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Cowichan Valley Regional District

Marine Discharge Outfall

Environmental Impact Study

Stage 1

Final – REV 0

Attention:

Cowichan Valley Regional District
175 Ingram Street
Duncan, BC
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1019-001
REV 0

Executive Summary

The Cowichan Valley Regional District (CVRD) is undertaking the development of Amendment 3 to the existing Central Sector Liquid Waste Management Plan (CSLWMP). The Central Sector is serviced by the Joint Utilities Board (JUB) Lagoon Systems co-owned by the City of Duncan and the Municipality of North Cowichan, and also provides service to properties within parts of CVRD Electoral Areas D and E and parts of Cowichan Tribes reserve.

The Joint Utilities Board (JUB) sewage treatment lagoons are located adjacent to the Cowichan River. The aerated lagoon treatment system produces secondary quality effluent, which is disinfected by chlorination, then dechlorinated. Treated wastewater is discharged into the lower reaches of the Cowichan River and subsequently to the Cowichan Estuary and ocean environment. In recent years, low flows in the Cowichan River have resulted in a situation where there is insufficient dilution of the effluent plume with respect to the river flow. This resulted in the temporary closure of the Cowichan River to recreational activities in August of 2014.

It is proposed that the point of discharge be moved from the Cowichan River to the marine environment of Satellite Channel, where significantly more dilution can be achieved and where the likelihood of interaction between the effluent plume and sensitive areas can be reduced. The proposed replacement outfall is recommended to support a population of 70,000.

This Stage 1 Environmental Impact Study (EIS) is intended to provide a review of known receiving environment conditions and a preliminary assessment of the potential impacts to the environment from the proposed marine outfall with respect to current regulatory requirements.

Satellite Channel is located along the east coast of Vancouver Island, within the Gulf Islands. The Cowichan and Koksilah Rivers discharge to the head of Cowichan Bay, which opens to Satellite Channel and Salish Sea. Water depths in excess of 50 m are easily achieved within Cowichan Bay and Satellite Channel, and the substrate composition is favorable for the installation of a marine outfall.

The near surface water currents are a combination of tidal circulation and estuarine flow. The estuarine flow results from the discharge of fresh water from the two major rivers at the head of Cowichan Bay. The tidal currents are likely to dominate the circulation within Cowichan Bay and Satellite Channel.

Receptors of concern in relation to the siting of a new outfall include; waterfront parks and primary recreational activities, important First Nations fishing areas, and intertidal and subtidal marine resources, particularly bivalve shellfish that, when harvested and consumed, can transfer pathogens which originated in the effluent plume to humans. Bivalve shellfish areas have been identified in Satellite Channel, such as at Boatswain Bank.

Areas suitable for the proposed outfall are limited within Satellite Channel. Limitations include:

- The regulatory minimum depth of discharge is 10 m;

- The maximum depth of the outfall should be minimized where possible to reduce construction and maintenance cost and safety;
- The point of discharge must be setback a minimum of 400 m from bivalve shellfish waters; and,
- High valued fishing areas, specifically Sansum Narrows; and.
- Numerous freighter anchor berths located within the bay. The proposed outfall should be constructed in a location that minimizes the chance of damage to the outfall from freighter anchors.

Based on these primary limitations, the preferred location for the discharge is over 400 m from the low water mark, at a depth of approximately 60 m, near Chery Point marina in the proximity of the existing Lambourn outfall.

Dilution modelling of the effluent plume was carried out for a discharge at the proposed location. The model predicts that the effluent plume will be trapped below a depth of 39 m and the minimum (worst case) dilution of the effluent plume is 219:1 at the boundary of the initial dilution zone (IDZ, 100m from the point of discharge). Based on the minimum dilution, identified effluent constituents will be within applicable water quality guidelines for aquatic health at the boundary of the IDZ.

Fecal coliform concentrations were calculated, with respect to distance from the outfall diffuser for effluent with and without disinfection. The fecal coliform concentration in the effluent, is anticipated to be 200 MPN/100 mL with disinfection and 1×10^5 (USEPA, 1986) without disinfection. A fecal coliform concentration of 14 MPN/100 mL is predicted within 5 m of the diffuser with disinfection, and within 1,200 m to 6,300 m from the diffuser without disinfection, depending on the tidal, meteorological, and effluent flow conditions. With disinfection, water quality guidelines for bivalve shellfish harvesting are predicted to be achieved at bivalve shellfish areas.

A Stage II EIS is recommended to verify the results of this study and to collect baseline receiving environment monitoring data prior to the installation of the outfall. An amendment of the LWPM will be prepared based on the results of this study.

The scope of the Stage 2 EIS should include; comprehensive effluent characterization, tidal current measurements, water column profiling, and 3 dimensional hydrodynamic modelling.

A pre-discharge receiving environment monitoring program is recommended for the proposed outfall replacement that includes the following components:

- Water quality sampling at the boundary of the IDZ and receptor sites
- Sediment chemistry and benthic community sampling
- Bio-accumulation testing in sediments, benthic infauna and wild tissue.

Based on the data collected from the pre-discharge receiving environment monitoring program, modifications to the proposed outfall placement may be required.

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1 Introduction

The Cowichan Valley Regional District (CVRD) is undertaking the development of Amendment 3 to the existing Central Sector Liquid Waste Management Plan (CSLWMP). The Central Sector is serviced by the Joint Utilities Board (JUB) Lagoon Systems co-owned by the City of Duncan and the Municipality of North Cowichan, also provides service to properties within parts of CVRD Electoral Areas D and E and parts of Cowichans Tribes reserve. The lagoons are located on the banks of the Cowichan River as shown in Figure 1, and treated wastewater is discharged into the lower reaches of the Cowichan River.

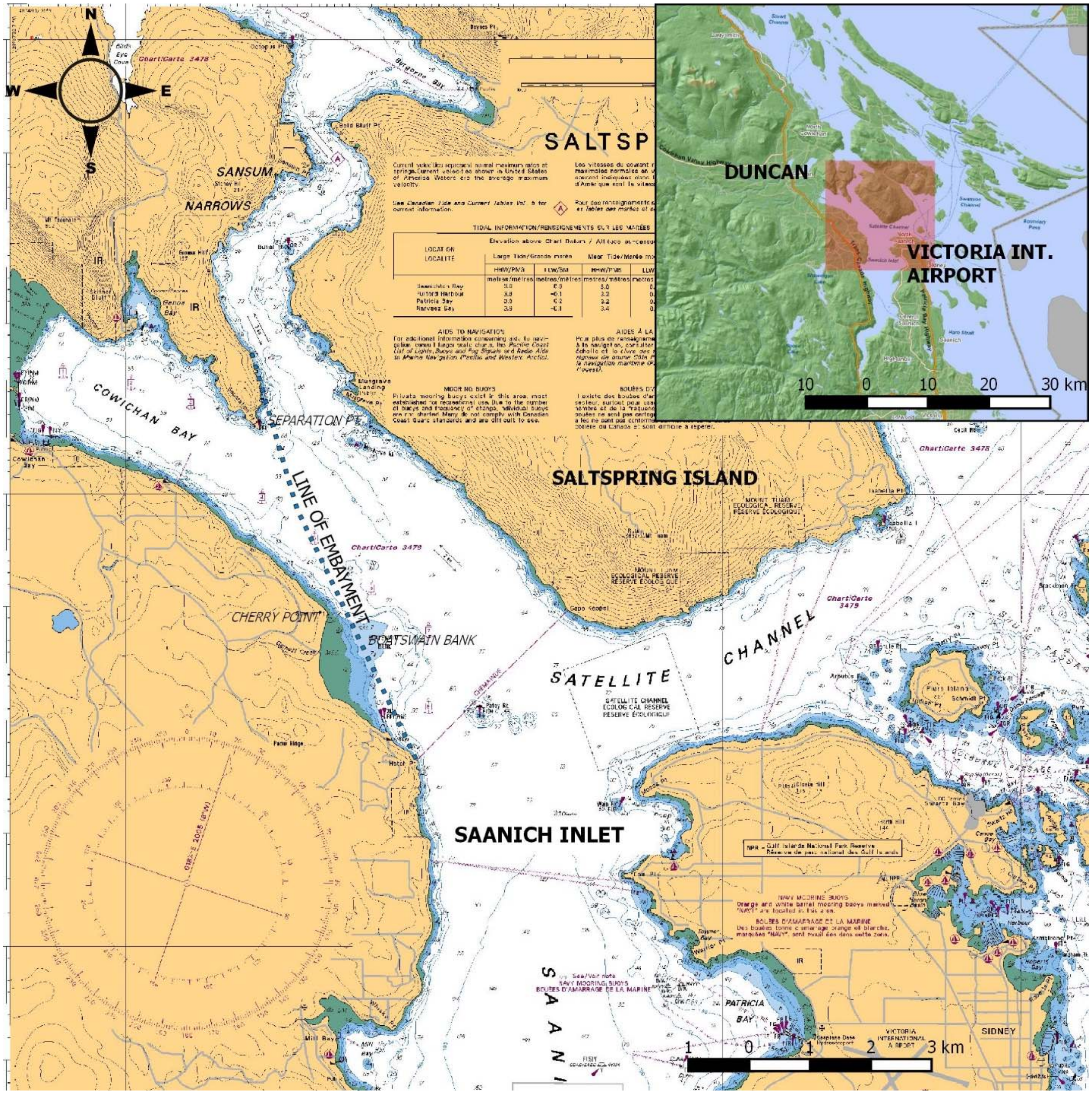
Low flows in the Cowichan River in recent years has resulted in a situation where there is insufficient dilution of the effluent plume with respect to the river flow. This has resulted in the temporary closure of the Cowichan River to recreational activities in August of 2014.

With increasing effluent flows projected and depressed river flows there are significant concerns about potential water quality impacts to river ecology, including salmon; and potential health impacts due to insufficient dilution.

It is proposed that the point of discharge be moved from the Cowichan River to the marine environment of Cowichan Bay or Satellite Channel. The proposed replacement outfall is recommended to support a population of 70,000 (Delcan, 2010).

This Stage I Environmental Impact Study (EIS) is intended to provide a review of known receiving environment conditions and to provide a preliminary assessment of the potential impacts to the environment from the proposed marine outfall with respect to current regulatory requirements.

Figure 1 Study Area



1.1 Scope of Work

For compliance with the Ministry of Environment (MOE) Municipal Wastewater Regulation, a new discharge requires the completion of an Environmental Impact Study as outlined in the *Environmental Impact Study Guideline – A companion Document to the Municipal Wastewater Regulation* (MELP, 2000). For a discharge to the marine environment with flows greater than 10,000 m^3/d, it is recommended that the EIS be completed in two stages.

Stage 1 is intended to be a desktop study, using existing available information as a basis for the analysis. Based on the results of the Stage 1 EIS, recommendations will be made for the Stage 2 EIS including the collection of site specific baseline data.

The specific objectives of the EIS will be:

1. Identify maximum daily and average annual effluent flow;
2. Identify influent and effluent sewage quality: BOD_5, TSS, Total P, NH_3 and fecal coliform levels;
3. Identify source control measures, as appropriate;
4. Locate on a marine chart or topographical map (1:50,000 or larger scale) and suitable larger scale site plan, the general location of the proposed discharge;
5. Identify any existing or proposed nearby discharges, including their quantity and quality;
6. Inventory receiving water uses, fisheries resources, commercial and shellfish leases, drinking water, recreational uses, irrigation, livestock watering, or other uses. Illustrate these uses on the marine chart or topographical map and site plan. Indicate applicable water quality guidelines;
7. Determine outfall depth/distance requirement using schedule 7, appendix 2;
8. Identify normal wind direction, tidal influences and marine/stream currents;
9. Estimate the initial dilution and subsequent dilution, diffusion and dispersion that will occur from the outfall diffuser, using worst-case values for seawater or stream temperature, pH, salinity and current or flows and effluent temperature and salinity;
10. Estimate the water quality at the edge of the IDZ and at any areas of concern (shellfish areas, beaches, water intakes, or others) for various treatment requirements (septic, primary, secondary as set out in schedule 3), using the most critical effluent quality parameters (e.g., NH_3 and fecal coliform levels), and compare these results with the water quality guidelines;
11. Based on the evaluation of the foregoing study task findings, recommend whether additional study tasks, including pre-discharge monitoring, are necessary;
12. Based on the evaluation of the foregoing study tasks findings, recommend the appropriate level of treatment and the optimum outfall location, depth and distance combination to ensure that there are no adverse effects on human health and the environment;
13. Recommend post-discharge effluent and environmental monitoring programs;
14. Summarize EIS findings and recommendations in a report with appropriate illustrations and supporting data and calculations

2 Study Area

The proposed location of the marine discharge outfall location will extend northeast of Cowichan Bay, near Cherry Point, into Satellite Channel (Figure 1).

3 Regulatory Framework

3.1 Existing Permit

The existing Cowichan River outfall discharge is permitted by the Ministry of Environment under Operational Certificate ME-01497 (Appendix 1). The permitted flow and effluent characteristics along with the outfall length and depth requirements are provided in Table 1.

Table 1 Permitted Effluent and Discharge Properties (Operational Certificate ME-01497)

Parameter		Maximum Value
Combined Maximum Flow		49,000 m^3/day
Maximum Flow between July 1 and September 30 each year		4,000 m^3/day
Effluent Quality	5-day Biochemical Oxygen Demand (BOD_5)	30 mg/L
	Total Suspended Solids (TSS):	40 mg/L
	Fecal Coliforms	200 CFU/100 mL median 7 consecutive samples 800 CFU/100 mL max any sample
	Toxicity (96hCL50)	100% of all samples > 50% survival after 96 hours in 100% effluent.
	pH	6-9
	Total Phosphorous	18 kg/d – months of July, August and September.

3.1.1 Effluent Monitoring

The effluent monitoring requirements to be reported to the Ministry of Environment under permit PE-1437 are provided in Table 2.

Table 2 Effluent Monitoring Requirements (Operational Certificate ME-01497)

Parameter	Frequency
Flow (24 hour period)	Recorded daily
5-Day Biochemical Oxygen Demand (BOD_5)	Recorded monthly
Total Suspended Solids (TSS)	Recorded monthly
Ammonia Nitrogen	Recorded monthly
Toxicity	Recorded quarterly
Fecal Coliform	Recorded weekly
pH	Recorded weekly
Ortho Phosphate Phosphorus (P), Total Phosphorus	Recorded monthly

3.1.2 Receiving Environmental Monitoring

The operational certificate requires two receiving environment monitoring station in the Cowichan River, one station is located approximately 50 m upstream of the point of discharge and a second is located approximately 200 m downstream of the of the point of discharge. Samples are to be collected at each station during the first 10 days of August each year. The samples are to be analyzed for:

- Total Phosphorous
- Ortho Phosphorous
- Total Nitrogen
- Ammonia Nitrogen
- pH
- Temperature.

Substrate in the in the Cowichan River is also to be monitored at three sites for Chlorophyll-a. The three sites are to be monitored once during the first 10 days of August, once in the third week of August and once during the first 10 days of September.

3.1.3 Outfall Inspection

The outfall is to be inspected once every five years or as otherwise required by the Regional Waste Manager.

3.2 Provincial and Federal Regulations

The regulatory agencies and applicable regulations concerned with the discharge of municipal wastewater include:

- BC Ministry of Environment, Environmental Management Act and the associated Municipal Wastewater Regulation.
- Environment Canada, Wastewater Systems Effluent Regulation

The *Environmental Management Act (EMA)*, allows communities to develop Liquid Waste Management Plans (LWMP), with the primary objective of protecting public health and environment, and to properly consult with the public. LWMPs are to detail how the community intends to manage its liquid waste in accordance with the EMA and the associated *Municipal Wastewater Regulation* (MWR). Where facilities do not meet the requirement of the MWR, the LWMP is to establish a schedule for upgrading substandard facilities.

The CVRD has an approved Central Sector Liquid Waste Management Plan (Dayton & Knight, 1999) and associated amendments (2001), in accordance with the Environmental Management Act.

Provincial requirements for wastewater discharges are outlined in the MWR. The MWR regulates minimum effluent quality and outfall design criteria based on the properties of the receiving environment and effluent flow rates. The current outfall discharge is located in what is considered to be under the category "streams, rivers and estuaries" (as defined in the MWR). Minimum effluent criteria for the discharge up to daily flows less than and greater than two times the average dry weather flow (ADWF) are outlined in Table 3 below. As the new outfall location is proposed to discharge effluent into a marine environment, the minimum effluent criteria for discharge is also provided in Table 3 for comparison.

Federally, the *Wastewater Systems Effluent Regulation* (WSER) establishes minimum effluent criteria for all discharges with flows greater than 10 m^3/day. There is no association to specific receiving environment conditions under the WSER. The minimum effluent criteria for the WSER are also outlined in Table 3 below.

Table 3 Minimum Effluent Requirements

	MWR Criteria (Rivers)		MWR Criteria (Embayed Marine Waters[2])		WSER[1]	ME-01497 (Existing Operational Certificate))
	Daily Flow	**< 2x ADWF**	D≥ **2x ADWF**	D< **2x ADWF**	D≥ **2x ADWF**	
Toxicity	Monitoring required [3]					Quarterly 100% of all samples > 50% survival after 96 hours in 100% effluent.
BOD_5[4]	≤ 45 mg/L	≤ 130 mg/L	≤ 45 mg/L	≤ 130 mg/L	< 25 mg/L (average)	< 30 mg/L (Maximum)
TSS [5]	≤ 45 mg/L	≤ 130 mg/L	≤ 45 mg/L	≤130 mg/L	< 25 mg/L (average)	< 40 mg/L (Maximum)
pH	6.0 - 9.0	n/a	6.0 - 9.0	n/a		6.0 - 9.0
Total phosphorus (P)	≤ 1	n/a	n/a			18 kg/d – months of July, August and September.
Ortho-phosphate as (P)	≤ 0.5	n/a	n/a			
Ammonia (as Nitrogen)	Based on receiving water characteristics[6]		Based on receiving water characteristics[6]		1.25 mg/L (Un-Ionized maximum at 15˚C ± 1˚C)	
Fecal Coliforms	Based on receiving water usage[7]		Based on receiving water usage[7]			200 CFU/100 mL median 7 consecutive samples 800 CFU/100 mL max any sample
Total Residual Chlorine	<0.02 mg/L (maximum)		<0.02 mg/L (maximum)		<0.02 mg/L (average)	

Notes:

1. The JUB treatment facility has a WSER transitional authorization effective Jan 1, 2015 to December 31, 2030. Allowable effluent concentrations prior to 2031 are provided in Appendix 1.

2. Embayed Marine Water is defined in the MWR as water; (a) located within a bay from which the access to the sea, by any route, has a maximum width of less than 1.5 km, (b) located, if a line less than 6 km long is drawn between any 2 points on a continuous coastline, on the shore side of the line, or (c) in which flushing action is identified in a notice given by a director to be inadequate". The proposed point of discharge is inside a line less than 6 km long and the discharge is embayed (see Figure 1).

3. The discharge must monitor the toxicity of the effluent in accordance with the 96 hour LC50 bioassay test as defined by Environment Canada's Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout, (Reference Method, EPS 1/RM/13), and if applicable Environment Canada's Procedure for pH Stabilization During the Testing of Acute Lethality of Wastewater Effluent to Rainbow Trout (Reference Method EPS 1/RM/50).

4. BOD_5 means the carbonaceous 5-day biochemical oxygen demand.

5. TSS means the total suspended solids or non-filterable residue.

6. Effluent standards for ammonia nitrogen are based on the predicted dilution within the effluent plume at the boundary of the IDZ. The IDZ is defined in the MWR as a cylindrical volume of water centered on the terminus of the outfall with a radius that is the lesser of 100 m or 25% of the width of the body of water; the cylinder extends from the seafloor to the surface of the water

   The allowable ammonia nitrogen concentration is based on back calculations of water quality guidelines and the predicted dilution of the effluent plume at the boundary of the IDZ. The most stringent water quality guideline, for the proposed discharge, is the average 5 to 30 day concentration of total ammonia nitrogen for the protection of marine life (MOE, 2001). The applicable guideline is based on a pH of 8.4 (MOE, 2001), a minimum salinity of 20 g/kg, and a maximum temperature of 15°C. In this case, the most stringent water quality guideline for ammonia nitrogen at the edge of the IDZ is 0.59 mg/L.

7. The allowable effluent fecal coliform concentration is back calculated from the predicted dilution at the boundary of the IDZ and any sensitive areas, and is based on the allowable fecal coliform concentration for these areas. The allowable fecal coliform concentration is dependent on the water based activities in the area of the discharge.

   For discharges to recreational use waters, the applicable water quality standard states that the number of fecal coliform organisms outside the IDZ must be less than 200 MPN /100 mL. Recreational usage is considered as "…any activity involving the intentional immersion (e.g., swimming) or incidental immersion (e.g., waterskiing) of the body, including the head, in natural waters" (Health and Welfare Canada, 1992).

   For discharges to shellfish bearing waters the applicable water quality standard is median or geometric mean of less than 14 MPN/100 mL at the edge of the IDZ (Canadian Food Inspection Agency, 2013), with not more than 10% of the samples exceeding 43 MPN/100 mL. For the purpose of this regulation, shellfish water means water bodies that "have or could have sufficient shellfish quantities that recreational or commercial harvesting would take place or water for which commercial shellfish leases have been issued" (British Columbia, 2012). Shellfish are defined as: "all edible species of oysters, clams, mussels and scallops either shucked, in the shell, fresh or fresh frozen or whole or in part. For the purposes of marine biotoxin control, predatory gastropod molluscs shall also be included" (Canadian Food Inspection Agency, 2013).

