelago 1994
3	Drake Inlet 1	1981	B	None
4	Drake Inlet 2	1994- A	10,000-20,000	None
5	Cornwall Inlet	Proposed	C (160,000)	Archipelago 1994
6	Whalen Creek	Early 1980's	B	None
7	Twins Creeks	1985-1988	60,000	None
8	Fraser Reach	Proposed	C	Pending
9	Gribbell Creek	1990-1993	20,000	None
10	Chute Lake	1993-1994	30,000	None
11	Ursula Channel	Proposed	10,000	Archipelago 1996
12	Riorden Creek	1988-1990	50,000	None
13	East Gribbell Creek	Proposed	50,000-60,000	Archipelago 1995
14	Little Tillhorn Creek	Proposed	C	Eric White 1997
15	Big Tillhorn Creek	Proposed	C (50,000-90,000)	Pending
16	Kitkiata Inlet	1987-1989, 1997 A	30,000-150,000	None
17	Gertrude Point	1989-1990	70,000	None
18	Kihess Creek	1988-1990	70,000	None
19	South Kitsaway	Proposed	15,000-20,000	Archipelago 1995, 199?
20	Eva Point	Proposed, Rejected	C	Archipelago 1995
21	Danube Bay	Proposed, Rejected	C	Archipelago 1995
22	Cheenis Creek	1994- A	15,000-20,000	Eric White 1993
23	Goat Harbour	1994- A	10,000-30,000	Eric White 1993
24	Bishop Bay	1980-1984; 1988-1989	60,000-90,000	None
25	Verney Passage	Proposed	15,000-90,000	Archipelago 1996
26	Ochwe Bay	1990-1994	100,000-120,000	None
27	Trip Creek	1997- A	25,000-50,000	Archipelago 1995
28	Triumph Creek	1989- A	50,000-100,000	None
29	Alan Reach South	Proposed	20,000-30,000	Archipelago 1996
30	Kiltuish Inlet (Grizzly No. 1)	1987-1988	20,000	None
31	Kiltuish Inlet (Grizzly No. 3)	1988-1989	18,000	None
32	Kiltuish Inlet (TO 258)	1989-1990	20,000	None
33	Kiltuish Inlet (Block 4)	1989-1990	20,000	None
34	Kiltuish Inlet (Block 6)	1989-1990	45,000	None
35	Kiltuish Inlet (Block 7)	1989-1990	20,000	None
36	Barrie Creek	Proposed	C (20,000-70,000)	Pending
37	Chief Matthews Bay	Proposed	C	Pending
38	Kemano Bay	1970-1978; 1990; 1994	50,000-100,000	None

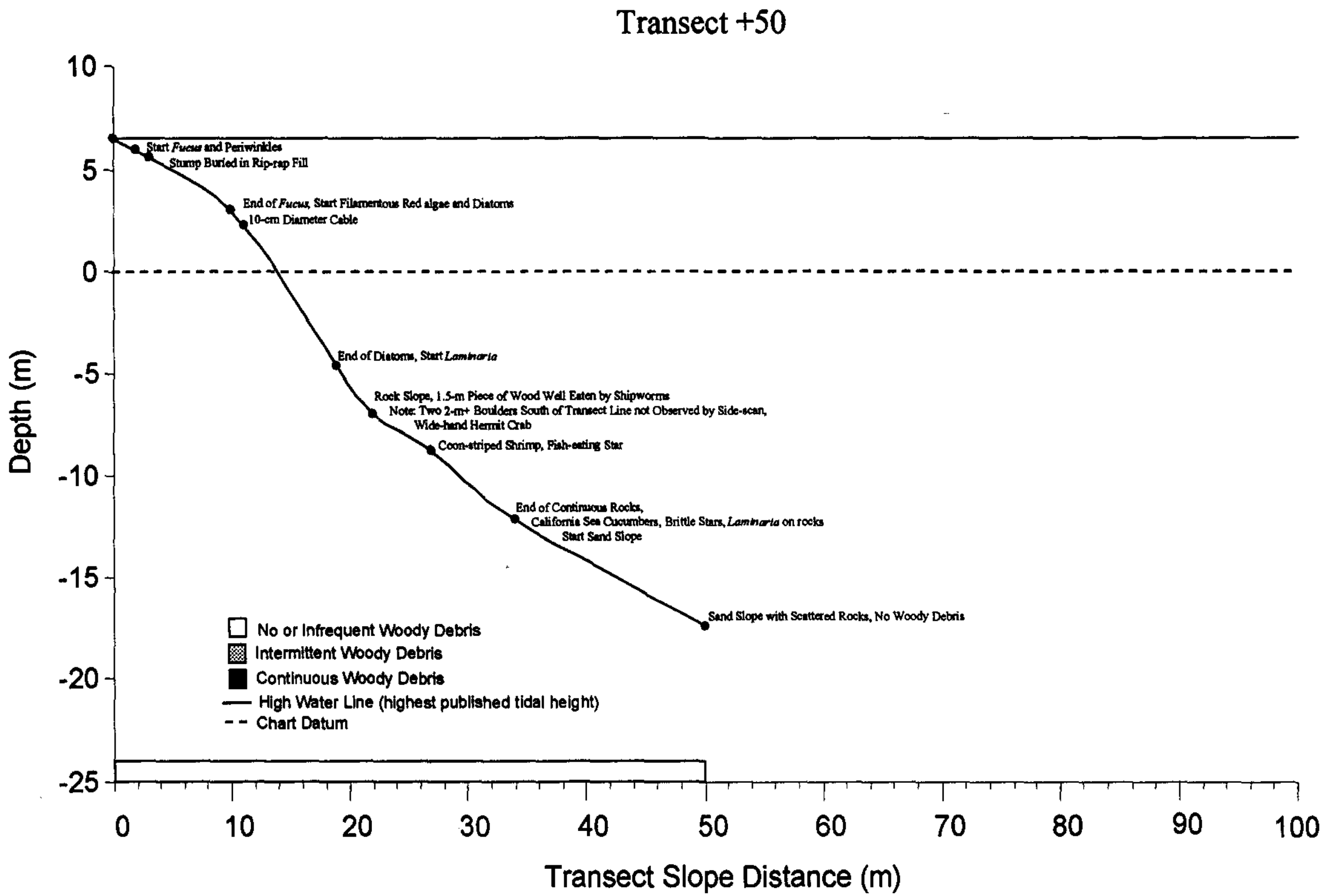
Appendix 1 (continued).