The MWR also specifies a number of engineering requirements specific for outfalls. Applicable requirements relating to the existing outfall include:

- the IDZ must not extend closer to shore than the mean low water mark;
- the IDZ must be located at least 300 m away from sensitive areas such as; recreational areas, aboriginal, commercial or recreational shellfish areas, domestic water intakes, agricultural water intakes, or any other sensitive area requiring protection as identified by a director;
- the outfall diffuser must be designed and located at a sufficient depth to maximize the frequency that trapping of the effluent occurs;
- the outfall diffuser is located to intercept the predominant current and avoid small currents that tend to move towards shore;
- depth and distance of the terminus are to be determined by an EIS and computer modelling of the discharge (but a minimum depth of 10 m below mean low water in marine waters);
- a minimum 10:1 initial dilution must be attained at the boundary of the IDZ through the use of a diffuser;
- outside the IDZ, the discharge does not cause water quality parameters to exceed water quality guidelines;
- the outfall is located such that it is protected from wave, boat and marine activity.

4 Wastewater Treatment System

4.1 Existing Wastewater Treatment and Disposal

Municipal wastewater is presently treated in the Joint Utilities Board (JUB) Wastewater Treatment Lagoons Facility. The facility is co-owned by the City of Duncan and the Municipality of North Cowichan, and also provides service to properties within part of CVRD Electoral Areas D and E and parts of the Cowichan Tribes reserves. The JUB Plant is a conventional aerated lagoon facility which provides secondary treatment with seasonal chemical phosphorus removal for wastewater originating from a population of approximately 37,170 (Delcan, 2013). The effluent is disinfected by chlorination, then dechlorinated. Effluent from the JUB wastewater treatment facility (lagoons) is discharged into the Cowichan River adjacent to the JUB facility.

4.1.1 Effluent Quality

The influent and effluent quality of the discharge from the JUB Wastewater Treatment Plant is provided in Table 4.

Table 4 Influent and Effluent Quality

Parameter	Influent	Effluent
Toxicity		100% survival rate
BOD_5 [4]	192 mg/L	12 mg/L
TSS [5]		15.7mg/L
pH		7
Total phosphorus (TP) Ammonia (as Nitrogen)		9.4 kg/d 19.4 mg/L
Fecal Coliforms		50 CFU/100 mL

4.2 Future Wastewater Treatment

Upgrades to the JUB Wastewater Treatment Lagoons Facility are to be addressed through a future amendment of the Central Sector Liquid Waste Management Plan (CSLWMP).

The future effluent flow rates were calculated based on a future catchment population of 70,000. Predicted effluent flow rates for the wastewater treatment system are provided in Table 5 (Delcan, 2010).

Table 5 Predicted effluent flow rates

Anticipated Effluent Flow	
Max Daily Flow	77,000 m^3/d (0.891 m^3/s)
Average Daily Flow	38,500 m^3/d (0.326 m^3/s)

4.3 Source Control and Inflow Infiltration

The source control program will include both regulatory and educational components to protect the discharge of wastes to a sewage system that may degrade the quality of the environment. The District of North Cowichan, The City of Duncan, and the Cowichan Valley Regional District, have the following sewer service bylaws in place for sewage discharged to the JUB:

District of North Cowichan   Sewer Services Bylaw, No. 2964

City of Duncan   Sewer Services Bylaw No. 1844, 1998

CVRD	No. 2476 – Cowichan Bay Sewer Systems Management Bylaw, 2003
	No. 1926 - Eagle Heights Sewer System Management Bylaw, 1999

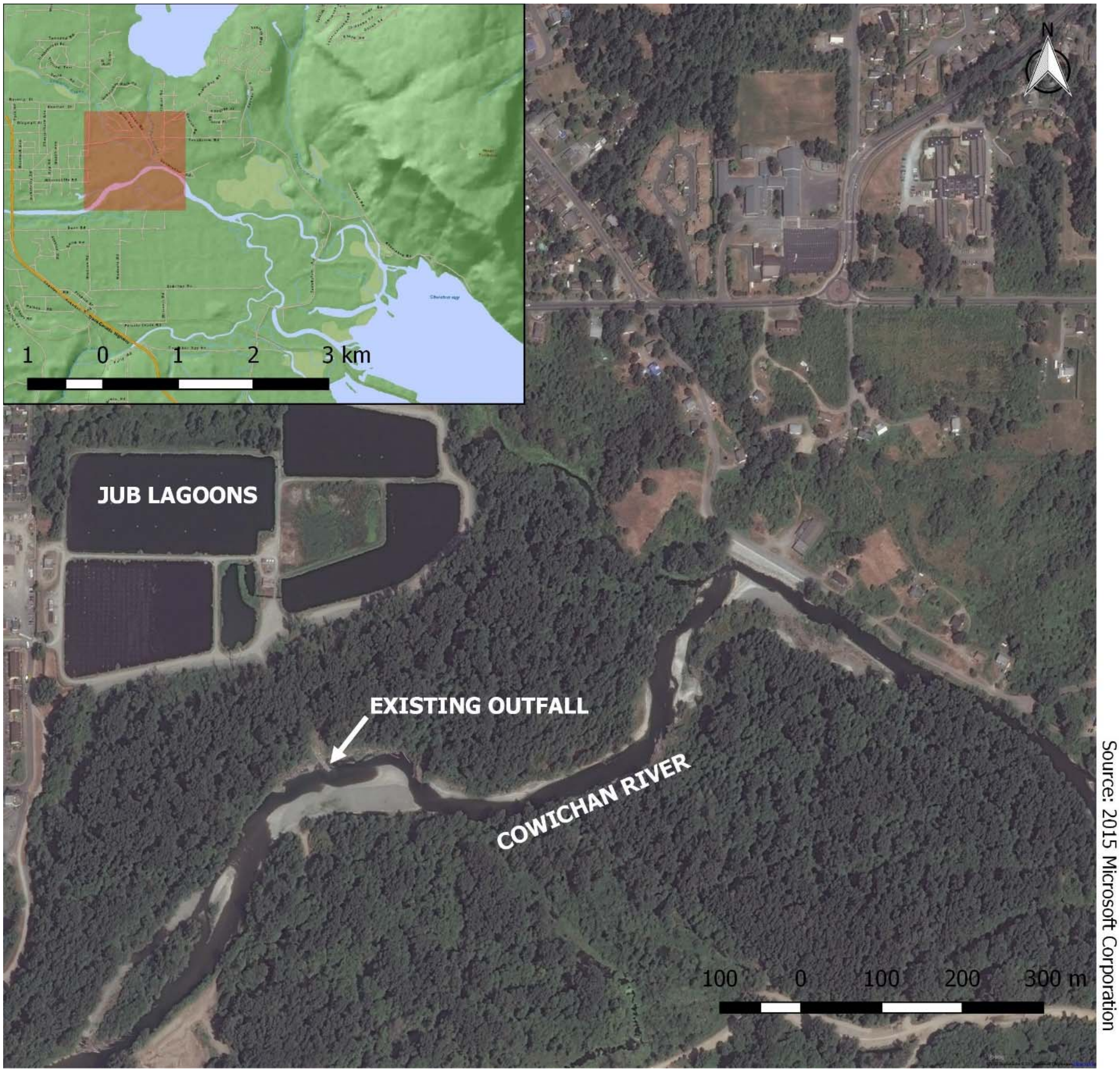
The CVRD will work with the District of North Cowichan, the City of Duncan and the Cowichan Tribes to continue improving on the source control program and include measures to complete monitoring of influent and effluent quality at the treatment plant.

Inflow and Infiltration refers to water entering the system through direct stormwater connections (inflow) and/or the infiltration of ground water into the system through leaks in the pipe network. All discharges are required to reduce inflow and infiltration. The CVRD and the member municipalities manage inflow and infiltration on an ongoing basis. Further details of the inflow and infiltration control program can be found in the LWMP.

5 Existing Receiving Environment Characteristics (Cowichan River)

Effluent from the JUB wastewater treatment facility (lagoons) is discharged into the Cowichan River adjacent to the JUB facility (Figure 2). Approximately 5 km upstream from the mouth of the river at Cowichan Bay.

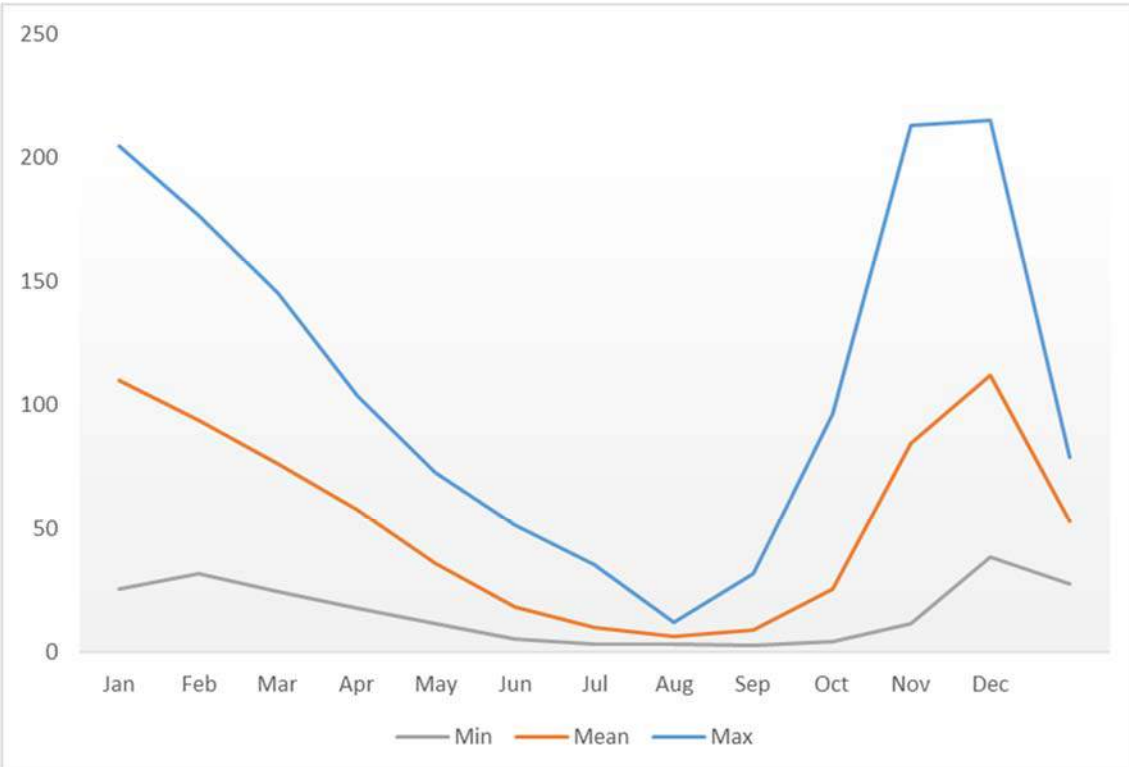
Figure 2 Cowichan River



During periods of low water flow, as shown in Figure 2 (Taken August 2013), the width of the river is less than 25 m at the point of discharge. River flow for the Cowichan River is plotted in Figure 3. Peak discharge from the river typically occurs in fall (November and December) while minimum flows occur in the summer (August and September). A review of predicted wastewater flow and Cowichan River flows (Delcan, 2010) concluded that the minimum dilution ratio (monthly mean effluent flow vs. lowest river flow) is 11.4:1 (discharges with dilution less than 10:1 are prohibited under the MWR). It is likely that river flows may decline in the future (Section 5.1) and therefore with increased effluent flow, the continued discharge to the Cowichan River is not a viable option.

Rerouting discharge from the Cowichan River would decrease the risk of water quality exceeding provincially approved guidelines for the protection of aquatic life.

Figure 3 Monthly Mean Discharge for Cowichan River Near Duncan



5.1 Climate Change

For the existing river outfall, the potential climate change effects were considered in terms of changes in water discharges, channel stability and sedimentation processes, as well as impacts from the downstream transport of large woody debris.

The science of climate change and its hydrologic effects on the Cowichan River is broad and complex. The Pacific Climate Change Impacts Consortium (PCIC) has provided a hydro-climatic overview of the expected changes for the province (Rodenhuis et al., 2009). For British Columbia, the range of average annual temperature is projected to increase by 1^{o} C to 3^{o} C, with a variation in average annual precipitation extending from 3% to 11% across the province. The PCIC regional analysis models indicate that by the fifth decade of the 21st century, the Cowichan Watershed region will likely be warmer and wetter. These trends are also projected by the PCIC's Plan2Adapt Analysis Tool (see Appendix 2, Figures 2-4).

Recent studies by the Cowichan Basin Water Management Forum (Westland, 2007), BC River Forecast Centre (Chapman, 2010), the BC Conservation Foundation (Sutherland, 2011; 2012), and the BC Ministry of Agriculture (2014) for the Cowichan Watershed region indicates that annual average temperatures will likely increase from 0.7^{o}C to more than 1.1^{o}C by 2020's. They are expected to further elevate between 1.3^{o}C and 1.9^{o}C by the 2050's. The hydrologic response of the Cowichan Watershed was assessed by the BC Conservation Foundation (Sutherland, 2011) by using a monthly water balance model that considered monthly precipitation and temperature forecasts. The reported results indicate that by the 2050's the average annual runoff for Cowichan River at Lake Cowichan and at Duncan, BC will rise by 11% and 14%. But, the increase in annual runoff will occur during the wetter fall and winter periods. Monthly streamflows will be less during the spring and summer due to less precipitation received during these annual seasons. At Lake Cowichan, the average reduction in runoff during the spring and summer periods are forecasted to be -13% and -5%. At Duncan, the runoff decreases elevate incrementally to -14% in the spring and -10% during the summer months. It should be noted that the study does caution that some uncertainty exists in the hydrologic model results due to lack of information concerning land cover and land use changes in the future.

5.2 Potential Risks to the Existing Outfall

If the existing river outfall were to remain at its current location along the Cowichan River, then erosion and scour processes would be expected to continue to cause localized channel shifting during moderate-to-high flow events. Channel bed forms will continue to develop (i.e., gravel bar complexes and alluvial islands) and channel patterns will likely change over time. Poor effluent mixing and diffusion would likely result during extended low flow periods when surface water areas and flow volumes reduce. Concentrated effluent discharge levels would likely occur as the relative position of the channel's thalweg continues to shift further away from the existing outfall location.

There is also a continued risk of damage to the river outfall from log strike, log jam formation and scour. By comparison, the potential risks to a deep water outfall location in Cowichan Bay or Satellite Channel would be associated with the positioning of the structure so that it is not within dedicated marine navigation zones, is not within high wave energy zones, is not subjected to excess nearshore sediment depositional processes, and would not be negatively affected by tide or potential sea level changes within the marine waters.

5.3 Cessation of Discharge from Existing Outfall

Given the future projection that stream flows will likely be less along the Cowichan River during the spring and summer by up to -14% in the spring and -10% during the summer months, the removal of the outfall and the cessation of effluent discharge from the Joint Utilities Sewage Lagoons Treatment Plant will provide a net overall benefit to the river's existing water quality because it will eliminate the nutrient loading from the treatment plant.

The Cowichan Valley Regional District (CVRD) has reported that discharges from the treatment plant have caused seasonal increases in nutrient levels despite significant improvements in phosphorus reduction in recent years (CVRD 2010). During low flow conditions in 2014, the Municipality of North Cowichan reported to BC Environment that water temperature, nitrite (NO_2), fecal coliforms and Escherichia coliforms exceeded BC Water Quality Guidelines along the lower Cowichan River. The elevated nitrite levels were from the treatment plant, with corrective actions undertaken after the event. However, a general concern was raised that if extended low flow periods persist and stream flows continue to decrease, the treatment plant would likely not be able to meet the provincial water quality guidelines in the future (Reitsma 2014).

Given the current channel geomorphic conditions and the migration of the river's thalweg away from existing outfall location, the use of temporary pipeline hoses to extend the outfall diffusers out into the active water flow area during extended low flow periods may likely be required again in order to achieve acceptable downstream effluent mixing and dilution ratios along the lower Cowichan River. Without maintaining or elevating the regulated flow discharge levels from the Lake Cowichan weir, then extended low flow periods will likely negatively impact fisheries and habitat conditions along the lower Cowichan River.

6 Receiving Environment Characteristics - Proposed Marine Discharge

The physical oceanographic characteristics of the receiving environment dictate the dilution, dispersion and potential impacts of an effluent plume discharged into the marine environment. Primarily the circulation patterns (current driven by wind and tides) and water column density affect the rate of dilution and fate of the effluent plume to intercept with potential receptors of concern. Oceanographic studies were carried out in relation to previous efforts in siting a marine outfall in Cowichan Bay and Satellite Channel (Dayton & Knight Ltd., 1993). Given that that scope of this study is based on available data this historical study provides the foundation for the characterization of Cowichan Bay and Satellite Channel.

The following sections outline the key oceanographic properties in the vicinity of the discharge based on the above studies and current reference material where applicable.

6.1 General Site Characteristics and Bathymetry

Cowichan Bay is located along the east coast of Vancouver Island, within the Gulf Islands. The bay is approximately 1.6 to 2 km wide and approximately 8 km long from Cherry Point at the eastern extent to the Cowichan and Kokssilah River Estuary at its head. To the south east, the Bay opens to Satellite Channel and Saanich Inlet. North of Separation Point, Satellite Channel leads into Sansum Narrows.

The *Municipal Wastewater Regulation* defines embayed waters as waters:

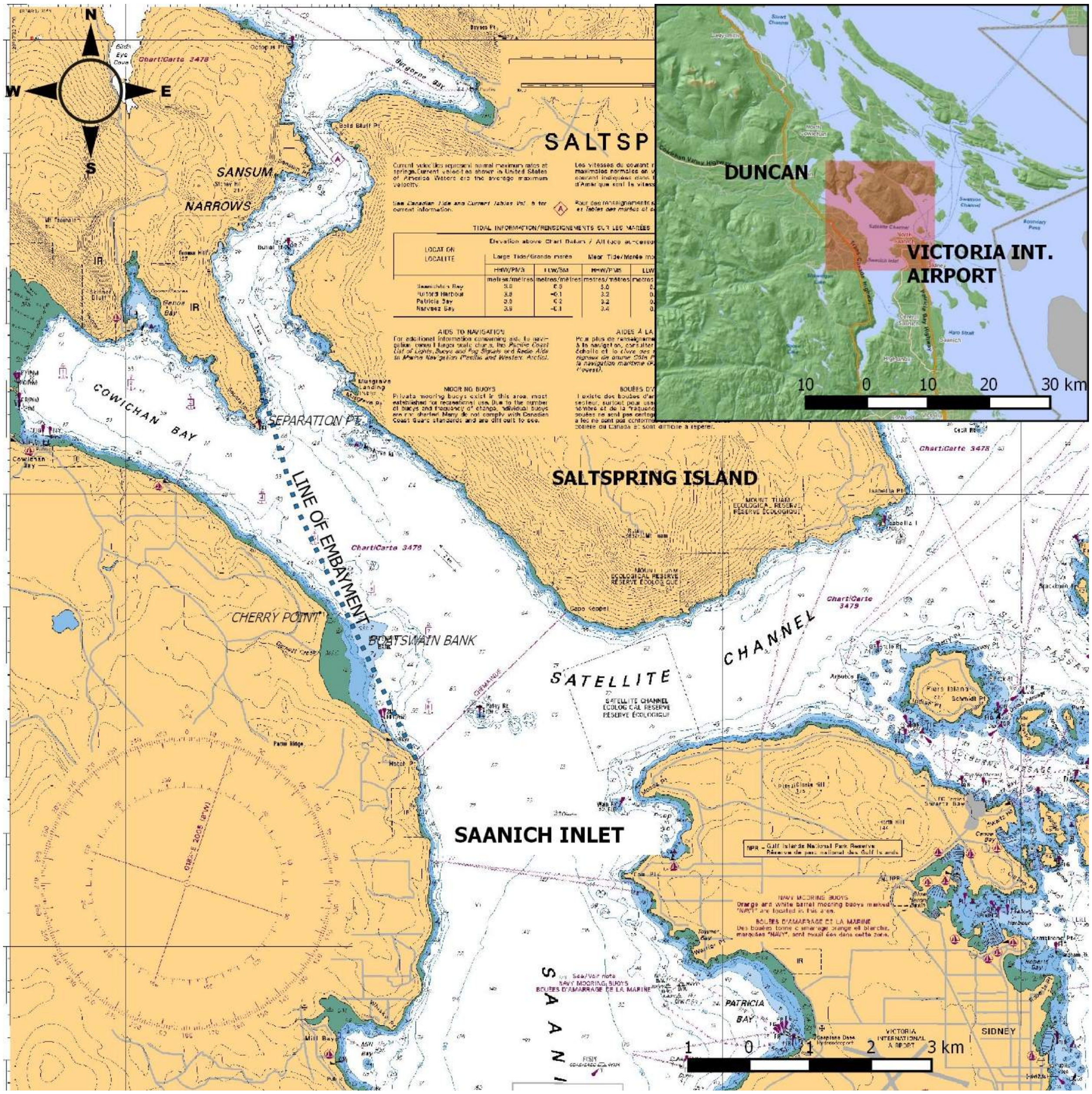
a. *located within a bay from which the access to the sea, by any route, has a maximum width of less than 1.5 km,*

b. *located, if a line less than 6 km long is drawn between any 2 points on a continuous coastline, on the shore side of the line, or .*

c. *in which flushing action is identified in a notice given by a director to be inadequate.*

The line of embayment, based on the 6 km line between two points on a continuous coastline is shown in Figure 4, and runs approximately between Separation Point and Boatswain Bank.

Figure 4 Line of Embayment and Bathymetry



Bathymetry (water depths) within the embayed area is shown on Figure 5. For marine and estuarine discharges the minimum allowable depth of discharge is 10 m. This is easily achieved, within 50 m of the low water mark in nearly along the southern and northern bank of Cowichan Bay. Large tidal flats are found at the head of Cowichan Bay (Cowichan River Estuary) and south of Cherry Point (Boatswain Bank). Depths increase to over 50 m throughout most of Cowichan Bay and to depth of over 100 m within Satellite Channel.

The central portions of Cowichan Bay appear to be relatively even with few significant features. The marine chart for the region indicates the seabed is composed primarily soft sediments throughout the majority of Cowichan Bay. The notable features of the study area are: a localized depression south east of Separation Point (depths in the depression are 135 m); and the comparably shallow water depth of Boatswain Bank (the 10 m depth contour extends 1.3 km from the high water line).