ID	Location	Annual Activity	Volume (m^3)	Surveys
39	Hotsprings Creek	1970, 1976; 1988-1990	25,000-30,000	None
40	Shearwater Point	1989, 1993	15,000-20,000	None
41	Barker Point	1989-1990	15,000-20,000	None
42	Collins Bay	1989-1994	50,000-120,000	None
43	Pike Creek	1995- A	50,000-100,000	None
44	Weewanie Creek	1970's	550,000	None
45	Eagle Bay	Proposed	50,000-60,000	Pending
46	Falls River	1991- A	50,000-120,000	None
47	Dala River	1992- A	80,000-130,000	None
48	Coste Island (1)	1980's	B	None
49	Coste Island (2)	Proposed	C (20,000)	Archipelago 1995
50	West Kitimat Arm	A	B	
51	Minette Bay (West)	B	B	
52	Minete Bay (East)	B	B	

A- Active operation in 1997.
B- Data not available.
C- Proposed site.
( )- Proposed volume.

Appendix 2. Profiles for the dive transects at Ochwe Bay (+50, 0, -20, -30, and -50) showing the wood debris distribution and the organisms observed. See Figure 15 for transect locations.

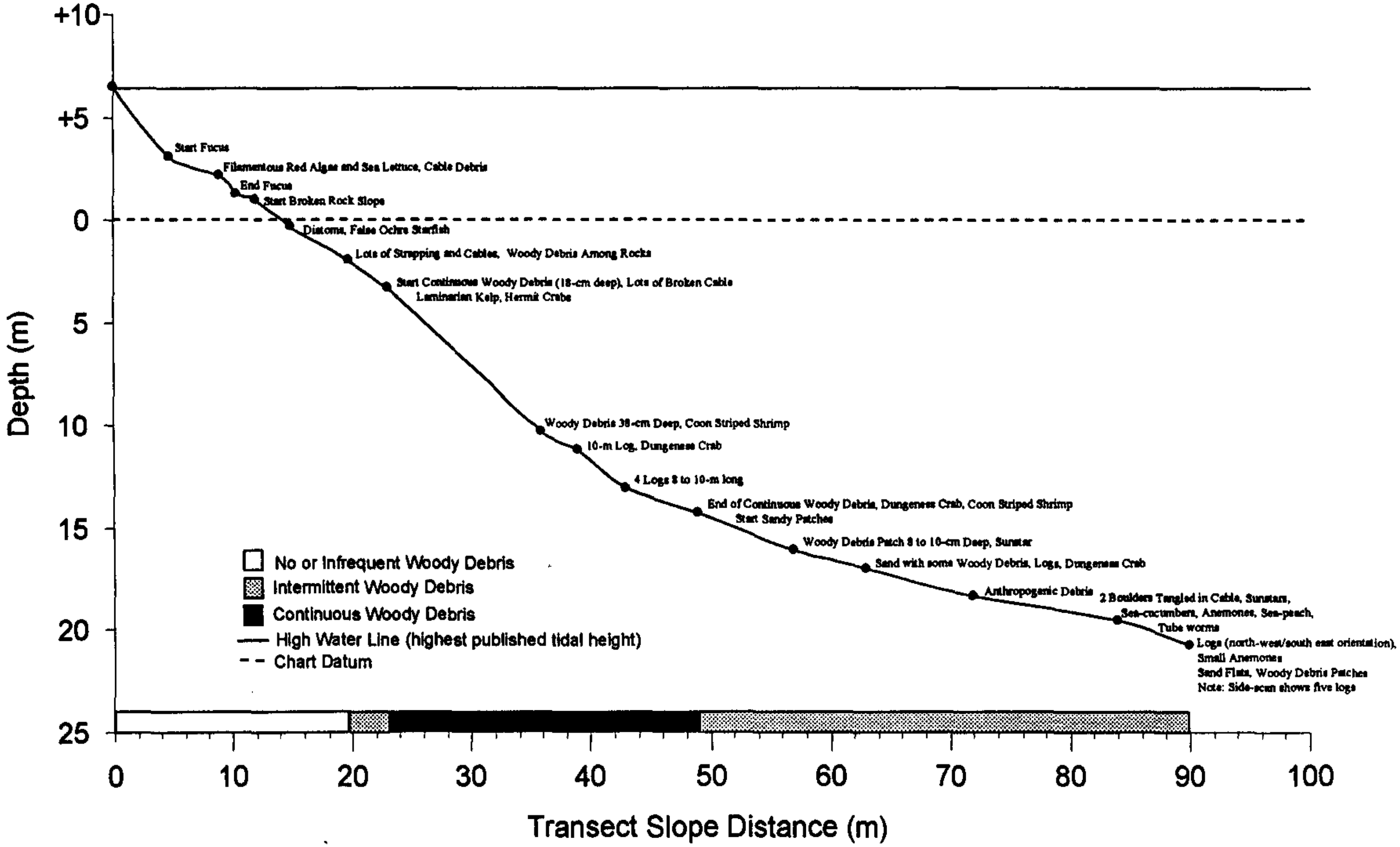
This page left blank purposely



Transect +50
10
5
0
-5
-10
-15
-20
-25
Depth (m)
Start Fucus and Periwinkles
Stump Buried in Rip-rap Fill
End of Fucus, Start Filamentous Red algae and Diatoms
10-cm Diameter Cable
End of Diatoms, Start Laminaria
Rock Slope, 1.5-m Piece of Wood Well Eaten by Shipworms
Note: Two 2-m+ Boulders South of Transect Line not Observed by Side-scan,
Wide-hand Hermit Crab
Coon-striped Shrimp, Fish-eating Star
End of Continuous Rocks,
California Sea Cucumbers, Brittle Stars, Laminaria on rocks
Start Sand Slope
Sand Slope with Scattered Rocks, No Woody Debris
No or Infrequent Woody Debris
Intermittent Woody Debris
Continuous Woody Debris
High Water Line (highest published tidal height)
Chart Datum
0
10
20
30
40
50
60
70
80
90
100
Transect Slope Distance (m)

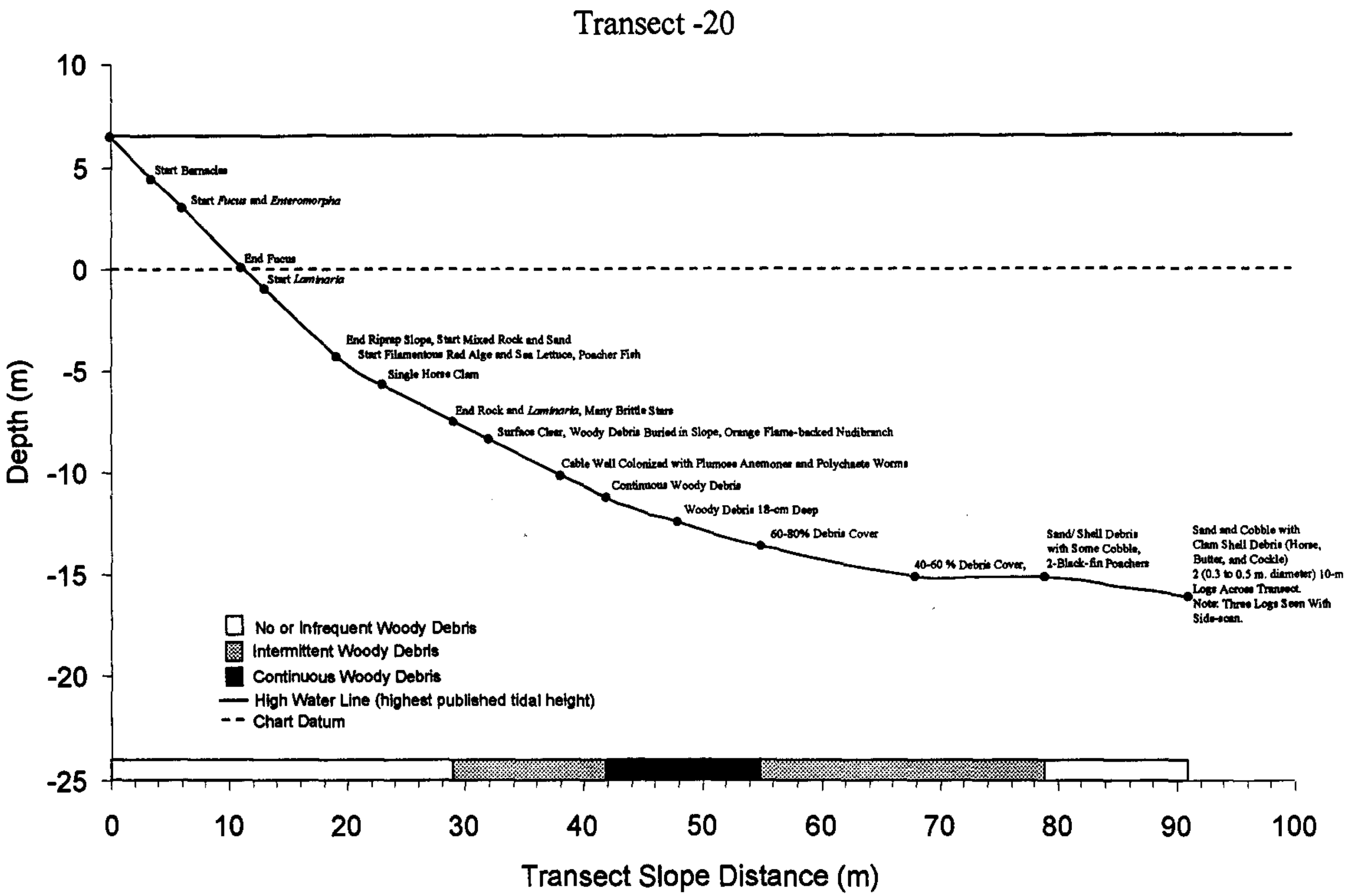
This page left blank purposely

Transect 0



+10
+5
0
5
10
15
20
25
Depth (m)
Start Fucus
Filamentous Red Algae and Sea Lettuce, Cable Debris
End Fucus
Start Broken Rock Slope
Diatoms, False Ochre Starfish
Lots of Strapping and Cables, Woody Debris Among Rocks
Start Continuous Woody Debris (18-cm deep), Lots of Broken Cable
Laminarian Kelp, Hermit Crabs
Woody Debris 38-cm Deep, Coon Striped Shrimp
10-m Log, Dungeness Crab
4 Logs 8 to 10-m long
End of Continuous Woody Debris, Dungeness Crab, Coon Striped Shrimp
Start Sandy Patches
Woody Debris Patch 8 to 10-cm Deep, Sunstar
Sand with some Woody Debris, Logs, Dungeness Crab
Anthropogenic Debris
2 Boulders Tangled in Cable, Sunstars,
Sea-cucumbers, Anemones, Sea-peach,
Tube worms
Logs (north-west/south east orientation),
Small Anemones
Sand Flats, Woody Debris Patches
Note: Side-scan shows five logs
No or Infrequent Woody Debris
Intermittent Woody Debris
Continuous Woody Debris
High Water Line (highest published tidal height)
Chart Datum
0
10
20
30
40
50
60
70
80
90
100
Transect Slope Distance (m)