With the exception of the Separation Point depression and Boatswain Bank, the depths within the study area and the substrate composition are both favorable for the installation of a marine outfall.

6.2 Existing Nearby Discharges

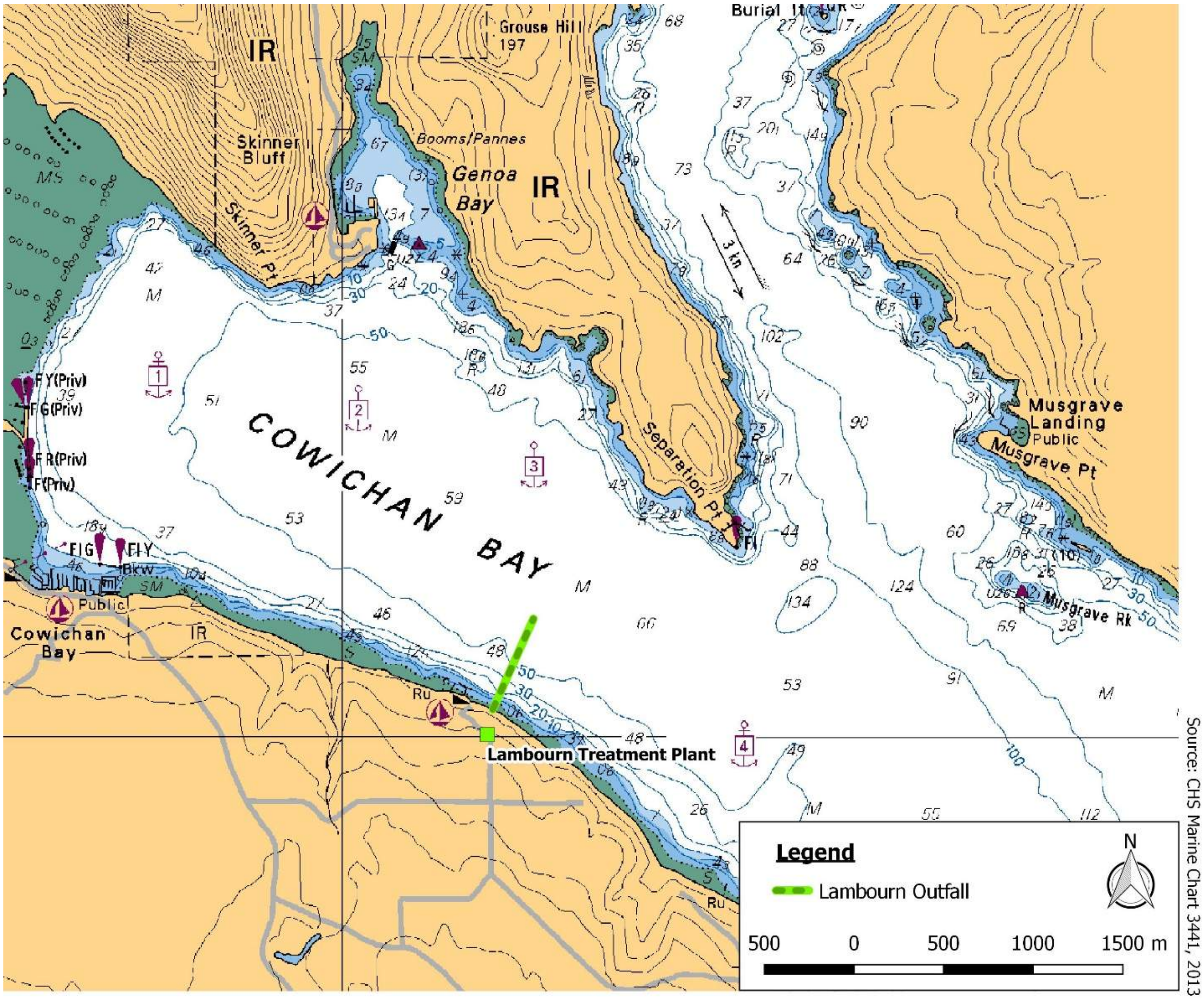
The existing discharge from the JUB Lagoons to the Cowichan River is the primary wastewater discharge to the study area. The Cowichan Valley Regional District operates the Lambourn Wastewater Treatment plant. Wastewater from the plant is discharged via a marine outfall. The outfall terminates at the following coordinates (48.666°N, 123.6523°W) and is shown in Figure 5.

The Lambourn Outfall commenced registration under the *Municipal Wastewater Regulation* in 2005, with the following effluent characteristics:

Flow	591 m^3/d (Maximum)
Total Suspended Solids	10 mg/L
Biochemical Oxygen	10 mg/L
Fecal Coliforms	14 MPN/100 mL
Total Nitrogen NO_3	10 mg/L
Total Nitrogen	20 mg/L

This discharge represents less than one percent of the maximum flow from the proposed JUB discharge (77,000 m^3/d). Given the high quality effluent discharged from the Lambourn outfall cumulative effects are predicted to be negligible if the two discharges are located in close proximity.

Figure 5 Lambourn Wastewater Treatment Plant and Outfall



6.3 Climate

As an overall summary, climate normals for Duncan Kelvin Creek (48°44'05 " N, 123°43'39" W) are provided in Table 6 (Environment Canada, 2014). The station is located approximately 11 km west of the proposed outfall. Temperature and precipitating values at the Duncan Kelvin Creek Station are expected to be reasonably consistent between the two locations. As wind conditions are not measured at the Duncan Kelvin Creek station, wind conditions for the Victoria Airport station are provided in Table 7 (Environment Canada, 2014). The Victoria International Airport (48°38'50" N, 123°25'33" W) is located approximately 18 km south east of the proposed outfall. However, wind conditions at the airport may not be completely representative of conditions near the outfall at Satellite Channel, due to influences of local topography.

Table 6 1981 to 2010 Canadian Climate Normals at Duncan Kelvin Creek Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average Temperature (°C)	3.6	4.4	6.3	9.1	12.4	15.3	17.9	17.8	15.2	10.1	5.8	3.3	10.1
Precipitation (mm)	248	139	135	82	49	37	22	33	32	119	228	236	1361

Table 7 1981 to 2010 Wind Normals at Victoria International Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Wind													
Speed (km/h)	9.4	9.5	9.9	9.9	9.3	9.1	8.4	7.8	7.2	8.2	9.8	10.4	9.1
Most Frequent Direction	W	W	W	W	W	W	SE	SE	W	W	W	W	W
Maximum Hourly Speed (km/h)	61	66	56	58	51	51	45	45	54	77	64	74	77
Direction of Maximum Hourly Speed	S	SW	W	SW	W	W	W	W	SW	E	E	W	E

6.4 Waves

Wave heights in the study area will be consistent with those of a semi-protected shoreline with a maximum fetch distance between 10 km and 50 km. A maximum wave height of approximately 1 m with a period of 4 seconds is estimated for a sustained wind of 80 km/h, (Holden, 1996). Waves of this height are unlikely to significantly impact a deep water discharge and would not pose a significant engineering challenge for the installation of the marine outfall.

6.5 Tides

The range of tide elevations expected in the study area are provided in Table 8 below. The tides are mixed semi diurnal, there are two high tides and two low tides each day with different amplitudes. The higher of the two high tides is referred to as the higher high water, and the lower of the two low tides is referred to as the lower low water.

All dilution modelling and impact assessment of the proposed effluent plume was carried out using the low water large tide conditions. This is a conservative estimate as there is the least volume/depth of water over the point of discharge and therefore the dilution potential is a minimum.

Table 8 Tide Range at Cowichan Bay (Fisheries and Oceans Canada, 2008a)

Water Level		Water Elevation (m) above chart datum
Higher High Water	Large Tide	4.0
	Mean Tide	3.3
Mean (~ Geodetic)		2.3
Lower Low Water	Mean Tide	0.9
	Large Tide	0.0

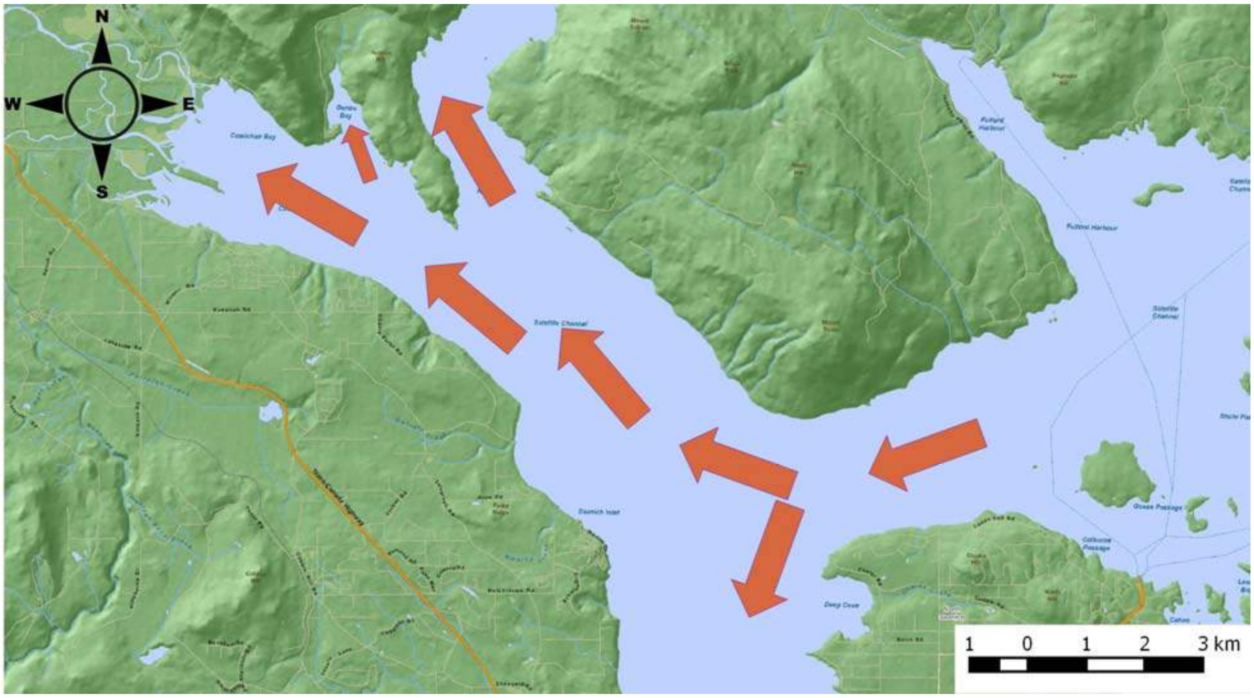
6.6 Currents

Currents within Cowichan Bay and Satellite Channel were assessed by Dayton and Knight Ltd. in 1993. The study investigated current patterns near the mouth of Cowichan Bay, using drogues and the collection of CTD (conductivity, temperature, and salinity) measurement, focusing on near surface currents using drogues to measure currents near the surface and at a depth of 10 m. The full results of the studies are presented in the report, *A physical oceanographic study of Cowichan Bay, Vancouver Island, British Columbia* (Appendix 3, Dayton and Knight, 1993).

The near surface water currents are a combination of tidal circulation and estuarine flow. The estuarine flow results from the discharge of fresh water from the two major rivers at the head of the bay. The fresh water, which is less dense that the salt water in Satellite Channel and Cowichan Bay will float at the surface. The continuous input of fresh water drives the surface layer seaward away from the mouth of the rivers. As the surface layer travels it slowly mixes with the underlying salt water, and increases in salinity (and density). Through this process, a net outflow of this “brackish” surface layer occurs. The net loss of salt water in the outflowing surface layer must be replaced, which results in a net inflow of underlying marine water. Based on the work completed by Dayton and Knight, the net inflow was estimated to extend from the brackish layer down to a depth of 20 m.

Superimposed on the estuarine circulation are currents driven by tides. The tidal currents will dominate the circulation within Cowichan Bay and Satellite Channel. The general current pattern during a flood tide, adapted from Dayton and Knight (1993) is provided in Figure 6. During the flood water flows to the northwest though Satellite Channel towards Sansum Narrows and into Cowichan Bay.

Figure 6 Flood Tide



During the ebb tide, two typical scenarios develop. Water flows to the south from Sansum Narrows to Satellite Channel. This southerly flow may encounter northerly flowing water from Saanich Inlet, resulting in eddies near the mouth of Cowichan Bay (Figure 7 and 8). If the water flowing from Saanich Inlet is flowing more to the east, the eddies will not develop and flow at the mouth of Cowichan Bay will be to the south east.

In Cowichan Bay, the ebb flow will tend to favor the southern side of the bay resulting in strong outflowing currents along the southern shore. This is partially a result of a clockwise eddy (or multiple eddies) that tend to develop south of separation point.

Figure 7 Ebb Tide (Flow from Saanich Inlet to the North)

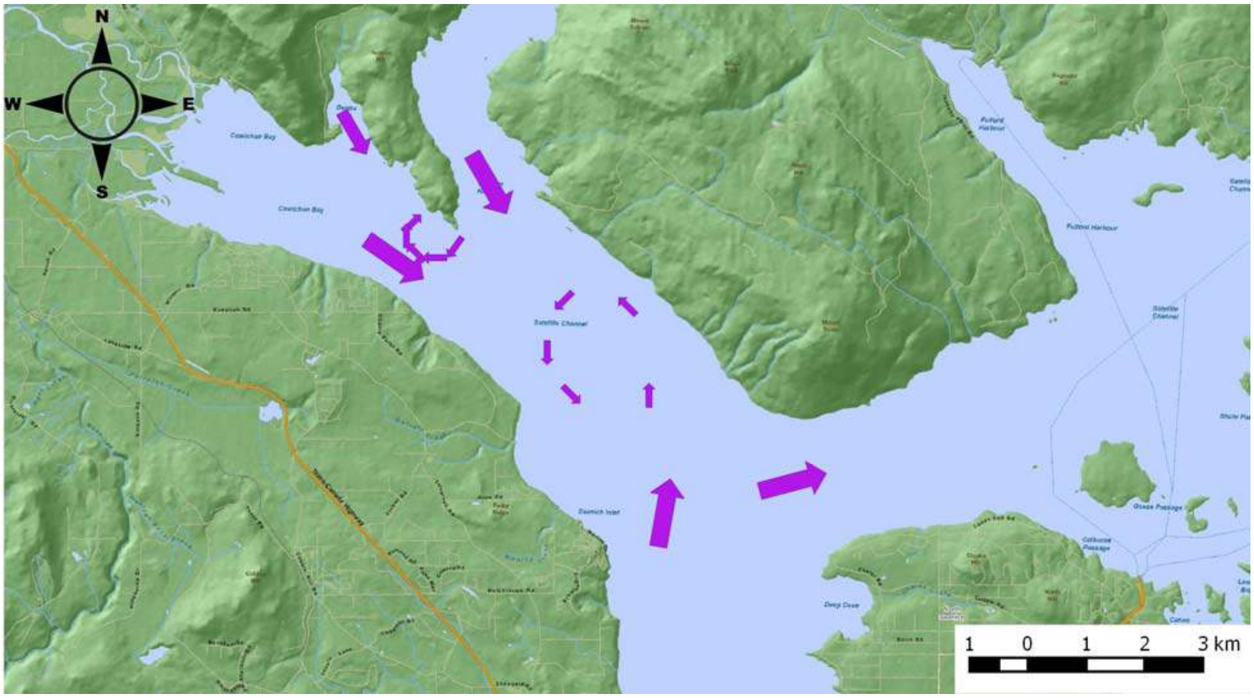
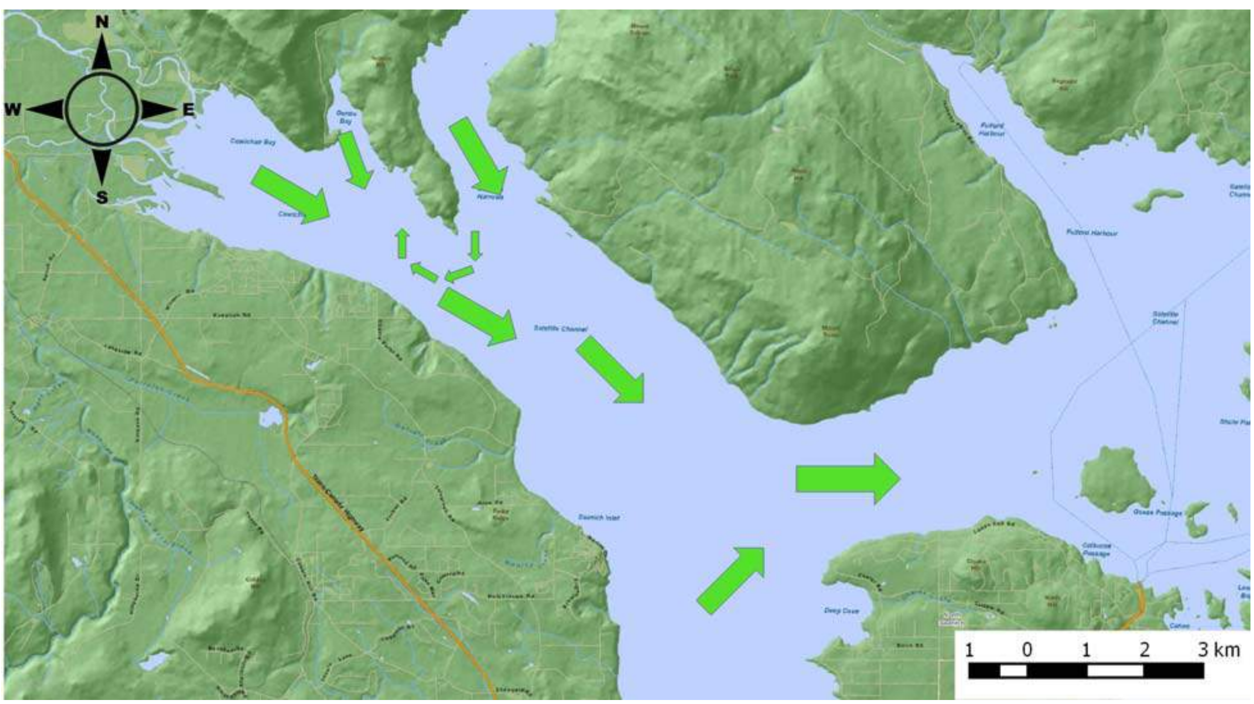


Figure 8 Ebb Tide (Flow from Saanich Inlet to the North East)



The diluted effluent plume will recirculated within these eddies; however, iven that they are not permanent structures (i.e. they form during specific tidal conditions and therefore may only last for portions of each day) and that there is strong flow past the mouth of Cowichan Bay, effluent released near the mouth of Cowichan Bay will ultimately mix with surrounding waters and be carried from the region.

Currents below a depth of 20 m are not known, the Dayton and Knight study suggested that current velocities at depth are likely to be lower. However, anecdotal evidence from work conducted on the Lambourn outfall suggested that current speeds at depth (>30 m) may be as strong or stronger than in the upper water column.

Additional oceanographic field studies should be conducted to confirm these assumptions.

6.7 Water Column Profiles (Density)

The density structure (stratification) of the receiving water column is a key variable in predicting the dilution that can be achieved when an effluent is discharged to the marine environment.

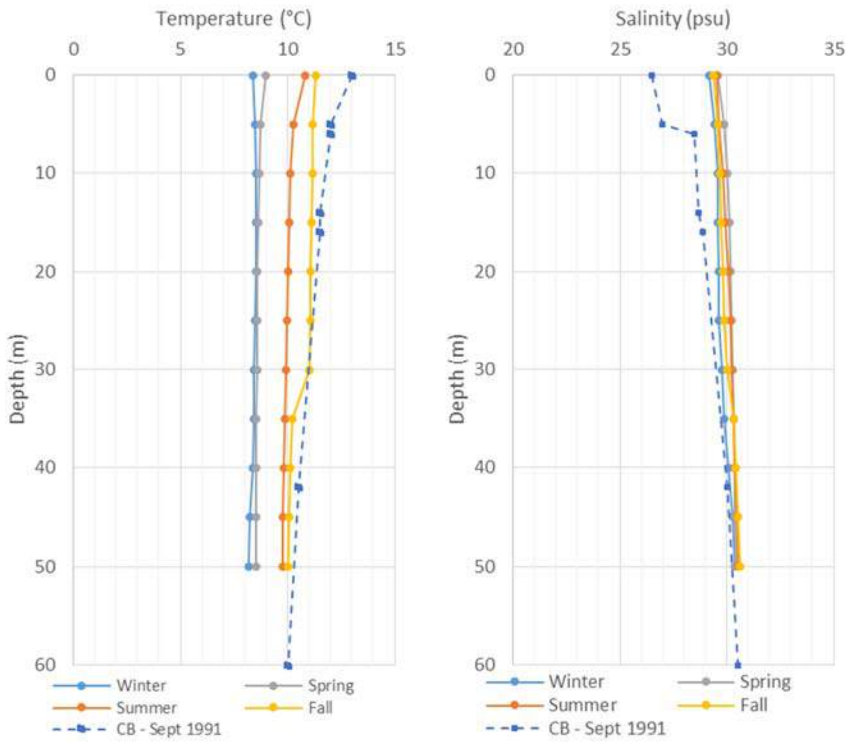
Prior to discharge, the effluent has a density close to that of the fresh water. As such it will be buoyant at the point of discharge with respect to the surrounding seawater. This difference in density of the two fluids causes an effluent to float upwards when released to seawater at depth. At the point of release into the seawater, the effluent mixes with the seawater by the turbulence of the mechanics of discharge and buoyant rise. Following its discharge, the effluent / ambient mixture (the plume) rises in reaction to the buoyancy flux (difference between density of the plume and the ambient) towards the ocean surface. As it rises, the plume entrains more ambient water, progressively increasing in density, (i.e. the temperature and salinity approaches that of the receiving environment).

If a density gradient exists in the receiving environment surface waters (i.e. stratification), the density of the effluent plume may reach a depth where its density is equal to that of the overlying water. When this occurs, the effluent plume will no longer be buoyant and will cease its buoyant rise (other than a temporary phenomenon of momentum) and will become “trapped”. If little or no stratification is present, or insufficient dilution is achieved, the effluent plume may continue to rise until it reaches the water surface.

Few site specific temperature and salinity profiles for the study area were available for this project. Profiles were collected within Cowichan Bay in September 1991 (Appendix 3, Dayton Knight, 1993). In addition, Fisheries and Oceans Canada (2009) have published seasonal mean temperature and salinity for the Gulf Islands. The seasonal temperature means and the Cowichan Bay profiles are plotted in Figure 9. The profile collected in Cowichan Bay is noticeably more stratified than mean profiles as a result of the input from the Cowichan River. The September 1991 profile was used for dilution modelling of the outfall.

The discharge of freshwater from the Cowichan River (Section 5) will have a significant influence on the salinity of the water within Cowichan Bay and the surrounding bodies of water. The monthly discharge rate for the Cowichan River (Wateroffice, 2015) is plotted in Figure 3. The rate of discharge in September 1991 (39.1 m^3/s) represents reasonably low flow conditions for the river and therefore stratification/surface water salinity are expected to be relatively low during these conditions. Peak discharge typically occurs in the winter when there is the highest rainfall to the region. Winter conditions are therefore expected to have the lowest salinities in the surface water and highest level of stratification (*i.e*. deepest trapping depth). Due to this seasonal difference, it is recommended that pre-discharge monitoring include both winter and summer conditions.

Figure 9 Temperature and Salinity Profiles



7 Receptors

The main receptors include ecological reserves, recreational areas and harvestable marine resources, particularly bivalve shellfish, from which pathogens in the effluent plume may be transferred to humans.

7.1 Ecological Reserves and Sensitive Areas

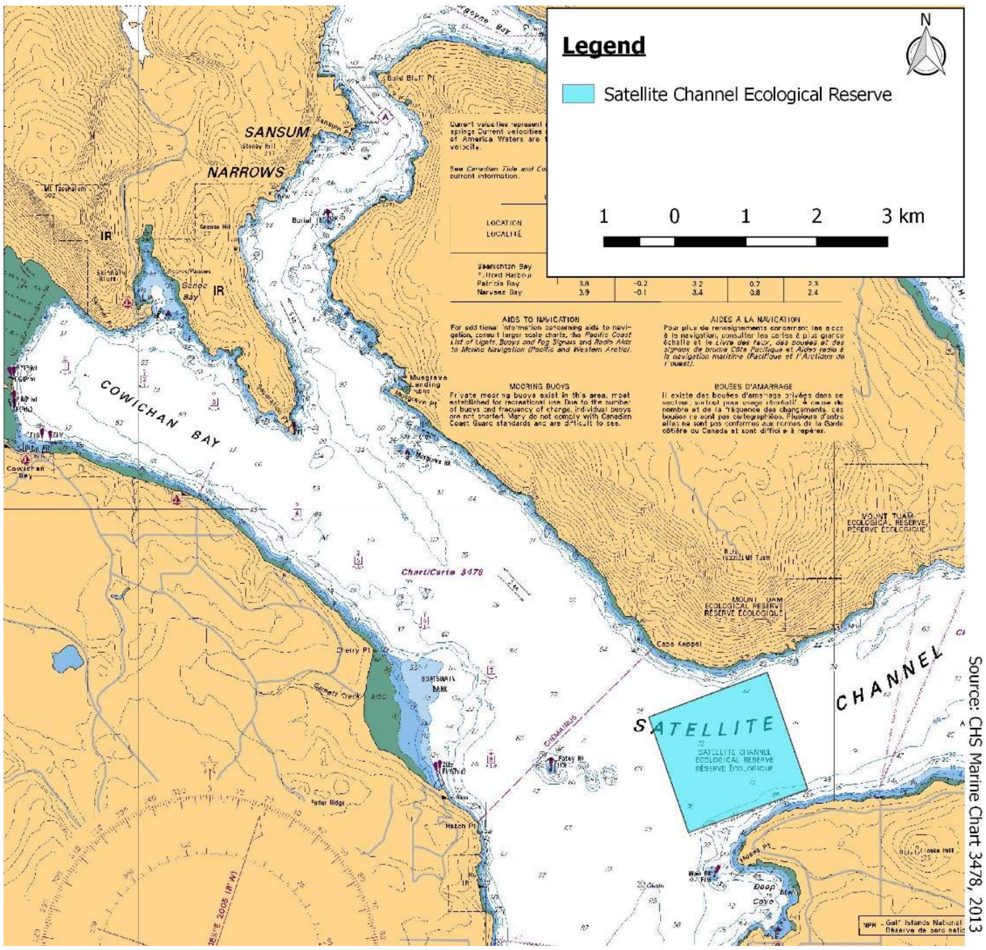
7.1.1 Satellite Channel Ecological Reserve

Satellite Channel Ecological Reserve (ER # 67) was established in 1975 and is a provincial reserve under the *Ecological Reserve Act* (Figure 10). It is a 343-hectare reserve located 200 metres south of Salt Spring Island and 200 metres north of Saanich Peninsula. It is the only completely subtidal marine protected area in British Columbia, as it consists only of seafloor habitat (British Columbia, 2014).

The primary role of Satellite Channel Ecological Reserve is to conserve rich benthic communities typical of fine-grained, level-bottom environments in the southern Gulf of Georgia.

The ecological reserve is located approximately 6.7 km from the proposed discharge location. No significant adverse effects to the ecological reserve are predicted from the proposed discharge.

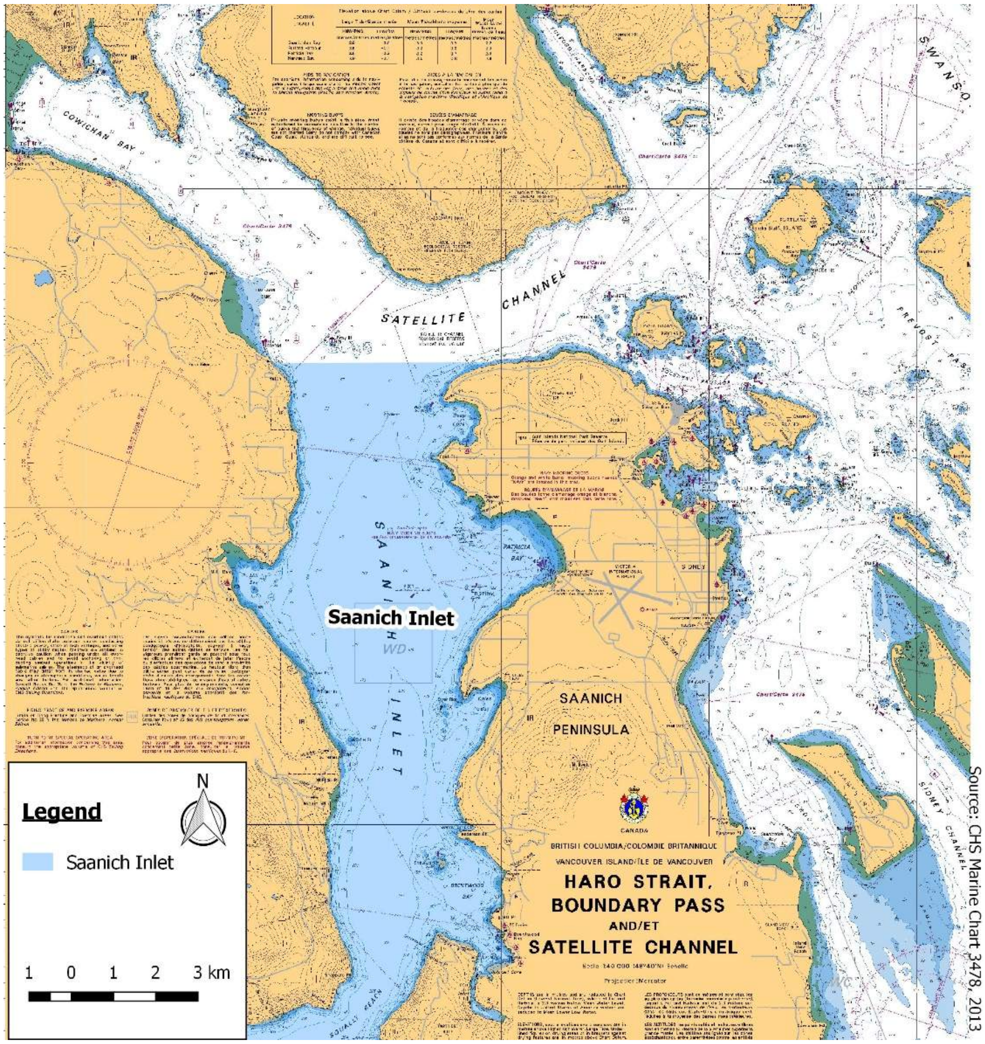
Figure 10 Satellite Channel Ecological Reserve



7.1.2 Saanich Inlet

Saanich Inlet, shown in Figure 11, was formed through glacial scarping. It is a sensitive ecosystem, and is very important ecologically and culturally (MOE, 1996).

Figure 11 Saanich Inlet



In July 1994, the Province of British Columbia initiated the Saanich Inlet Study to provide baseline information required to make a wide range of future decisions regarding zoning, land use, habitat management, and pollution prevention. The Study terms of reference were:

"to determine the sensitivity of Saanich Inlet to contaminants and marine habitat disturbances from urban and rural development, and to determine the capacity of the Inlet to assimilate these contaminants and marine habitat disturbances without environmental degradation. Contaminants to be considered include those associated with sewage effluents, and urban and rural storm, drainage and agricultural runoff."

The study determined that nutrient addition to waters less than 50 m deep is predicted to cause blooms of phytoplankton, which are indicative of negative effects. It also found that major eelgrass beds were present, and Saanich Inlet provided spawning and rearing habitat for salmon (MOE, 1996).

In regards to Saanich Inlet, the *Municipal Wastewater Regulation* states that:

"Discharge to the Saanich Inlet is under a moratorium, and a discharger must not discharge to the Saanich Inlet unless the discharger first conducts an enhanced environmental impact study as recommended by the Saanich Inlet Study."

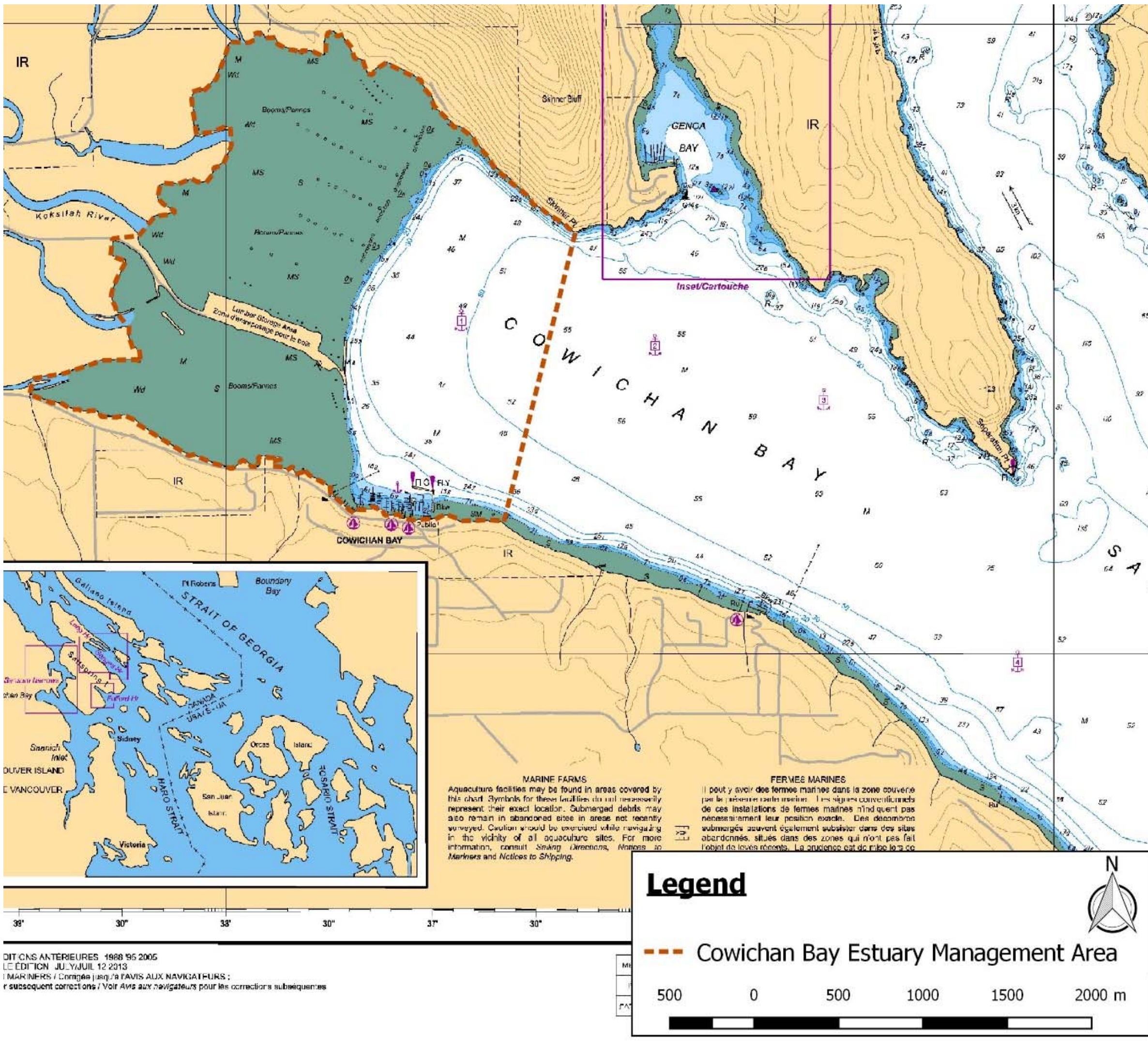
This project does not propose to discharge effluent to Saanich Inlet.

7.1.3 Cowichan Estuary

The Cowichan Estuary is an ecologically important estuary, providing habitat for numerous species, including over 200 bird species, and four salmon species. It is highly valued for cultural and recreational reasons as well. High industrial use of the area resulted in the degradation of estuarine habitats. To address these impacts, the Cowichan Estuary Environmental Management Plan (CEEMP) was established in 1987 to provide guidance for the protection of the estuary and its important cultural and ecological value. The management plan acknowledges that industry and other activities are well established in the Cowichan Estuary. It aims to limit the detrimental environmental impacts of those activities and to avoid further habitat loss. Area designations were created to indicate the type of activity that is acceptable to occur in that designated area. These include: industrial/commercial, agriculture, log storage, habitat management, and conservation/recreation. The boundary of the Cowichan Bay Estuary Management area is shown in Figure 12.

The proposed discharge is well beyond the Cowichan Estuary boundary; however the construction of the pipeline will likely be proposed to transit through a portion of the estuary.

Figure 12 Cowichan Bay Estuary Management Area



7.2 Aquatic Resources

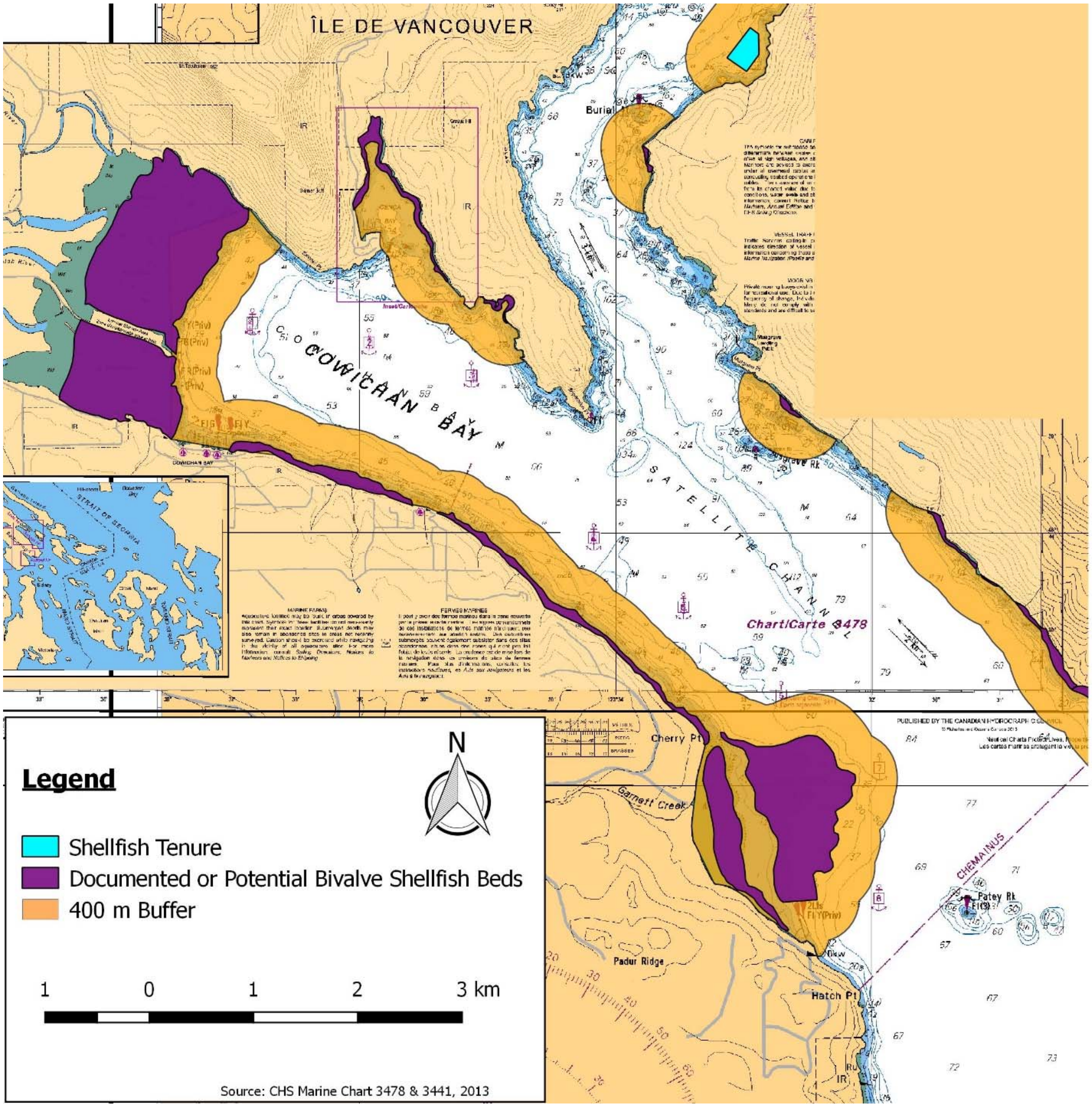
7.2.1 Shellfish

Bivalve Shellfish

As defined in the MWR, shellfish waters means "*bodies of water capable of supporting shellfish in quantities that permit aboriginal, commercial or recreational shellfish harvesting".*

Figure 13 shows the known shellfish beds and shellfish tenures in the area. A buffer of 400 m is shown to indicate the minimum offset from each area as required under the MWR. Effluent discharge is not permitted within this 400 m buffer.

Figure 13 Bivalve Shellfish Locations



Sanitary Closures

An area will be closed to commercial bivalve shellfish harvesting for a variety of sanitary reasons. Fisheries and Oceans Canada identifies permanent bivalve fishing prohibited areas (no harvesting for any purpose).

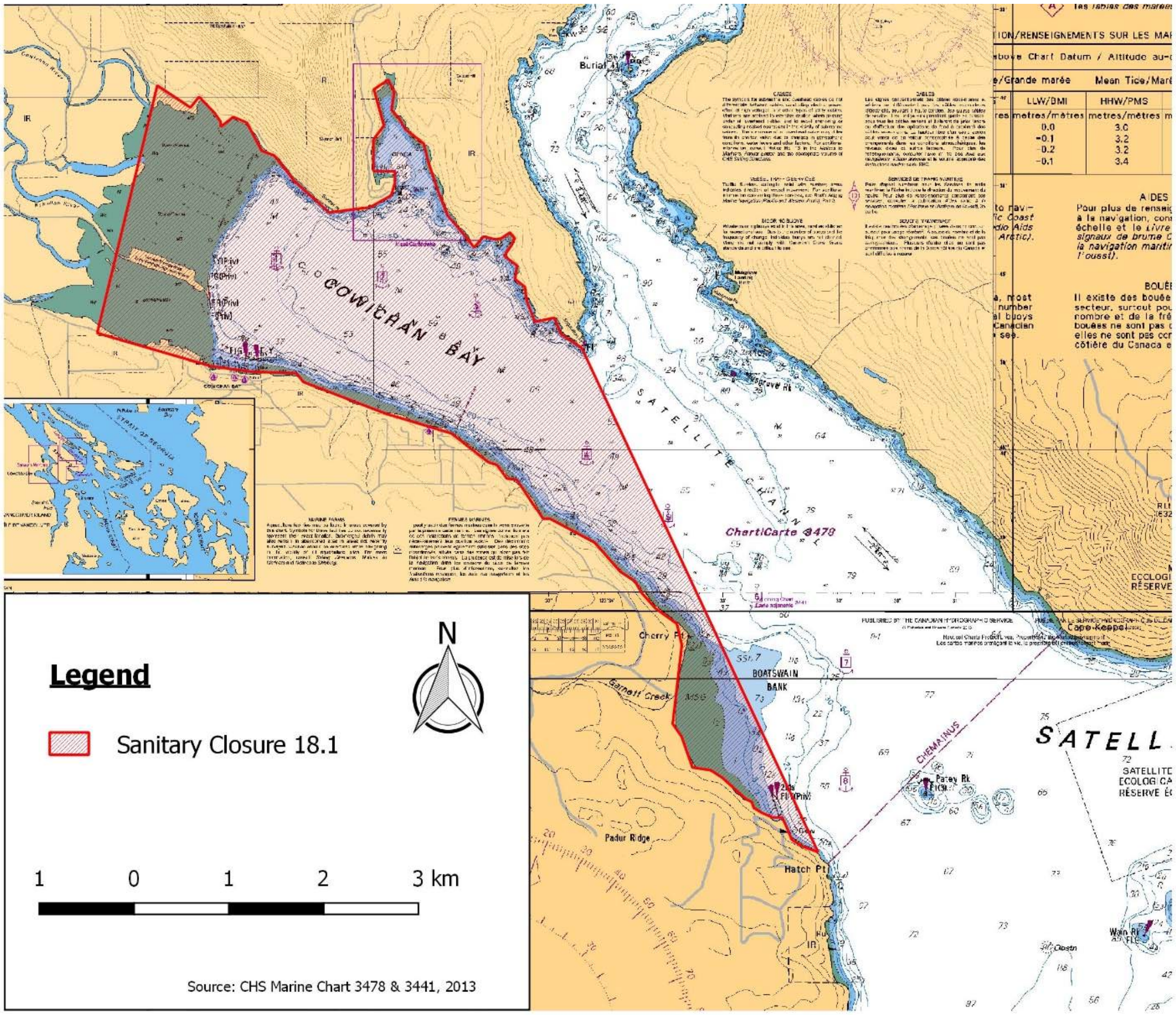
These areas are:

- within 300 m of industrial, municipal and sewage treatment plant outfall discharges;
- within a minimum 125 m of marinas, wharves, finfish net pens, float homes or other floating living accommodation facilities, including live aboard boats (DFO, 2014).