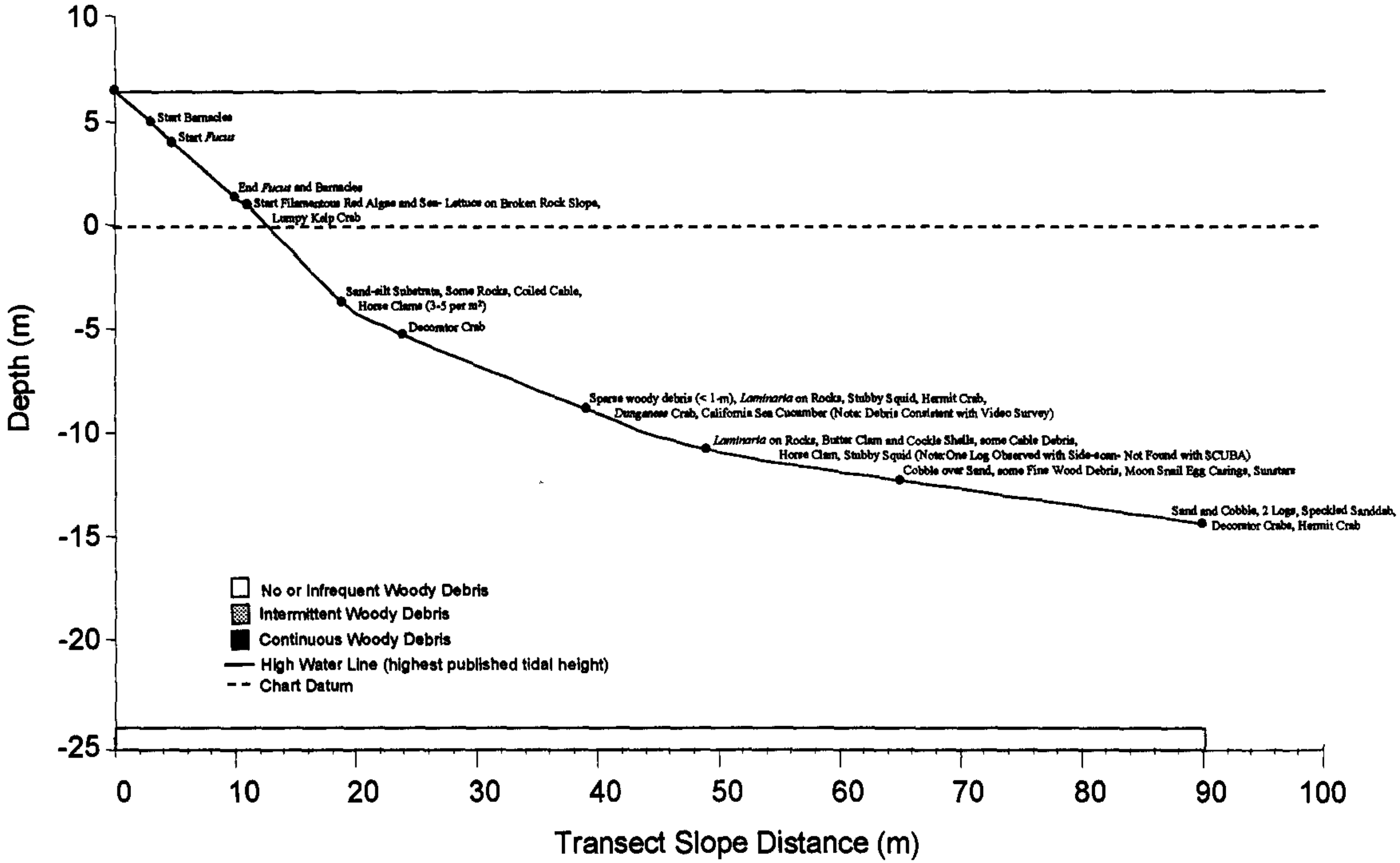
This page left blank purposely



Transect -20
Depth (m)
Transect Slope Distance (m)
10
5
0
-5
-10
-15
-20
-25
0
10
20
30
40
50
60
70
80
90
100
Start Barnacles
Start Fucus and Enteromorpha
End Fucus
Start Laminaria
End Riprap Slope, Start Mixed Rock and Sand
Start Filamentous Red Alge and Sea Lettuce, Poacher Fish
Single Horse Clam
End Rock and Laminaria, Many Brittle Stars
Surface Clear, Woody Debris Buried in Slope, Orange Flame-backed Nudibranch
Cable Well Colonized with Plumose Anemones and Polychaete Worms
Continuous Woody Debris
Woody Debris 18-cm Deep
60-80% Debris Cover
40-60 % Debris Cover,
Sand/ Shell Debris
with Some Cobble,
2-Black-fin Poachers
Sand and Cobble with
Clam Shell Debris (Horse,
Butter, and Cockle)
2 (0.3 to 0.5 m. diameter) 10-m
Logs Across Transect.
Note: Three Logs Seen With
Side-scan.
No or Infrequent Woody Debris
Intermittent Woody Debris
Continuous Woody Debris
High Water Line (highest published tidal height)
Chart Datum