The project area is located within Pacific Fishery Management Area 18. The proposed outfall is located within an area that is currently under sanitary closure 18.1 (Figure 14). Area 18.1 includes waters and intertidal foreshore of Cowichan Bay, including Genoa Bay and Boatswain Bank, lying inside a line drawn from Separation Point to Hatch Point.

The relocation of the outfall is anticipated to be a positive step forward to achieving a regional goal of re-opening bivalve shellfish harvesting in Cowichan Bay. The discharge of effluent at depth is intended to limit the direct interaction between the effluent plume and harvestable shellfish. Presently, the effluent plume is carried into Cowichan Bay in the outflow from the river in the surface waters. A trapped effluent plume at depth will reduce the likelihood of pathogenic organisms from the effluent plume reaching harvestable bivalve shellfish.

Figure 14 Sanitary Closure 18.1



This area has documented bivalve shellfish with known commercial and First Nations harvesting.

Other Shellfish

Other (non-bivalve) shellfish are prevalent within Cowichan Bay including several species of Crab, shrimp and prawns. Cowichan bay is an important First Nation crab harvesting area. Cabs are also harvested commercially within the region.

Underwater surveys completed in the Cowichan Bay Estuary (Archipelago, 2005), identified numerous species of crab including; Dungeness crab (*Cancer magister*), red rock crab (*Cancer productus*), Cancer sp. (*C. magister*, *C. gracilis*, *C. Productus*), and kelp crab (*Pugettia sp*.).

Dungeness crab are harvested within Cowichan Bay, Satellite Channel, and Sansum Narrows. Between 2001 to 2009, 357,500 kg of Dungeness crab have been harvested from the study area (Fisheries and Oceans Canada, 2013a). In the same time period, 64,900 kg of prawn and shrimp have also been harvested from the study area (Fisheries and Oceans Canada, 2013a).

Fisheries and Oceans Canada does not implement closures at municipal wastewater discharges for crab, shrimp and prawn harvesting (*pers. com. Elysha Gordon*).

7.2.2 Anadromous Fish

The Cowichan River originates from Cowichan Lake, flows east approximately 47 km and drains to Cowichan Bay on the southeastern corner of Vancouver Island. Prior to discharging into the bay, the river forks into a north and south arm. The Cowichan watershed is known for its abundance and diversity of resident and anadromous fish populations. Because of this, the system is used for the US/Canada Pacific Salmon Treaty as an index river for the Georgia Basin (CVRD 2010). A search of the provincial Fisheries Inventory Data Queries (MOE 2015) identified numerous fish species in the Cowichan River. Major anadromous species include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), chum salmon (*O. keta*) and steelhead (*O. mykiss*). Resident fish species in the system include rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*) and the introduced brown trout (*Salmo trutta*). Both resident and sea-run cutthroat trout (*O. clarkii*) have been documented in the Cowichan River.

Predominantly, anadromous fish migrate and spawn in the Cowichan River during the fall and winter months. Chinook and coho salmon typically spawn in the system from November to December, with chinook utilizing the mainstem and coho accessing smaller tributaries to reproduce (MOE 2015). The chum salmon migration and spawning period typically extends longer, beginning in November continuing into February. In the spring, steelhead spawning occurs in April and May. A spring run also occurs for Chinook salmon but it is small and not well documented (PSC 2014).

Somenos and Quamichan creeks are similar to the mainstem, and include coho and chum salmon, steelhead, rainbow trout, cutthroat trout and brown trout (MOE 2015). Near the outfall, a total of three fish passage obstacles are documented in the mainstem and in the two tributaries. One barrier is located on the southern arm of the mainstem where the river drains into the bay (Obstacle ID 22776; MOE 2015). The other two obstacles are in Quamichan Creek (falls, Obstacle ID 18673) and in Somenos Creek (beaver dam, Obstacle ID 31723), approximately 450 m upstream and 200 m upstream from the Cowichan River mainstem, respectively (MOE 2015). The beaver dam is presently being managed and is only an obstacle to fish passage during summer month with low water conditions (Pers.Com. Mackay).

Within the Cowichan watershed, population declines have been observed for chinook, coho and steelhead (CVRD 2010). Key factors affecting fisheries resources in the Cowichan River, as identified in the 2010 State of the Environment by the Cowichan Valley Regional District, include:

- low water levels from low precipitation and flow alteration (i.e. weir on Cowichan Lake and intakes for the Crofton Mill and the City of Duncan);
- poor water quality (i.e. high water temperatures and sedimentation); and
- loss of spawning and rearing habitat due to development.

Cowichan Bay and Satellite Channel is a migratory corridor for outmigrating juvenile salmon and returning adult.

The proposed marine outfall discharge location is unlikely to negatively impact salmon as it is located away from freshwater spawning grounds and from shallow nearshore marine rearing and foraging areas.

7.2.3 Herring

Pacific herring (*Clupea pallasii*) is a pelagic species that inhabits the inshore and offshore waters of the North Pacific. Herring is fished commercially in BC, as well as fished by First Nations for food, social and ceremonial purposes. They are also important forage fish for other commercially harvested fish species.

Herring school in shallow vegetated inshore areas to spawn in the spring. Figure 15 shows the areas in which herring spawn along Satellite Channel and Salt Spring Island. Figure 16 shows the areas within Saanich Inlet where herring spawn. The project area is not considered to be a significant herring spawn area.

Figure 15 Herring Spawning Locations along Swanson Channel, Section 181

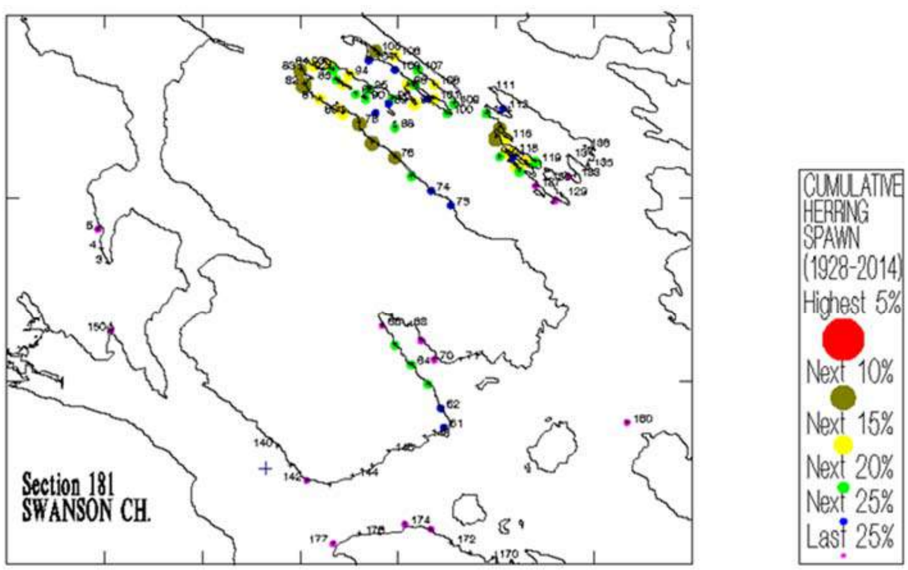
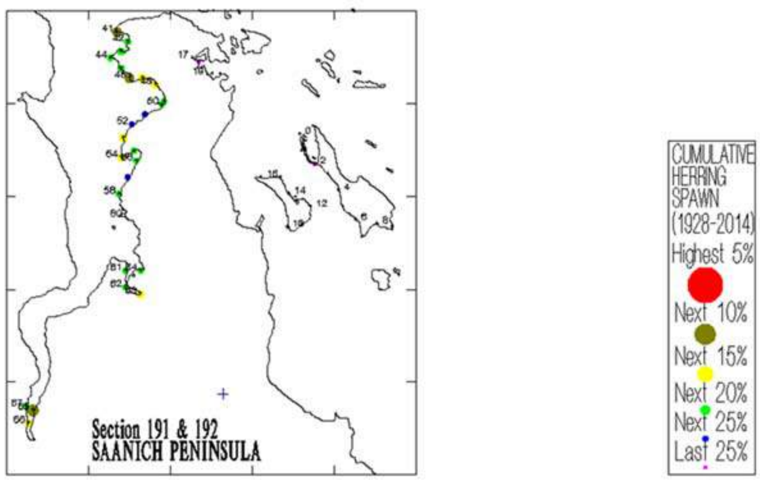


Figure 16 Herring Spawning Locations along Saanich Peninsula, Section 191 & 192

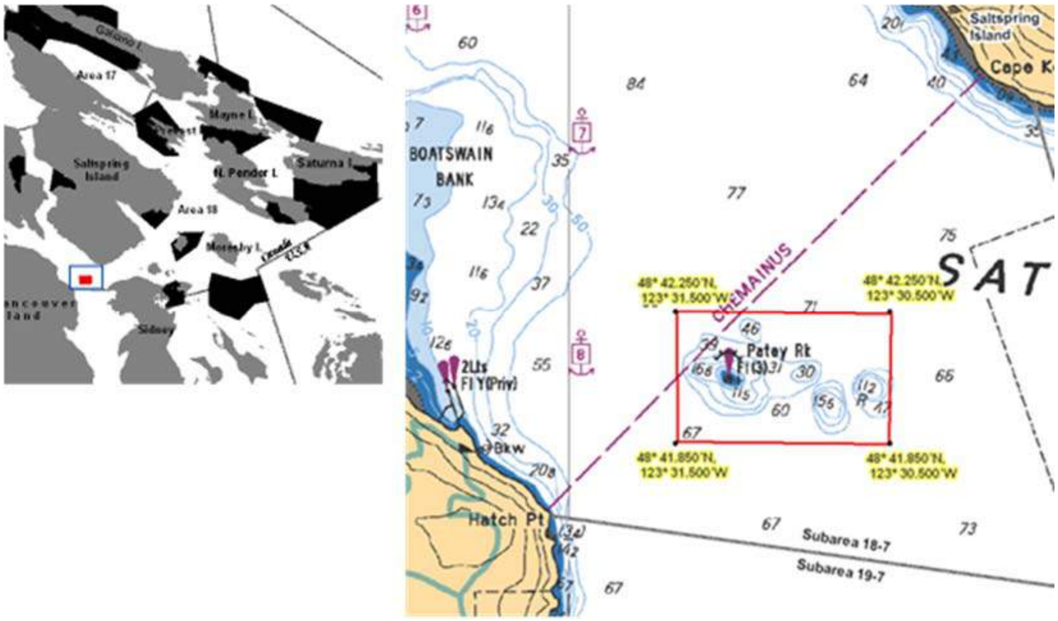


7.2.4 Rockfish

There are 37 species of rockfish typically caught in fisheries in British Columbia. Inshore rockfish species include yelloweye, quillback, copper, china, and tiger. Rockfish are an important species for First Nations, commercial and recreational harvesters. Rockfish Conservation Areas (RCAs) have been established throughout the B.C. coast to mitigate low abundance and over fishing. Within RCAs, inshore rockfish are protected from recreational and commercial fisheries. Figure 17 and Figure 18 show the Rockfish Conservation Areas in proximity to the proposed outfall location (DFO 2008b).

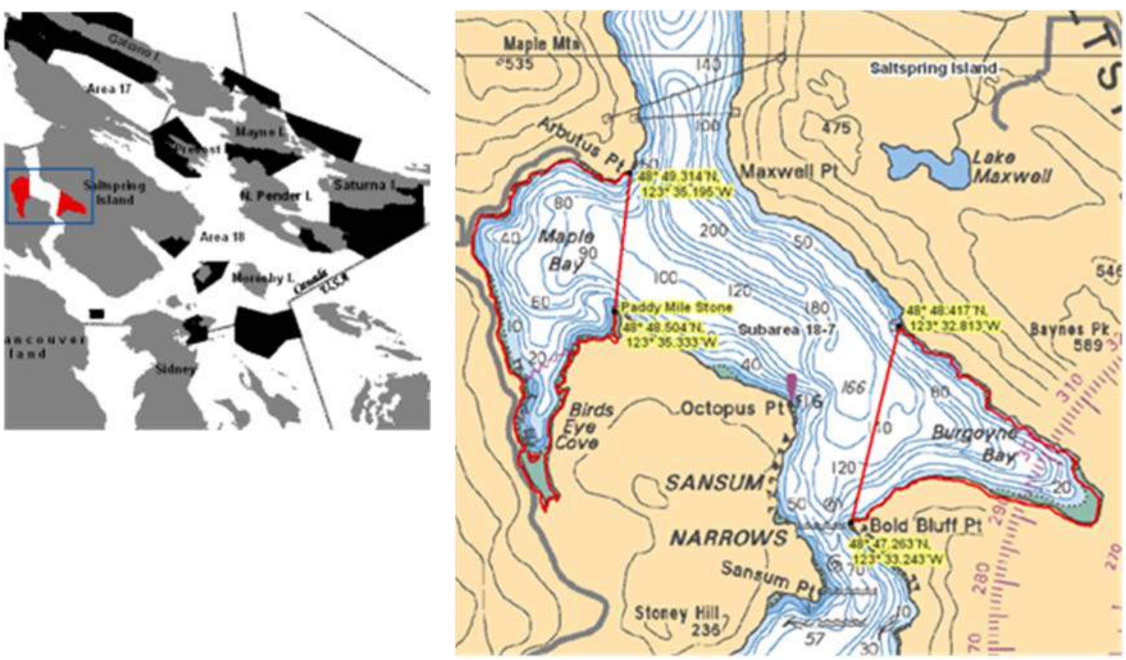
The proposed outfall location is located over a soft sediment substrate, which is a less preferred habitat by rockfish.

Figure 17 Rockfish Conservation Area – Patey Rock, p.142



Source DFO, 2008b

Figure 18 Rockfish Conservation Area – Maple Bay and Burgoyne Bay, p.137



Source: DFO, 2008a

7.2.5 Aquatic Plants

Eelgrass communities are one of the most productive and vulnerable ecological communities of BC's coast. Eelgrass beds function like biodiverse aquatic nurseries and refuges for a range of species, as well as foraging grounds for numerous resident and migratory species (EC, 2002). It is estimated that over 80 percent of commercial fish and shellfish species depend on eelgrass habitat at some point in their lifecycle. Land use changes and developments have led to a loss of natural estuarine habitat in British Columbia. Agriculture, forestry, and dredging for commercial and residential development have all contributed to the loss. Figure 19 shows the location of eelgrass beds in and around Cowichan Bay.

Kelp forests are another important ecosystem due to their productivity. They provide vital habitat for numerous species. Figure 20 shows the locations of kelp beds near the proposed project area. While there are no kelp beds located directly within Cowichan Bay, there are kelp beds reported nearby in Sansum Narrows.

The construction of the outfall pipeline through eelgrass or kelp forests is the most likely source of degradation of aquatic plants. Construction activities should adhere to Fisheries and Oceans *Canada Measures to Avoid Causing Harm to Fish and Fish Habitat* (2013b) and include compensation measures if required.

Figure 19 Eelgrass Bed Locations

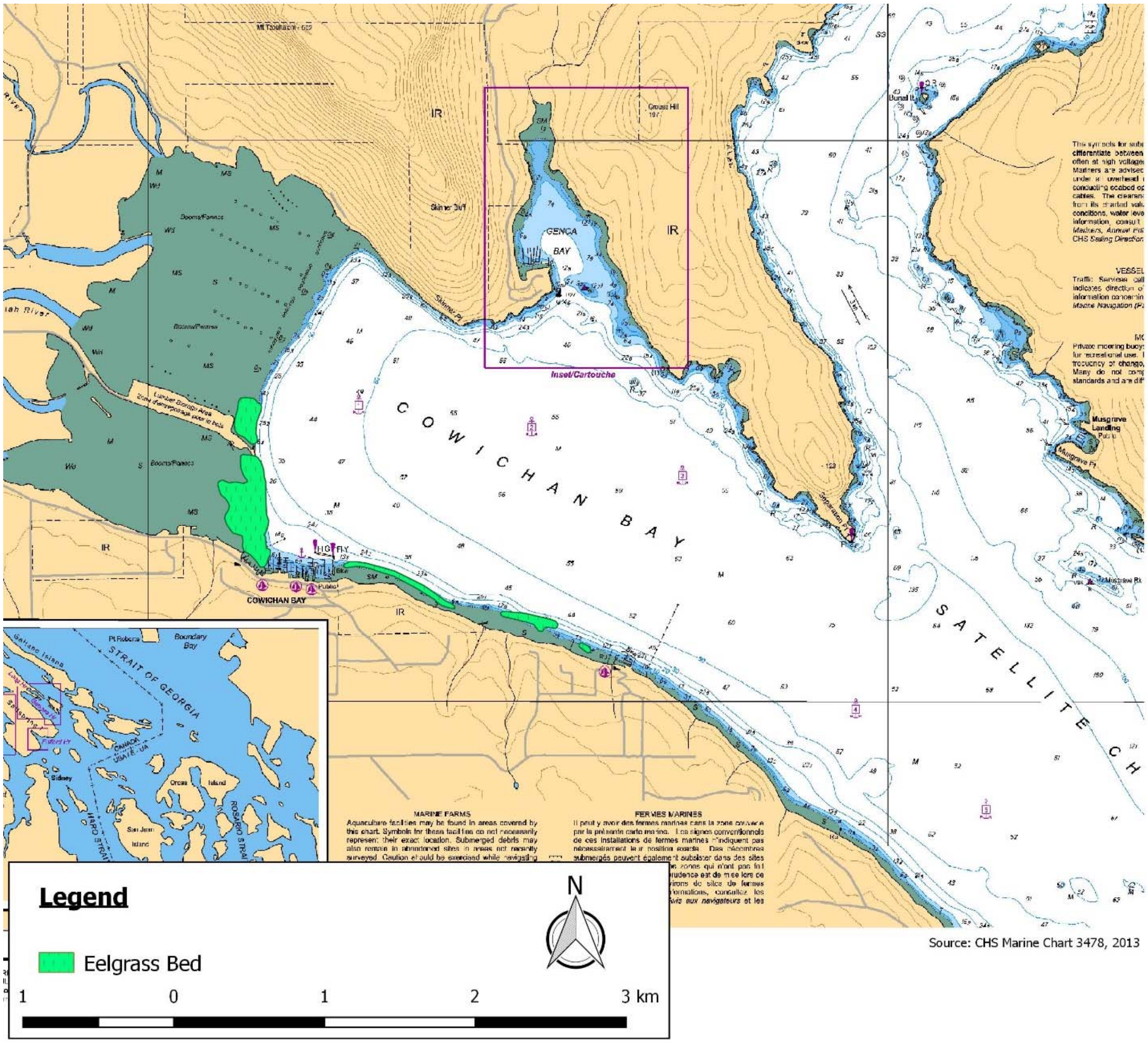
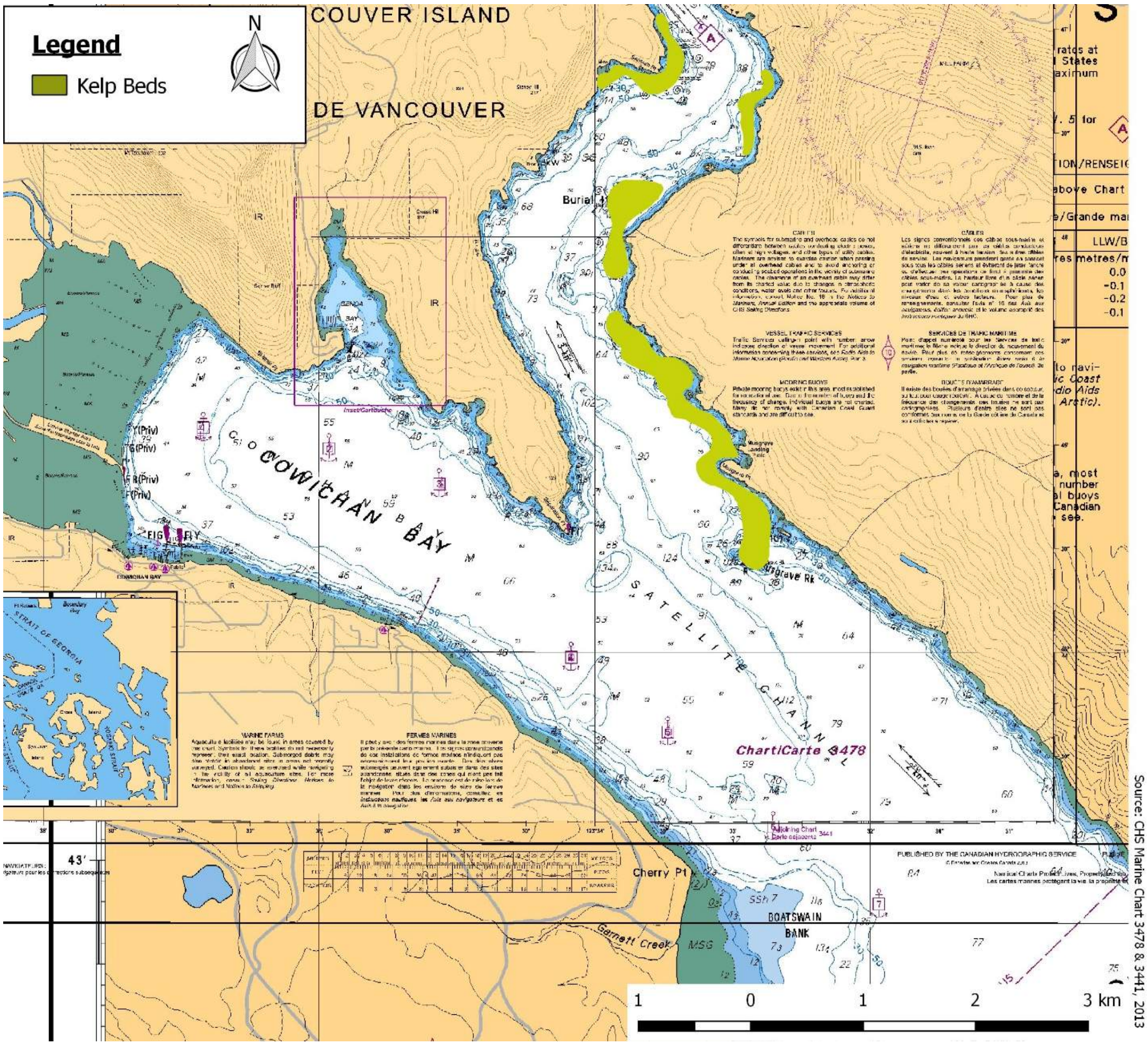


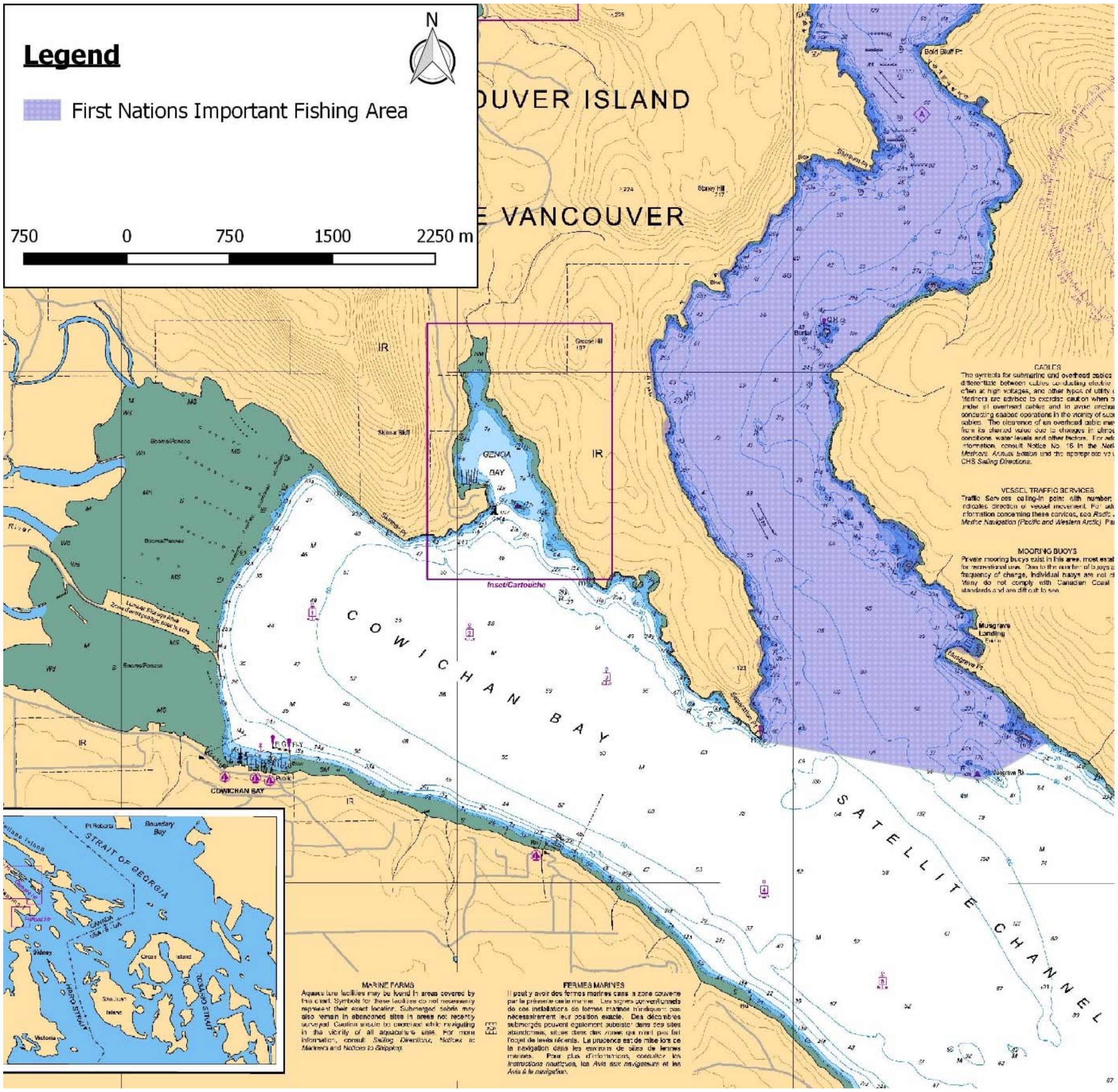
Figure 20 Kelp Forest Locations



7.2.6 Important First Nations Fishing Area

The siting of the new outfall was discussed with the Cowichan Tribes in relation to fisheries resources. The Cowichan Tribes indicated that they fish throughout Cowichan Bay and Satellite Channel, and that Sansum Narrows was considered of particularly high importance, as shown in Figure 21. A discharge proposed directly into Sansum Narrows was avoided.

Figure 21 Important First Nations Fishing Area



Source: CHS Marine Chart 3478, 2013

7.3 Marine Mammals

A number of marine mammals that are listed federally and/or provincially at risk have the potential of occurring, on occasion, in Satellite Channel and around the south end of Salt Spring Island. These species are listed in Table 9.

Table 9 Marine Mammals at Risk

Common Name	Scientific Name	Federal Status	BC Status
Killer whale (southern resident)	*Orcinus orca pop. 5*	Endangered	Red
Killer whale (West Coast transient)	*Orcinus orca pop. 3*	Threatened	Red
Grey whale	*Eschrichtius robustus*	Special Concern	Blue
Humpback whale	*Megaptera novaeangliae*	Special Concern	Blue
Stellar sea lion	*Eumetopias jubatus*	Special Concern	Blue
Harbour porpoise	*Phocoena phocoena*	Special Concern	Blue

7.3.1 Grey Whales

Grey whales (*E. robustus*) are currently designated by COSEWIC as a species of special concern, and are blue-listed under the BC Wildlife Act. Grey whales are usually found in shallow (< 60 m) water close to shore. Grey whales (*E. robustus*) feed predominantly on amphipod crustaceans by scooping up sediment and straining it through their baleen (DFO, 2008c). Grey whales (*E. robustus*) off British Columbia similarly prefer shallow nearshore habitats with mud or sand bottom.

Localized nutrient loading due to untreated sewage discharge has the potential to degrade or contaminate feeding areas, especially soft sediment feeding grounds (DFO, 2008c). As grey whales (*E. robustus*) ingest sediments when feeding, they are potentially susceptible to sediment-bound toxins.

The proposed discharge is not within a known grey whale feeding area.

7.3.2 Killer Whales

Four designated populations of killer whale occur in the coastal and offshore waters of British Columbia (Northern Resident population, Southern Resident population, West Coast Transient population, and Offshore population). All four populations migrate and feed along the coast of Vancouver Island (COSEWIC, 2008). The Southern Resident population is designated as endangered by COSEWIC, with the remaining Pacific populations designated as threatened. The offshore population is a blue listed species, with the remaining Pacific populations listed as red by the BC Wildlife Act.

Killer whales (*O. orca*) feed primarily on marine mammals and fish. There is evidence that Resident killer whale abundance is limited by the availability of their primary prey, Chinook salmon (*O. tshawytscha*) (Ford *et al.*, 2005). Chinook salmon are particularly vulnerable to over-fishing or activities that negatively impact their spawning habitat. The outfall discharges are unlikely to negatively impact salmon spawning habitat as Chinook spawn in major river systems. Marine mammals, such as Steller Sea Lions (*E. jubatus*) are also an important prey species (COSEWIC, 2003). The presence of pinnipeds is dependent primarily on the presence of their food. Impacts to kelp beds and the foraging areas of pinnipeds could have a negative impact on the prey abundance of killer whales.

The proposed discharge is not within critical habitat for killer whales.

7.3.3 Stellar Sea Lions

Stellar Sea Lions (*E. jubatus*) are a species of special concern as designated by COSEWIC, and a provincially blue listed species under the BC Wildlife Act. Sea Lions were observed in Hammond Bay in November 2014, during field activities related to this EIS. The closest winter haulout (nonbreeding) site to the outfall location is Entrance Island (MOE, 2010). There are only three rookery sites (breeding) in British Columbia (off the northeastern tip of Vancouver Island, off the southern tip of the Queen Charlotte Islands and off the northern mainland coast) (COSEWIC, 2003).

Preferred prey in BC include, but are not limited to, Pacific Herring (*Clupea harengus pallasii*), Pacific Hake (*Merluccius productus*), sandlance (*Ammodytes hexapterus*), salmon (*Oncorhynchus spp*.), Spiny Dogfish (*Squalus acanthias*), eulachon (*Thaleichthys pacificus*), sardines (*Sardinops spp*.), and rockfish (*Sebastes spp*.) (COSEWIC, 2003). Besides humans, the main predators of Steller sea lions are killer whales (*O. orca*). The prey species of Stellar sea lions are most vulnerable during spawning and juvenile stages. Impacts to prey species spawning and rearing sites, such as kelp and eelgrass beds could have an adverse impact on their prey.

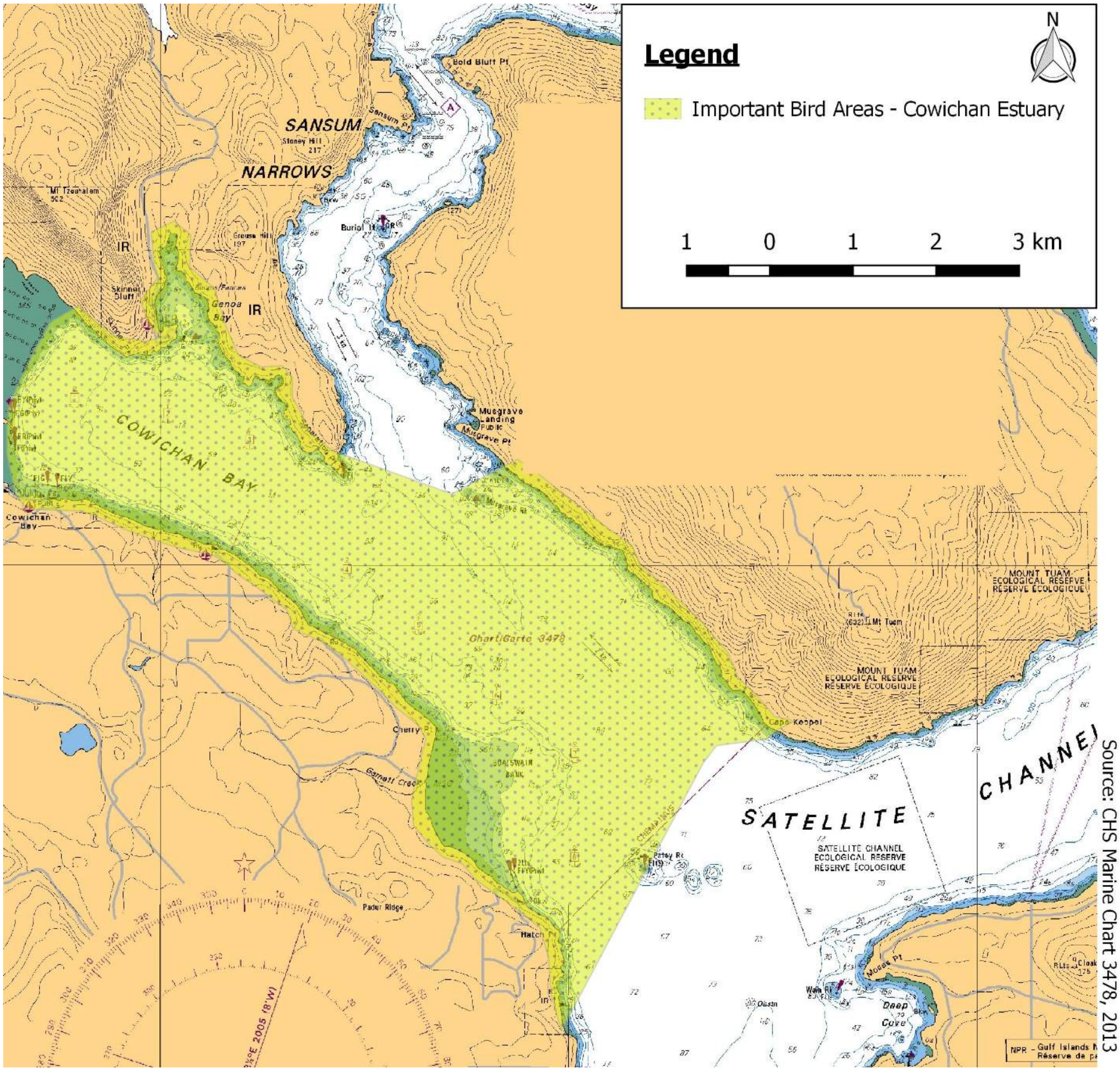
The proposed discharge is not located near known sea lion haul out locations or within prey species spawning areas.

7.4 Important Bird Areas

The Cowichan Estuary supports more than one per cent of the world population of several species of water birds. The abundance and variety of bird species supported has led the Cowichan Estuary to be classified as an Important Bird Area (IBA) in Canada. It has a total area of 38.2k km^2 and is made up of salt and brackish marshes, mud flats and estuary habitats important to a variety of nesting and migrating birds (See Figure 22) (IBA Canada, 2015).

The CVRD recognizes the Cowichan Estuary as a globally significant Important Bird Area. Moving the discharge from the Cowichan River to the marine environment, will improve water quality of the estuary for bird use. Bird use in the area should be considered when developing impact mitigation measures for outfall construction.

Figure 22 Cowichan Estuary Important Bird Area

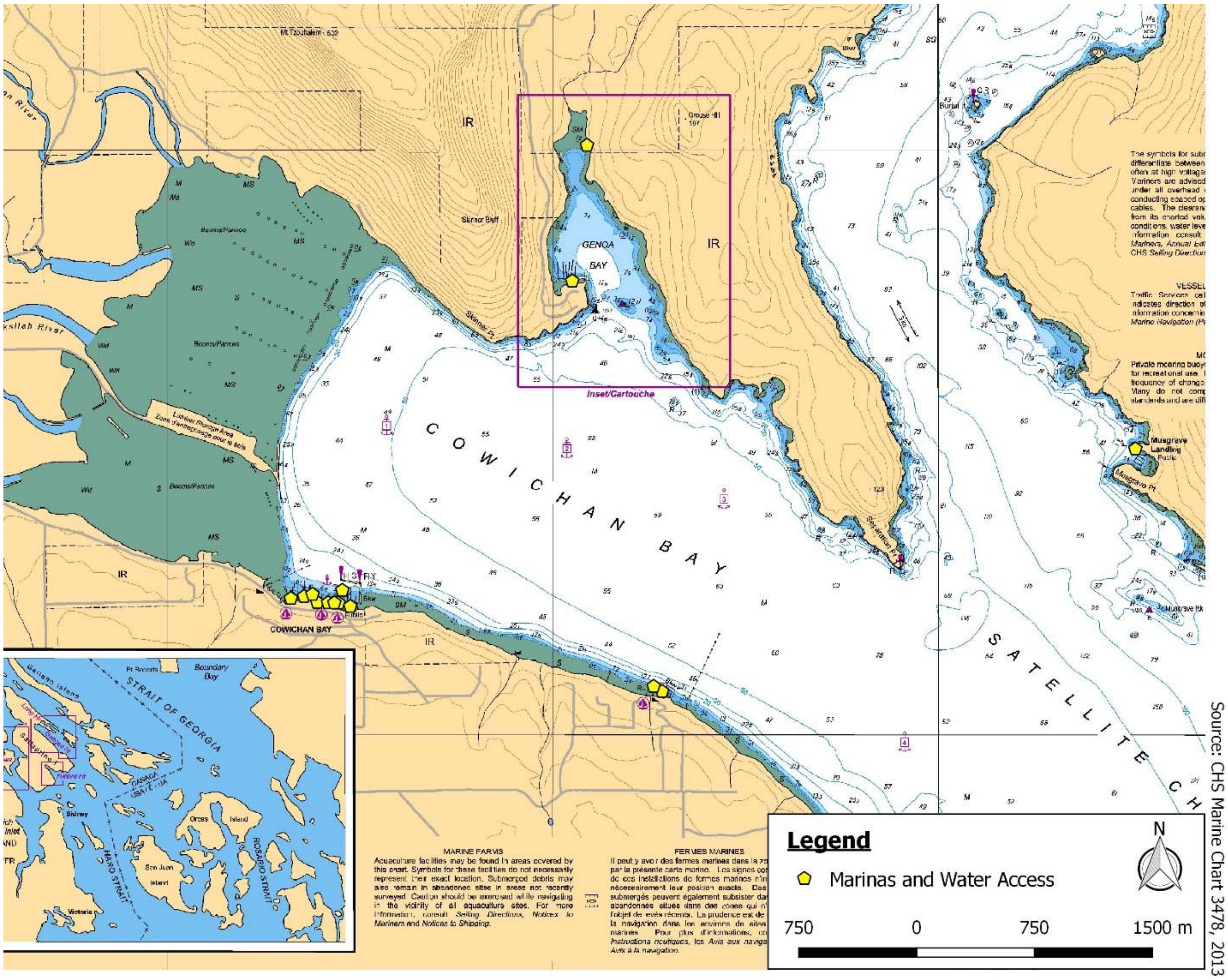


7.5 Recreational Use

7.5.1 Marinas and Waterfront Access

Several waterfront points of public access occur within 5 km of Cowichan Bay and Satellite Channel. Those recognized by BC Marine Conservation Analysis (BCMCA, 2015a) database are shown in Figure 23 below.

Figure 23 Marinas and Water Access



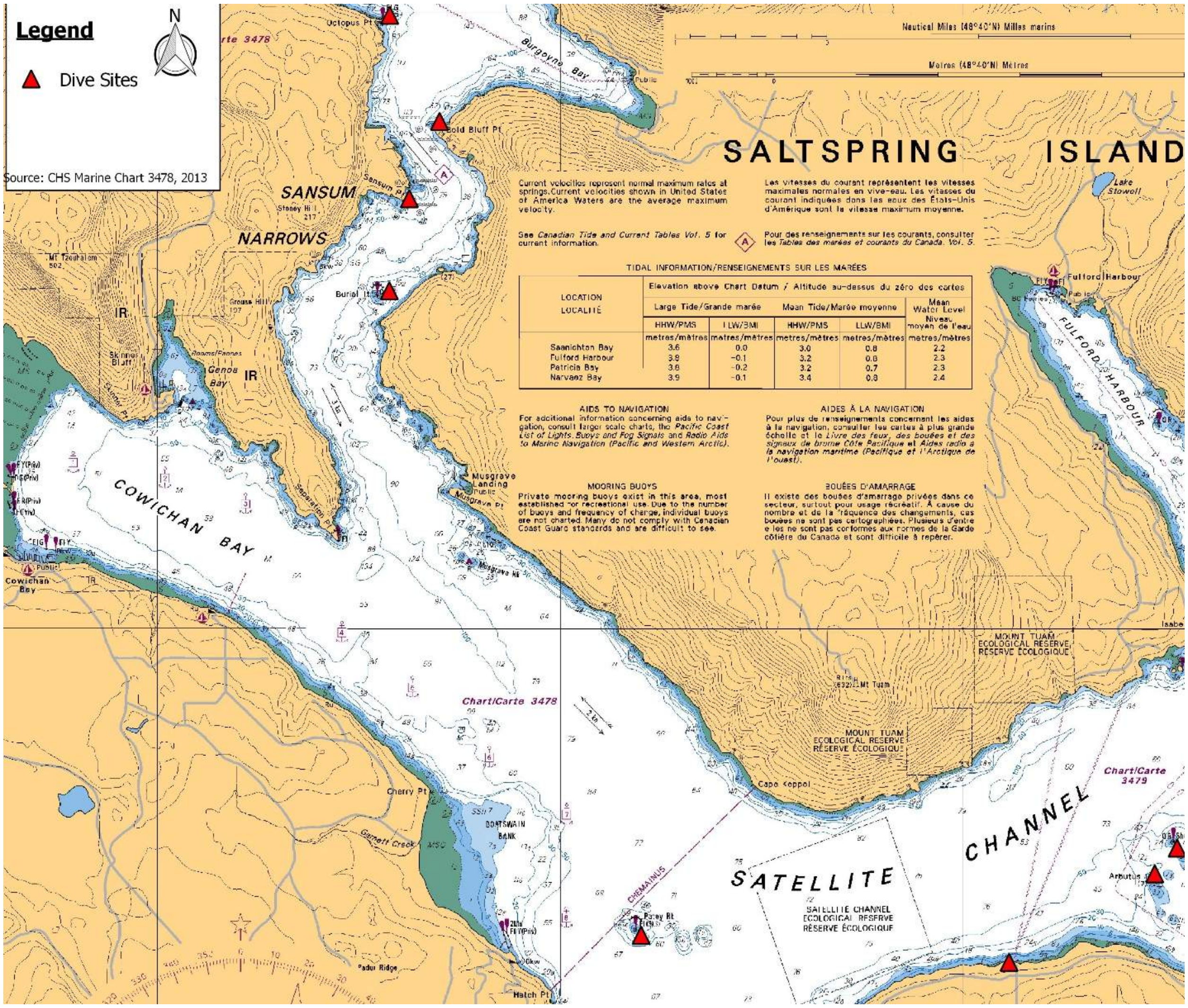
7.5.2 Fishing and Boating

The proposed discharge is located near the entrance to Cowichan Bay, the location of a number of docks and marinas in Cowichan Bay. Recreational fishing, boating, and kayaking is common at Cowichan Bay due to its proximity to high-use moorage locations.