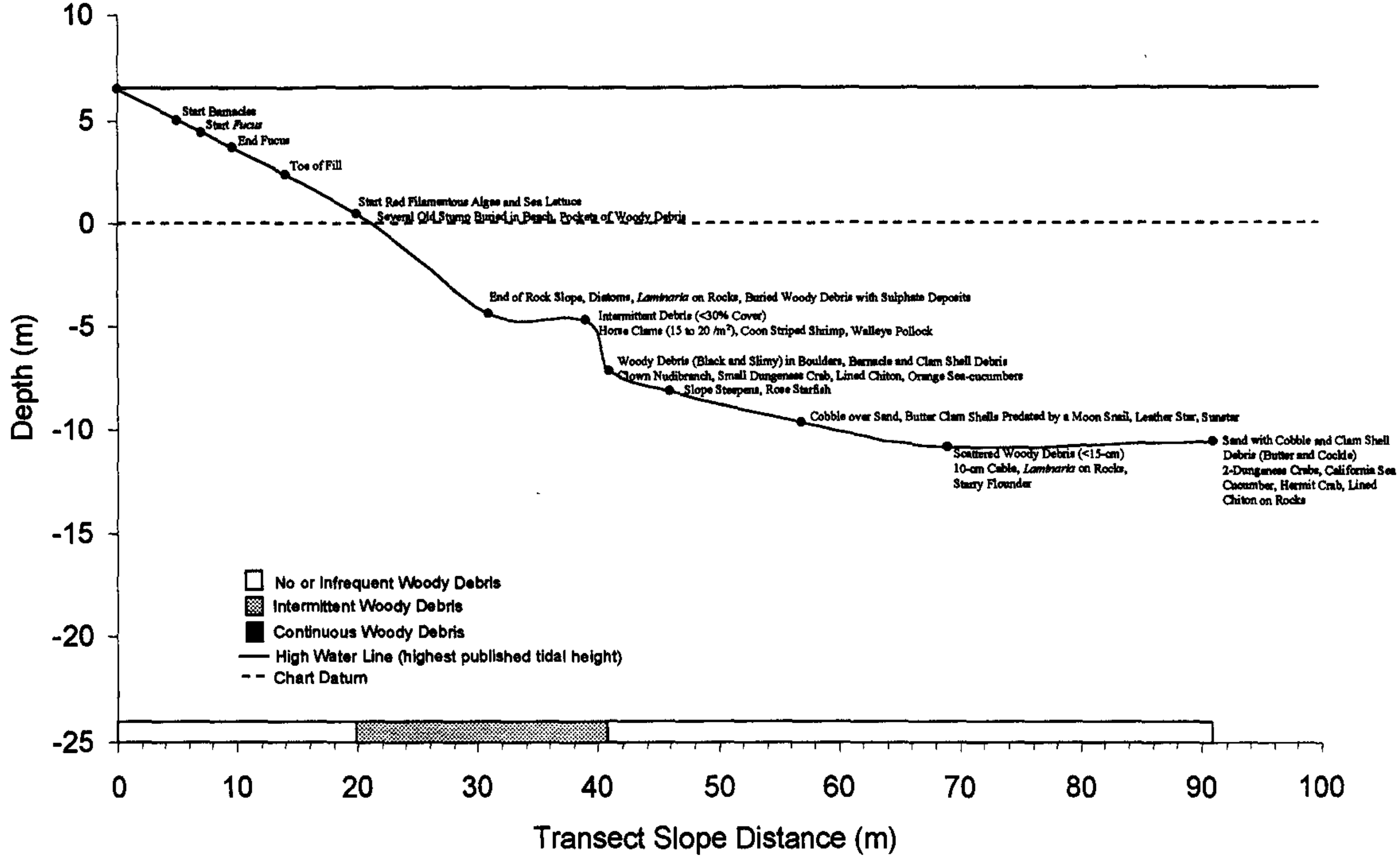
This page left blank purposely

Transect -30


10
5
0
-5
-10
-15
-20
-25
Depth (m)
Start Barnacles
Start Fucus
End Fucus and Barnacles
Start Filamentous Red Algae and Sea- Lettuce on Broken Rock Slope,
Lumpy Kelp Crab
Sand-silt Substrate, Some Rocks, Coiled Cable,
Horse Clams (3-5 per m²)
Decorator Crab
Sparse woody debris (< 1-m), Laminaria on Rocks, Stubby Squid, Hermit Crab,
Dungeness Crab, California Sea Cucumber (Note: Debris Consistent with Video Survey)
Laminaria on Rocks, Butter Clam and Cockle Shells, some Cable Debris,
Horse Clam, Stubby Squid (Note:One Log Observed with Side-scan- Not Found with SCUBA)
Cobble over Sand, some Fine Wood Debris, Moon Snail Egg Casings, Sunstars
Sand and Cobble, 2 Logs, Speckled Sanddab,
Decorator Crabs, Hermit Crab
No or Infrequent Woody Debris
Intermittent Woody Debris
Continuous Woody Debris
High Water Line (highest published tidal height)
Chart Datum
0
10
20
30
40
50
60
70
80
90
100
Transect Slope Distance (m)