7.5.3 Diving

Diving is a major form of tourism and recreation along the coast of BC. The shores and inlets of Vancouver Island are of particular interest for avid divers. Saanich Inlet offers many dive sites. Figure 24 shows the shore and boat accessed dive sites listed in the BC Marine Conservation Analysis database (BCMCA, 2015b).

Figure 24 Dive Sites



7.6 Commercial Use

7.6.1 Log Booming

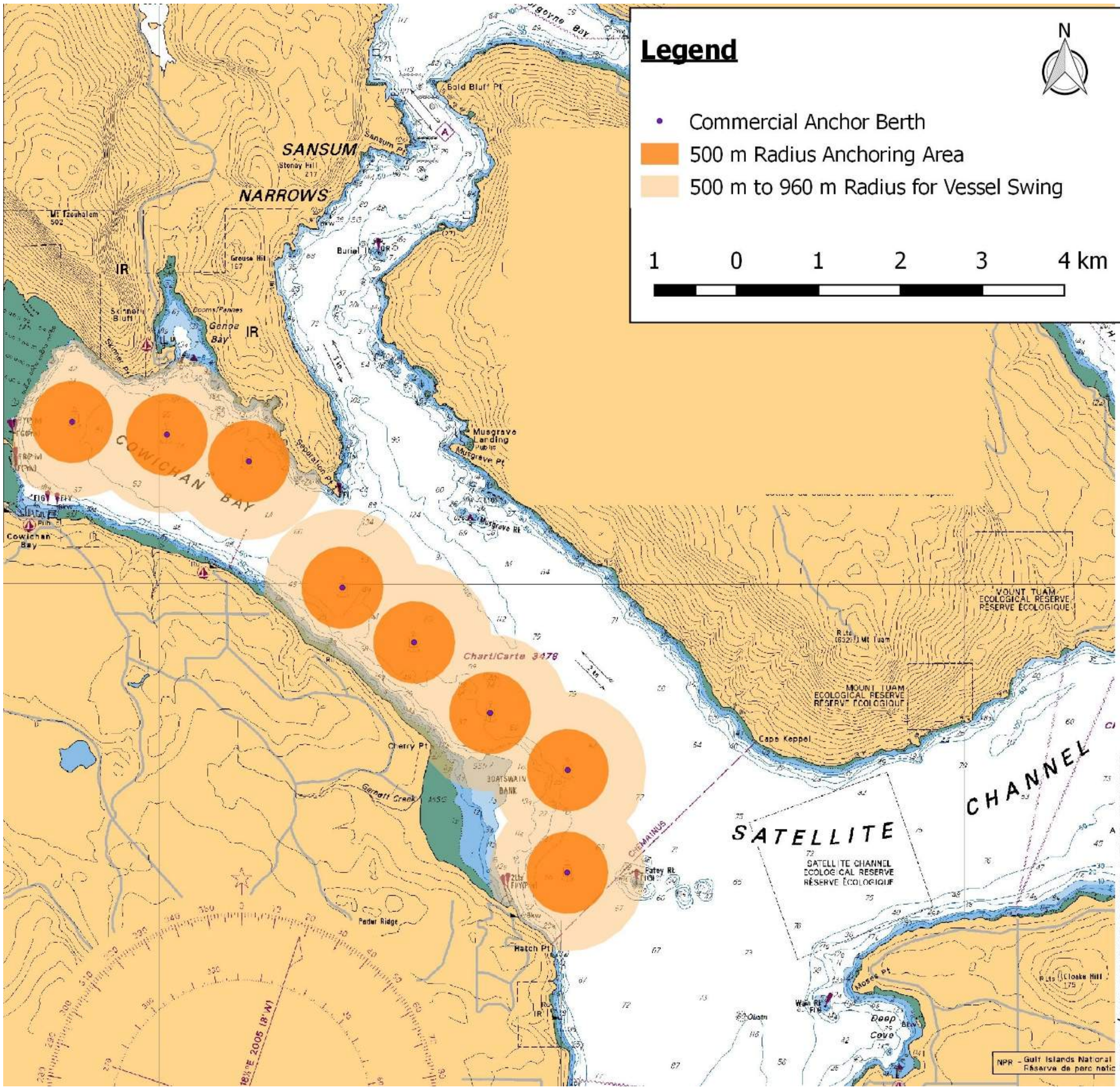
Cowichan Bay provides an area for log booming and storage. It is a well-protected area, making it an ideal facility for log-handling. Its location provides access for barge and ship loading, and also allows for the direct towing of log booms to other areas of Vancouver Island as well as the coast of mainland BC (Hayes Forest Services, 2015).

7.6.2 Anchor Berths

Satellite Channel and Cowichan Bay are used by commercial vessels that both transit and anchor for varying lengths of time. Cowichan Bay falls under a jurisdiction which mandates commercial vessels of a minimum size or greater to take aboard a Pilot to advise and work with the vessel Master to transit, arrive at a berth, or to find safe anchorage. There are presently eight anchor berths within Cowichan Bay and extending south along the shore of Satellite Channel (Figure 25).

Typically, an area with a diameter of 1,000 m is designated for anchoring surrounding the anchor berth. It is a recommended practice to not place any marine infrastructure within, or immediately adjacent to the limits of the anchor exclusion zone, and to add an additional buffer of several hundred meters for safety.

Figure 25 Anchor Berths and Anchoring Area



7.6.3 Western Stevedoring

Western Stevedoring is the company that operates the Cowichan Bay Dock facility. They specialize in the handling of forest related products, but handle a variety of general cargo. The terminal area they service is 8 hectares of paved area that can be used for the assembly and storage of lumber. The dock facility generates shipping traffic through Cowichan Bay.

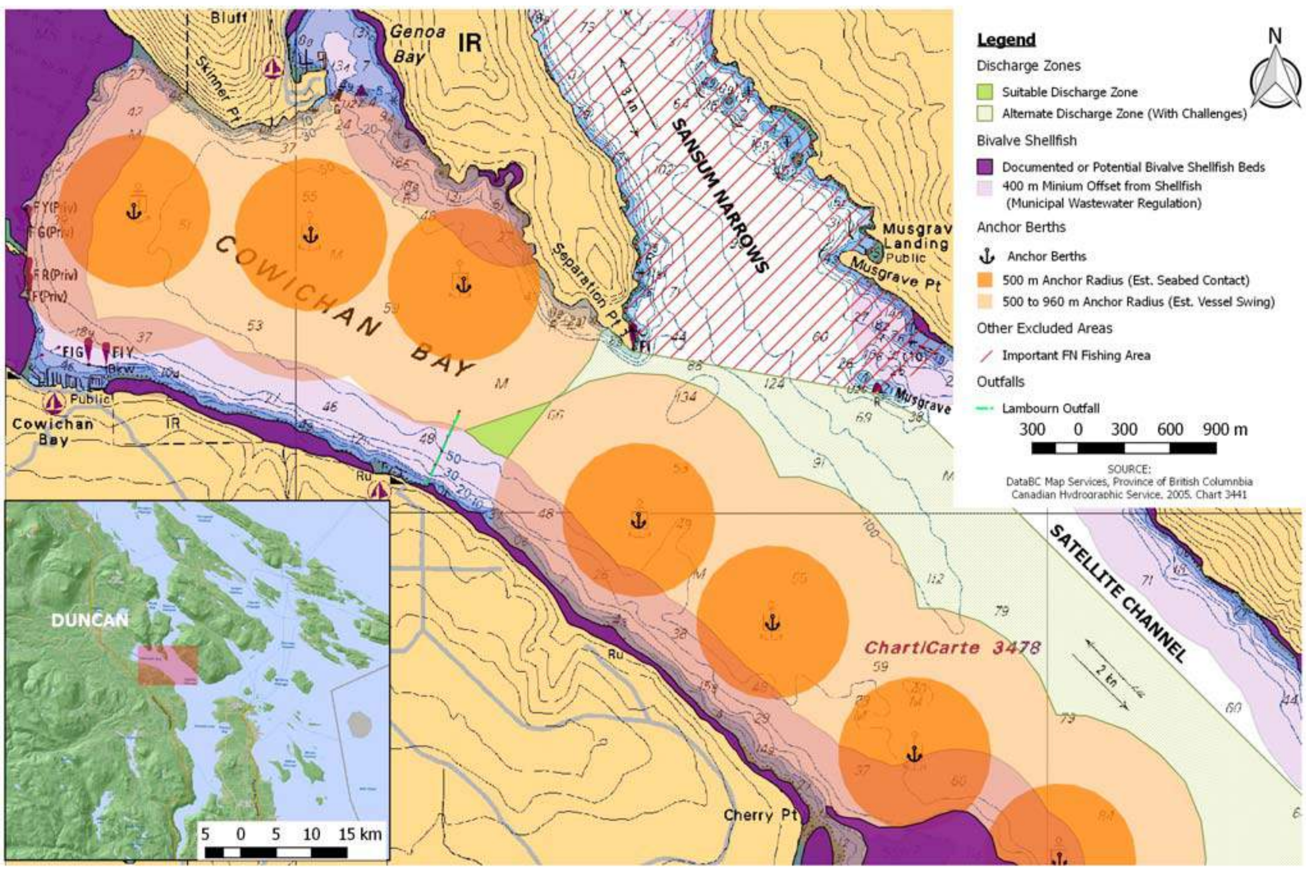
8 Outfall Siting

The recommended outfall terminus was located based on key environmental, regulatory and engineering constraints regarding an outfall. The key constraints included:

- Minimum 400 m offset (100 m IDZ plus 300 m offset) from bivalve shellfish waters;
- The location of anchor berths; and,
- Important first nations fisheries area;

A relatively small discharge zone remains as being suitable after eliminating areas due to constraints. The suitable discharge zone is shown in green, located east of the Lambourn outfall (Figure 26).

Figure 26 Suitable Discharge Zone



9 Dilution Modelling

Preliminary dilution modeling was completed for the proposed diffuser location. The purpose of the dilution modeling was to determine whether the proposed diffuser concepts would provide sufficient dilution of the effluent plume to meet applicable water quality guidelines.

The preliminary dilution modeling was completed using the following effluent properties and diffuser configurations (Table 10).

Table 10 Effluent Flow and Diffuser Configuration

Parameter	Value	
Effluent Flow		
Max Daily Flow	77,000	m^3/d
	0.891	m^3/s
	38,500	m^3/d
	3.26	m^3/s
Diffuser		
Length	100	m
Number of Ports	10	#
Port Diameter	150	mm
Port Discharge Orientation	Vertical (up)	
Port Spacing	10	m
Port Depth	60	m
Diffuser Alignment	90	Degree (Relative to Current)

9.1 Model Description

Dilution analysis was completed to predict the concentration of the effluent as it travels away from the outfall terminus during initial dilution and subsequent dispersion, and to predict the trapping depth of the effluent plume. Modelling was conducted using the USEPA computer modelling package called Visual Plumes, which is recommended by the BC MOE (MELP 2000). The Visual Plumes model predicts the dilution of the effluent plume during its initial dilution and subsequent dispersion. The initial dilution of the effluent plume is predicted by the UM3 model within Visual Plumes which is based on the UM model (Baumgartner *et al.* 1979).

The initial dilution of the effluent plume occurs immediately after the effluent is discharged. It is a combination of the mixing that occurs between the receiving environment and the "jet" of effluent discharged at a high velocity, and the mixing that occurs as the buoyant effluent plume rises though the water column. The effluent plume will continue to rise until the density of the effluent plume reaches that of the surrounding water. The depth where this occurs is referred to as the "trapping depth". Subsequent dispersion refers to the reduction in concentration as the effluent mixes with the receiving environment through ambient turbulence as current moves the plume laterally.

The effluent plume was modeled to estimate the minimum dilution and the shallowest trapping depth, which are considered to be the two “worst case results” for marine discharges.

9.2 Results

Results of dilution modelling are provided in Table 11 below. The predicted trapping depth of the effluent plume is provided along with predicted dilution of the effluent plume at the boundary of the 100 m radius Initial Dilution Zone (IDZ) as defined in the *Municipal Wastewater Regulation* (British Columbia, 2012)

Table 11 Dilution Modelling Results

Effluent Flow	77,000 m^3/d		38,500 m^3/d	
Current Speed	Minimum	Maximum	Minimum	Maximum
Trapping Depth (m)	39 m	52 m	41 m	54 m
Dilution at IDZ (#:1)	219:1	649:1	821:1	425:1

For all ambient conditions the effluent plume is predicted to remain trapped below the water surface. The minimum trapping depth of 39 m below the water surface is predicted to occur at times with minimum currents.

The minimum dilution of 219:1 of the effluent plume at the boundary of the IDZ is predicted to occur at times with minimum current.

9.3 Implication for Effluent Quality

The results of the effluent plume modelling were used to back calculate acceptable effluent quality limits based on water quality guidelines for typical parameters at the boundary of the IDZ and at the nearest shoreline distance.

Guidelines for the protection of marine aquatic life need to be met at the boundary of the IDZ. Some conventional parameters for which water quality guidelines to be achieved at the boundary of the IDZ are listed in Table 12. The maximum allowable effluent concentration based on a dilution of 219:1 is provided in the table. It is expected that effluent quality will be within the allowable concentrations based on the initial dilution predictions.

Table 12 Summary of typical physical and chemical water quality guidelines

Water Quality Guideline	BC Water Quality Guideline	Allowable Effluent Concentration
Ammonia Nitrogen	0.66 mg/L *	144 mg/L
Nitrate	3.7 mg/L	810 mg/L
TSS	5 mg/L	1,095 mg/L
Copper	2 µg/L	438 µg/L

* Based on an ambient temperature of 20 ºC, salinity of 20 ppt, and pH of 8.2.

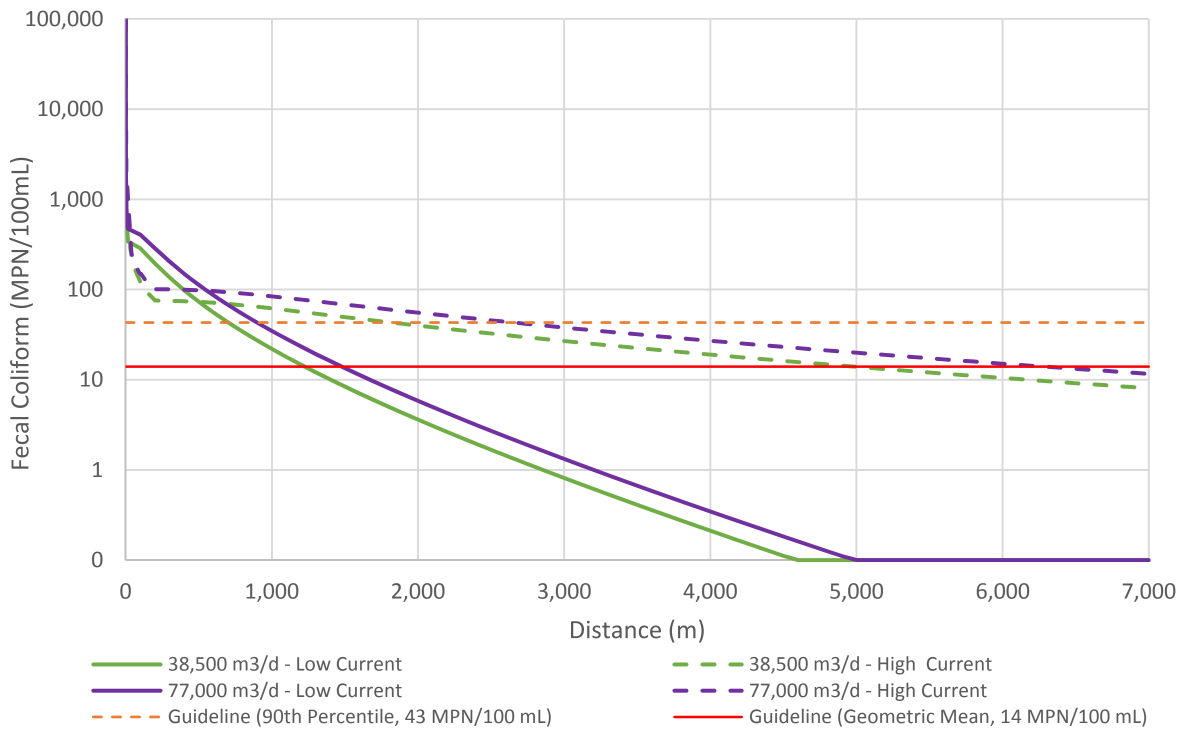
Fecal coliform concentrations were calculated with respect to distance from the outfall diffuser assuming an initial fecal coliform concentration with disinfection of 200 MPN /100 mL and without disinfection of 1 x 10^5 MPN/100 mL (USEPA, 1986). A T90 decay rate of T90 13.5 hrs. was used for modelling. The predicted concentration in the effluent plume with respect to distance from the point if discharge are plotted in Figure 27.

Water quality guideline for shellfish harvesting, for the protection of human health is a median of less than 14 MPN/100 mL, and a 90th percentile concentration less than 43 MPN/100 mL (Ministry of Environment, 2001). Assuming the continued disinfection of the effluent, a concentration of 14 MPN/100 mL will be achieved in the receiving environment at all times within a 5 m (horizontally) from the individual diffuser ports.

For un-disinfected effluent, a concentration of 14 MPN/100 mL is predicted within 1,200 to 6,300 m from the proposed diffuser location depending on the tidal, meteorological, and effluent flow conditions.

Shellfish water quality guidelines may therefore be exceeded at the distance to documented shellfish waters within Cowichan Bay without disinfection of the effluent. In order to achieve a fecal coliform concentrations less than 14 MPN/100 mL at a distance of 400 m (the minimum distance from the point of discharge to the shellfish waters), an effluent concentration of 14,000 MPN/100 mL would be required.

Figure 27 Predicted Fecal Coliform Concentrations with Distance from the Point of Discharge (Without Disinfection)



10 Emerging Contaminants

There is a growing concern for the potential impact to the marine environment from “emerging contaminants”. The term “emerging contaminants” refers to substances that are released into the environment for which no regulations are established. Due to their large number (1000's), published data concerning occurrence and potential toxicological effects is limited. The source of contaminants in the aquatic environment is mainly from sewage effluents, storm water, and combined sewage overflows (CSOs). Although reported concentrations tend to be generally low for many of these compounds, questions have been raised over the potential impacts of emerging pollutants in the environment on human and animal health after long-term exposure. A review of some substances of concern (including emerging contaminants), sources and likely occurrence, known toxicity, as well as treatment options for removal in municipal wastewater in Canada has been done for the national 2006 CCME wastewater strategy (CCME, 2005). Concerns include pathogen resistance to antibiotics and endocrine disruption, impacts on development, spawning and other behaviors in organisms like shellfish.

Emerging pollutants include a wide range of substances including pharmaceuticals and personal care products (PPCPs), illicit drugs, hormones and steroids, benzothiazoles, benzotriazoles, polychlorinated naphthalenes (PCNs), perfluorochemicals (PFCs), polychlorinated alkanes

(PCAs), polydimethylsiloxanes (PDMSs), synthetic musks, quaternary ammonium compounds (QACs), bisphenol A (BPA), triclosan (TCS), triclocarban (TCC), as well as polar pesticides, veterinary products, industrial compounds/by-products, food additives and engineered nano-materials (Lapworth *et a*l., 2012).

Wastewater treatment facilities are not specifically engineered to remove PPCP's. Each chemical is different and removal efficiencies vary from no removal to 100% removal. Factors like temperature, pH, presence of nitrifying bacteria, solids retention time and hydraulic retention time can effect the removal efficiencies. However, secondary treatment technologies that remove suspended solids, oxygen demand or nutrients also remove PPCP's. The JUB treatment facility is a high level secondary treatment system with screening, grit removal, biological oxidation, settling, phosphorus removal and disinfection. This type of system has been shown to reduce PPCP concentrations. For example, Ethinylestradiol is an orally bio-active estrogen used in almost all modern formulations of oral contraceptive pills and one of the most commonly used medications. Transformation and bio-degradation are believed to be the main 2 processes for removal. Removal is generally insignificant with primary treatment (screening) and primary sedimentation. Most of the removal occurs with secondary biological treatment which can remove most, if not all estrogenic activity.

Two contaminant groups which can be considered "emerging" have been relatively well-studied, probably because they are the most ubiquitous and common globally. These include the flame-retardants (PBDEs), and the hydrocarbons (PAHs). In addition, PCBs have been well studied as persistent and bio-accumulative organic compounds and thus provide an important model for understanding food-chain uptake kinetics and circulation properties of other, emerging persistent organic pollutants. High concentrations of PCB's are still found in marine mammals and some fish in B.C. (Cullon *et al*. 2005; Ross *et al.,* 2013).