This page left blank purposely

Transect -50


10
5
0
-5
-10
-15
-20
-25
Depth (m)
0
10
20
30
40
50
60
70
80
90
100
Transect Slope Distance (m)
Start Barnacles
Start Fucus
End Fucus
Toe of Fill
Start Red Filamentous Algae and Sea Lettuce
Several Old Stump Buried in Beach, Pockets of Woody Debris
End of Rock Slope, Diatoms, Laminaria on Rocks, Buried Woody Debris with Sulphate Deposits
Intermittent Debris (<30% Cover)
Horse Clams (15 to 20 /m²), Coon Striped Shrimp, Walleye Pollock
Woody Debris (Black and Slimy) in Boulders, Barnacle and Clam Shell Debris
Clown Nudibranch, Small Dungeness Crab, Lined Chiton, Orange Sea-cucumbers
Slope Steepens, Rose Starfish
Cobble over Sand, Butter Clam Shells Predated by a Moon Snail, Leather Star, Sunstar
Scattered Woody Debris (<15-cm)
10-cm Cable, Laminaria on Rocks,
Starry Flounder
Sand with Cobble and Clam Shell
Debris (Butter and Cockle)
2-Dungeness Crabs, California Sea
Cucumber, Hermit Crab, Lined
Chiton on Rocks
No or Infrequent Woody Debris
Intermittent Woody Debris
Continuous Woody Debris
High Water Line (highest published tidal height)
Chart Datum

This page left blank purposely

Appendix 3. List of potential log dump study sites near Bella Coola, British Columbia (from Department of Fisheries and Oceans, unpublished files, 1998).

Location	Comments	Estimated Activity	Estimated Annual Volume (m^3)	Actual Activity	Actual Volume	Biological Assessment (Surveyors)	Photos	Maps	Forest Company	Lease Number	Depth (m) (from Hydrographic chart) 75 m from shore	200 m from shore	Mid-Channel
DF= David Flegel, M.o.F., Bella Coola, B.C. **BK= Brad Koroluk, DFO Habitat Technician, Bella Coola.**													
Jenny Inlet (King Island)		86/87-current	75,000 (DF)			n	n	y	Interfor	5401671	5	19	25
Frenchman Creek	very little volume yet, daily wood volume to be moved due to wind exposure (DF)	93-3 yr	35000			y (Grizzly Holdings Ltd)	y-see orig. Grizz survey	y	Interfor		1	41	82
Fog Creek		95-00	50000 (DF)			y (Grizzly Holdings Ltd)	n	y	Interfor	5404632	3	14	100
Green River (Dean Channel near Green River, King Island)	not built as of early 1999, wood will be dumped but not stored (DF)	1998-2008	1 million			y (Mid coast Aquatics)	n	y	Interfor		2	82	142
Hole in the Wall	2 million+ 20 year operation (DF)	20 years	2M+ (total)			n	n	n	Crown Zellerbach, Interfor	n	3	55	137
Mud Bay (Dave Lake Main Line)	proposed as a camp; no activity as of 1999.	1997(BK)	B			n	n	y 1:500	Dean Channel Forests Products	5402936	1	41	137
Skoquiltzt Bay and Carlson Inlet	not built	1991- 30 yr)	30000			n	n	y	Small Business	5402936	2	44	134
Kimsquit River Dump	built 1980 (DF)	1980-1999	130000 to 200000	79-89	130000-200000	A	yes, plans date back to 1979 in file	A	Doman	5402936, 0353822, 5404118	2	13	27
Kimsquit Dump (Kimsquit Bay)	Has not been used for 20 years (DF)	A	A			A	A	A	A		1	25	46

Location	Comments	Estimated Activity	Estimated Annual Volume (m^3)	Actual Activity	Actual Volume	Biological Assessment (Surveyors)	Photos	Maps	Forest Company	Lease Number	Depth (m) (from Hydrographic chart)		
											75 m from shore	200 m from shore	Mid-Channel
Labouchere Channel Westside	Old Dump used in 1930's (look for pilings) Between Labouchere Pt and Ovesen Pt. (DF)	A	A			n	n	n	n	n	10	41	148
Twin Creeks	1987-1998	20000 to 30000	n			n	n	n	SWC Holdings	n	4	33	164
Minerva Creek	Not Active for 20 years (DF)	A	A			A	A	A	Crown Zellerbach	A	6	27	164
Wolverine Creek Quatna Inlet	Not active for 5 to 7 years (DF)	A	A			A	A	A	Interfor	A	6	27	142
Kwatna Bay	Old site, used for 25 yrs, 2-3 million (DF)	A	A		2-3 million	n	n	n	Interfor	A	1	18	18
Kwatna Inlet	(Quatlena River)	94-95?(BK)	50000 (DF)			y- (Heiltsuk Fisheries Program (1994)	y	y	Interfor	A	2	11	22
Restoration Bay	Not Built (DF)	1997- (10 years)	30000 (for 10 years)			n	n	y	Interfor	5405762	5	44	82
Namu (Doc Creek)	1st year was 1986 (DF)	1986- ?	200000/ year (DF)			n	n	y 1981	MB	5401632	1	27	55
Breakwater Cove (Burke Narrows)	Not Built	A	20000 to 30000 over 5 years (DF)			y (Eric White)	y	y	Small Business	5405718	4	27	41
Cousins Inlet Ocean Falls	Not a great site, proximity to Ocean Falls may create conflicts (BK)	proposed 1985	A			A	A	y (very basic)	Small Business		7	16	16
Ash River (Ocean Falls)	Not a great site, proximity to Ocean Falls may create conflicts (BK)	91 applic.	12000/a 1 yr			n	n	y	Ash River Investments	5405108/ 5403698			

											Depth (m) (from Hydrographic chart)		
Location	**Comments**	**Estimated Activity**	**Estimated Annual Volume (m^3)**	**Actual Activity**	**Actual Volume**	**Biological Assessment (Surveyors)**	**Photos**	**Maps**	**Forest Company**	**Lease Number**	**75 m from shore**	**200 m from shore**	**Mid-Channel**
Cousins Inlet		98 applic	100000/a (10 yrs)			y- (Mid Coast Aquatics)	y	y	Interfor	5406297	1	14	16
Bella Coola	Old Crown Zellerbach. In estuary	A	A			A	y- photos of deactivation	A	Crown Zellerbach		5	41	77
Bella Coola	Amendment in 1991	A	A			A	A	y	CFI, Interfor	54081858, 0275705, 0337836			
North Bentinck West of Clayton Falls	associated with dryland sort (DF)	92 applic	A			n	n	y	Mid Coasts Wharves	5401858			
North Bentinck East of Clayton Creek	log dump only (DF)	many years (DF)	100000 to 300000 (DF)			n	n	y	CFI	337836			
Windy Bay	used 3-4 years (DF)	91 applic. (10 yr)	15-30000			n	n	y	Small Business	5402889	8	44	104
Green Bay (North Bentinck Arm)	old railway logged site (DF)	A	A			A	A	A	A	A	4	38	137
South Bentinck Arm just south of Tallheo point	Old site used for 40 years ago (DF)	A	A			n	n	n	A	A	11	41	134
Larso Bay	Semi-active road accessible, (DF)	late 60's to 1980, application 1992	1 million+ (DF)		1 million +(DF)	n	n	y	Interfor	324555, 5403091	5	33	79
South Bentinck (East side)		1997 (BK) 3 years	20000			y- (Grizzly Holdings Ltd)	y	y	Interfor	5406170 South Bentinck Arm	3	38	86
South Bentinck (Noeick)	Old site not used since 1980 (DF)	98 applic for use of old site	2-3 million	30 years (BK)		n	n	y	Interfor	A	3	16	44
Taleomey	late 70's current	renew appl 88	A			n	n	y	Interfor	353827	2	13	18

Location	Comments	Estimated Activity	Estimated Annual Volume (m^3)	Actual Activity	Actual Volume	Biological Assessment (Surveyors)	Photos	Maps	Forest Company	Lease Number	Depth (m) (from Hydrographic chart) 75 m from shore	200 m from shore	Mid-Channel
Wash -wash East-side	old site	1986-1994 (DF)	100000			n	n	n	Doman	A	4	14	27
Wash -wash West-side	old site used before 1970 (DF)	A	A			n	n	n	Crown Zellerbach		14	25	25
Old site reactivated	Reactivated two years ago.												
West Side (South Bentinck)	exact location of site not clear	93-94/(BK)	up to100000/a			n	n	y	Interfor	5402372 Interfor S.Bentinck Westside	14	44	66
Burnt Island Harbour (Rivers Inlet)		94 prop.	10000					y	Small Business	5405717			
Wycless Lagoon	application 97	3 yr	20000			n	n	y	Interfor	5405833			
Security Bay								y (1/250 in file)	Weldwood	349818			
Draney Inlet		98 applic	40000/a (5 yrs)			y - Grizzly	y	y	Interfor	5406227			
Fish Egg	Small Volume Site in sheltered, relatively shallow location. More info in file in Bella Coola.							y	Mill Timber				
Hardy Inlet		98 applic .				n	n	y	Interfor				
Spiller Inlet (Ingram Bay)		94 applic.				y Heiltsuk	n	y	Western Forest Products				
Yeo Cove (near Spiller Channel) (Outside of area)		proposed '94)							Small Business				