PBDE's found to accumulate in marine sediments tend to be dominated by heavier-brominated congeners (mostly PBDE 209) near discharge sources, with distillation and debromination evident away from discharge sources (Grant et al., 2010; Salvado et al., 2012). These types of PBDE's have a strong affinity for organic particulates; therefore they are typically largely removed by treatment processes that remove particulates, such as secondary and tertiary treatment. PAH's are not allowed to be deposited into sewer systems through source control, therefore it would be expected that PAH's would not be discharged by the JUB treatment facility. PCBs are considered "legacy" compounds, banned since the 1970s; therefore the introduction of new PCB's to the environment through sewage based effluents should no longer be occurring.

An ocean environment provides superior risk management over a river discharge. Lower concentrations in the receiving environment mean lower risk of potential effects to the organisms that live in the aquatic environment. A deep ocean discharge provides rapid dilution, which immediately lowers concentrations, and distances the treated wastewater from sensitive shallow habitats, like eelgrass beds, where juvenile fish such as salmon are rearing.

Monitoring this wide range of substances is a challenge for regulatory programs. An integrated approach should be developed which includes using biological-effect techniques with chemical measurements, and second, assessment tools are required. Proposals for both of these have been initiated by International Council for the Exploration of the Sea (ICES) and Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) working groups and workshops (Thain *et al.,* 2008).

The Vancouver Aquarium proposed BC Pollution Watch Project (PWP), and the complimentary Salish Sea Ambient Monitoring Exchange (SSAMEx, a collaboration of methodology and data sharing for monitoring agencies) are developing a regional monitoring program for the Salish Sea. The list of contaminant groups that these programs focus on, is recommended as a good template for regulatory agencies concerned with emerging contaminant issues and should be considered when developing future effluent and receiving monitoring programs.

11 Recommendations for Stage 2 EIS & Receiving Environment Monitoring

It is recommended that a Stage 2 EIS should be initiated based on a proposed discharge within the preferred discharge zone identified in Section 8 of this EIS. The scope of the Stage 2 EIS was adapted from the scope of work outlined in the EIS guideline document (MELP, 2000) and should include the following:

1. initiate pre-discharge monitoring (as outlined in the following sections);
2. comprehensive effluent characterization;
3. conduct one month of current meter readings;
4. measure seasonal conductivity/temperature/ depth (CTD) profiles;
5. dilution modelling of the effluent plume should be augmented using three dimensional hydrodynamic model to model the behaviour of the effluent plume and to predict the initial and “far field”, dilution of the effluent plume. Specifically, the concentration of the effluent plume at the boundary of the initial dilution zone and shellfish waters should be determined; and,
6. results of the modelling will be used to predict the water quality at the IDZ and areas of concern with respect to applicable water quality guidelines.

Recommendations from the study should include:

1. minimum effluent quality / treatment standards that should be met for the protection of both human health and the environment; and,
2. post-discharge effluent and receiving environment monitoring.

11.1 Pre-discharge Studies/ Receiving Environmental Monitoring

Receiving environment monitoring is a requirement under the *Municipal Wastewater Regulation*. Section 19 of the MWR states the EIS must establish a monitoring plan for both pre- and post-discharge that include details on monitoring locations, sampling parameters and frequencies (i.e. a schedule) (BC, 2012). The pre-discharge monitoring is intended to provide a robust characterization of receiving environment conditions prior to the discharge of effluent. Post discharge receiving monitoring will then be designed to measure changes (spatial and temporal) in the receiving environment.

Section 20 of the MWR requires the receiving environmental monitoring program to:

- *Provide at least one control sampling station outside the influence of the IDZ [S. 20(1)(a)]*
- *Obtain data to assess potential impacts of the discharge [S. 20(1)(b)i];*
- *Assess whether the discharge causes applicable water quality guidelines to be exceeded beyond the edge of the IDZ [S. 20(1)(b)ii]; and*
- *Document pre-discharge conditions [S. 20(1) (c)], especially during "the most critical period of the year" [S. 20(2)].*

The following provides recommendations for pre-discharge monitoring.

11.1.1 Monitoring Objectives

Proposed monitoring program should include the following objectives;

1. Characterize baseline (pre-discharge) conditions, including seasonal variations in water quality.
2. Characterize receiving environment water quality near the proposed discharge zone and nearby sensitive receptors.
3. Characterize receiving environment conditions at a control station.
4. Compare water quality results with applicable water quality guidelines.
5. Characterize sediment physical, chemical and bacterial conditions along a gradient from the outfall diffuser.
6. Characterize benthic macroinvertebrate communities along a gradient from the outfall diffuser.
7. Characterize the spatial distribution of sediment contaminants along the same gradient.
8. Compare sediment quality to relevant sediment quality guidelines.
9. Statistically test for spatial differences in benthic community along the gradient.
10. Based on the findings, adjust the post-discharge monitoring study design as needed. Include water stations located on the IDZ and at the terminus of the outfall.

To address objective #8 and #9 above, field and laboratory methods and sampling factors should be harmonized as much as possible with those proposed in the new Vancouver Aquarium's proposed BC Pollution Watch Project (PWP, Appendix 4), and the complimentary Salish Sea Ambient Monitoring Exchange (SSAMEx, a collaboration of methodology and data sharing for monitoring agencies: Appendix 4). The two complimentary programs are developing a regional monitoring program for the Salish Sea. The PWP/SSAMEx is recommended as a good template for agencies concerned with emerging contaminant issues and should be considered when developing effluent and receiving environment monitoring programs.

Harmonizing with the SSAMEx / PWP (Appendix 4) will help our understanding of receiving environment effects and sensitivities from the JUB outfall by providing a regional context and a regional pool of background sediment conditions for comparison with their local results. This will allow a broader, regional assessment of whether observed effects in the region of the JUB outfall are related to the outfall, or are related to changing coastal background (ambient) conditions. This extended database provides detailed information on natural (background) biotic conditions expected under specific (present-day) substrate, depth and sedimentation regimes throughout the Sailish Sea. This allows the inclusion of a range of depth and sediment types in the monitoring program, without the need for extensive nearby reference sampling.

11.2 Water Quality Monitoring

The following section outlines recommendations for pre-discharge receiving environment water quality monitoring. Specific analytes are listed that are to be measured either in-situ or by an appropriate analytical laboratory (Table 13).

Table 13 Pre-discharge Monitoring Requirements

	Parameters	Frequency	Sampling
Water Column Profiles	• Dissolved Oxygen (mg/L) • Temperature (˚C) • pH • Salinity (ppt)	The sampling protocol should consist of 5 weekly samples in 30 days.	In-situ
Water Samples	• *E.coli* • Fecal coliforms • *Enterococcus* • Total Ammonia • Nitrate		Laboratory Analysis
	• Total Metals	Samples should be collected once first week of the 5 weekly samples in 30 days.	Laboratory Analysis

Table 14 Proposed Monitoring Parameters

Group	Anayte	Applicable Guideline or Criteria	Applicable Location
In-Situ	• pH [1]	BC	IDZ
	• Temperature [1]	BC	IDZ
	• Salinity [1]		IDZ
	• Dissolved Oxygen	BC	IDZ
Laboratory Analysis (Bacteriology)	• Fecal Coliform	BC	Primary Recreation, Secondary Recreation, & Shellfish Waters
	• E. Coli		
	• Enterococci		
Laboratory Analysis (Conventional Parameters)	• Total Suspended Solids	BC	IDZ
	• Total Ammonia Nitrogen	BC	IDZ
	• Nitrate Nitrogen	BC	IDZ
	• Total Metals	BC / CCME	IDZ

[1] Ambient temperature, salinity, and pH are required to determine the appropriate ammonia guideline for the protection of aquatic life.

Timing and Frequency

Pre-discharge monitoring must be conducted prior (suggested to be at least 90 days) to commissioning of the wastewater system. A minimum of two seasons should be sampled to represent the seasonal variation in the receiving environment. It is recommended that monitoring should occur in the summer with minimum discharge from the Cowichan River and the winter with maximum discharge from the Cowichan River.

For each season it is recommended that samples be collected to both provide a statistically significant number of samples to appropriately compare to applicable water quality guidelines and to account for seasonal variations. For microbiological and ammonia samples this includes the collection of a minimum of 5 weekly samples within a 30 day period. This is required for the calculation of mean, geometric means and 90th percentile microbiological concentrations for comparison with applicable water quality guidelines.

Station Locations

A total of 5 stations are recommended as part of pre-discharge monitoring (Figure 27). These include:

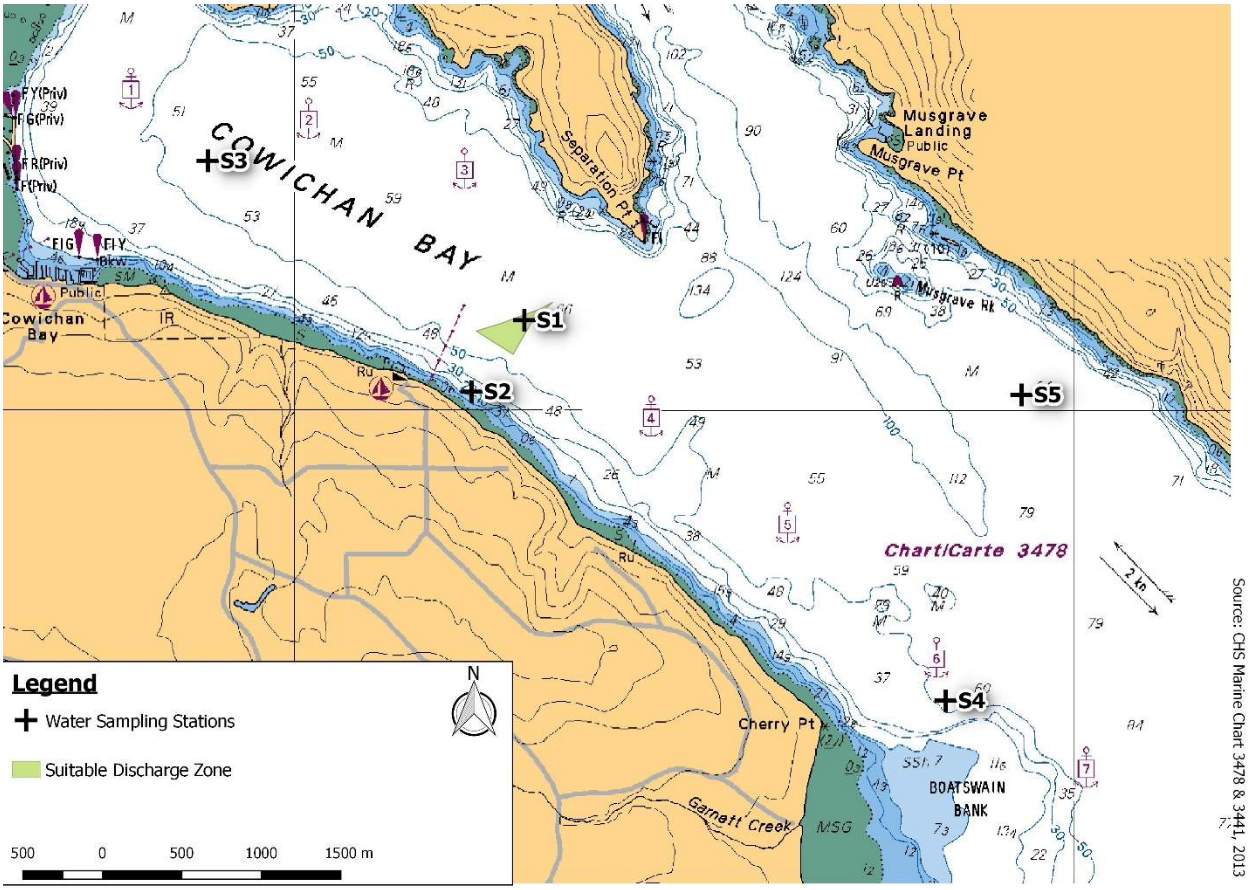
- A discharge zone station (S1) as shown on the map in Figure 28. This station is positioned in the area suitable for discharge. Prior to the commissioning of the wastewater treatment facility it is assumed that water within a 400 m radius of the point of discharge is sufficiently homogeneous to justify a single sampling station at this location.
- It is recommended that a station inshore to the suitable discharge zone be sampled (S2). This area has documented or potential bivalve shellfish beds and could be an area with recreational activity.
- A reference station located in Cowichan Bay (S3).
- A station north of Boatswain Bank (S4). This area has documented bivalve shellfish with known commercial and First Nations harvesting.
- A background station located in a similar depth of water as the outfall terminus in Satellite Channel, near the mouth of Sansum Narrows and Cowichan Bay. This station located away from the proposed and existing outfall and the influence of other known significant potential pollution sources.

The station coordinates are listed in Table 15.

Table 15 Sampling Stations

Monitoring Stations	Description	Latitude	Longitude
S1	Discharge zone	48.7384 °N	123.5804 °N
S2	Shoreline near discharge zone	48.7344 °N	123.5849 °N
S3	Cowichan Bay Station	48.7474 °N	123.6074 °N
S4	North of Boatswain Bank	48.7170 °N	123.5444 °N
S5	Background Station	48.7342 °N	123.5379 °N

Figure 28 Sampling Stations



Sample Depths

At all stations, samples should be collected approximately 1 to 2 m above the seabed and at the water surface. At the S1, S3, S5, stations, water samples should also be collected at a depth of 40 m (the minimum predicted trapping depth of the effluent plume).

Initiation of Post Discharge Monitoring

Following commissioning of the discharge, post discharge monitoring should be initiated in the same fashion (5 samples in 30 days, stations, depths and analytes) as the above pre-discharge monitoring, with the addition of stations along the IDZ and at the outfall terminus. Post discharge monitoring should be conducted in both summer and winter for a minimum period of 2 years, after which the program should be re-assessed.

11.3 Benthic Environment Monitoring

Benthic monitoring is intended to assess potential longer term impacts of the discharge. Deposition of organic matter and contaminants originating from the discharge may accumulate on the surrounding seafloor resulting in potential changes to the seabed chemistry and benthic community which contribute to the uptake of contaminates into the marine food web.

Sediment quality should be analyzed as part of the receiving environmental monitoring. Sediment samples should be taken from each of the pre-discharge monitoring stations.

Tiered levels of monitoring parameters are recommended for all participants in the SSAMEx and PWP (Table 16), according to the needs and requirements of the specific monitoring program, and to provide a full understanding of sediment contaminants input, sources and fate, as well as biological effects relative to expected background (ambient) conditions. These parameters have been shown to be critical for understanding receiving environment effects from the Iona outfall off Vancouver (Burd *et al*., 2012a) and are also typically included in the other major outfall monitoring programs in coastal BC.

The Sediment (Component A) and Benthic (Component C) Tier 1 parameters in Table 16 are specifically recommended for the JUB receiving environment monitoring program. Tier 2 parameters are recommended if detailed hydrodynamic modeling warrant additional baseline sampling. Detailed descriptions of methodologies and resolution/quality control for all parameters in Table 16 can be supplied by the SSAMEx/PWP team at the Vancouver Aquarium upon request (contact Dr. Brenda Burd, brenda.burd@vanaqua.org).

Bio-accumulation

If the CVRD and its partners in the CSLWMP choose to participate in the SSAMEx/PWP programs, it is recommended that wild tissue contaminants (C) be included for 2 selected stations for the first survey (one shallow and one subtidal sediment station), and on some schedule (every 2-5 years) following.

Contaminants to be measured as part of the SSAMEx/PWP will vary by monitoring station as per final study design, and will be contingent upon funding. For example, Tier 1 will consist of an elementary screen for a short list of contaminants, Tier 2 an intermediate list, and Tier 3 an advanced list with a wide range of contaminants of concern. A description of methods, resolution and quality control for each suite of parameters can be supplied upon request by the SSAMEx/PWP.

11.3.1 Sampling Grid

It is recommended that a pattern allowing for the statistical analyses of three outfall and habitat related gradients be completed. This should include stations upslope, adjacent and downslope of the diffuser and in the predominant current directions. Spatial coverage is less important than clearly understanding sediment chemistry characteristics and associated biological responses related to the outfall. Exact spacing is also less important than finding suitable substrates for sampling, and following depth contours. Reference stations should also be included in the monitoring.

Table 16 SSAMEx/PWP Monitoring Parameters

MATRIX	CATEGORY	ANALYTE/TARGET	USE	Tier 1	Tier 2	Tier 3
COMPONENT A: SEDIMENT	*Basic*	**TOC, TIC, TN, C/N isotopes, AVS, pH, Granulometry**				
	metals, metalloids and derivates	**metals***	Paints, industry, effluents			
	PCBs	**PCBs**	dielectric and coolant fluids			
	BFRs	**PBDEs**	flame retardant			
	HC	**16USEPA- PAHs**	fuel			
	PFCs	**PFCs**	electronic parts, firefighting foam, photo imaging, hydraulic fluids and textiles			
	Alkylphenols	**nonylphenols**	antioxidants, oil additives, detergents, emulsifiers, and solubilizers, precursors of non-ionic surfactants			
	Alkylphenols	**octyphenol**	antioxidants, oil additives, detergents, emulsifiers, and solubilizers, precursors of non-ionic surfactants, cosmetic, pesticides			
	OC Pesticides	**OC Pesticides**				
	dioxins and furans	**Dioxines and Furans**	by-products in the manufacture of some organochlorides, incineration of chlorine-containing substances (I.e. PVC), chlorine bleaching of paper			
	Neonicotinoid pesticides					
	Multiresidue pesticides (MRES)					

metals *: Cd, Cr, Cu, Fe, Ni, Pb, Zn, Co, Se, V, Hg, As, organic lead compounds, organic Hg compounds, organic tin compounds

MATRIX	*CATEGORY*	ANALYTE/TARGET	USE	Tier 1	Tier 2	Tier 3
COMPONENT B: Tissue- wild mussels	*General Characterization*	**C/N isotopes**				
	metals, metalloids and derivates	**metals***				
	PCBs	**PCBs**				
	HC	**16-PAHs**				
	BFRs	**PBDEs**				
	PFCs	**PFCs**				
	Alkylphenols	**Nonylphenol**				
	Alkylphenols	**octyphenol**				
	OC Pesticides	**OC Pesticides**				
	dioxins and furans	**Dioxines and Furans**	by-products in the manufacture of some organochlorides, incineration of chlorine-containing substances (I.e. PVC), chlorine bleaching of paper			
	TBBP-A					
	HBCD					
	Neonicotinoid pesticides					
	Multiresidue pesticides (MRES)					
	PPCP					
	Microplastics					

metals *: Cd, Cr, Cu, Fe, Ni, Pb, Zn, Co, Se, V, Hg, As, organic lead compounds, organic Hg compounds, organic tin compounds

MATRIX	*CATEGORY*	ANALYTE/TARGET	*USE*	Tier 1	Tier 2	Tier 3
COMPONENT C: Benthic ecology	*Benthos effects*	**Bulk benthos sorting to major groups with bulk wet weights**	Bulk macrofaunal organic biomass/production effects			
	Benthos effects	**Species IDs for all organisms, wet weight biomass for three size classes per species, trophic classification, reference collection, external verifications**	alteration of biological component of sediments due to stressors			

12 Conclusion

The following conclusions were drawn from the results of this investigation:

- The JUB intends to construct a replacement for their existing outfall in Cowichan River. The replacement marine outfall will discharge effluent through a multiport diffuser located in Cowichan Bay / Satellite Channel. The new outfall is recommended to support a population of 70,000.
- The maximum daily flow for the proposed outfall is predicted to discharge at a rate of 77,000 m^3/d, the average dry weather flow rate is 38,500 m^3/d.
- Effluent from the proposed outfall will be discharged to the embayed marine environment of the Cowichan Bay and Satellite Channel. The minimum water depth (at low tide) at the proposed diffuser will be approximately 50 m relative to chart datum.
- The near surface water currents in the area of the proposed discharge are a combination of tidal circulation and estuarine flow. The tidal currents are anticipated to dominate the circulation within Cowichan Bay and Satellite Channel. During the flood water flows to the northwest though Satellite Channel towards Sansum Narrows and into Cowichan Bay. During the ebb tide, two typical scenarios develop. Water flows to the south from of Sansum Narrow, to Satelite Channel. This southerly flow may encounter northerly flowing water from Saanich Inlet, resulting eddies near the mouth of Cowichan Bay. If the water flowing from Saanich Inlet is flowing more to the east, the eddies will not develop and flow at the mouth of Cowichan Bay will be to the south east.
- Water column profile properties in Cowichan Bay are dominated by the inflow of the Cowichan River during spring and summer when surface water salinities throughout the Cowichan Bay and Satellite Channel drop considerably due to freshet conditions. Dilution modelling of the effluent plume was completed for summer conditions.
- The main receptors of concern include recreational areas and harvestable marine resources, particularly bivalve shellfish, that when consumed, can transfer pathogens from the effluent plume to humans.
- Shellfish occur and are harvested within Sansum Narrows and Satellite Channel. Intertidal clam beds are known to occur throughout Boatswain Bank. These areas are outside of the existing Sanitary Closure 18.1. Additional intertidal and subtidal shellfish resources are documented within Sanitary closure 18.1 which are as near as 1 km from the outfall diffuser. Shellfish are known to occur in Cowichan Bay and Genoa Bay.
- There is an important First Nations fishing area within Sansum Narrows, north of the proposed outfall.
- Recreational activities in the study area include kayaking, fishing, and SCUBA diving.

- Anchor berths located in Cowichan Bay and Satellite Channel limit suitable areas for the construction of the outfall.
- Based on known receptors and water uses, the preferred location for the outfall terminus is within the line of embayment in proximity to the existing Lambourn Outfall. The point of discharge will be at least 400 m from known shellfish beds and other sensitive receptors.
- Dilution modelling of the effluent plume was carried out assuming the maximum daily flow under anticipated summer receiving environment conditions. The modelling results predicted that;
    - the effluent plume will be trapped below a depth of 39 m; this means that the bulk mass of effluent is not predicted to reach recreational or shellfish waters. Secondary current mixing mechanisms have the potential to bring diluted effluent above the trapping depth.
    - the minimum dilution of the effluent plume at the boundary of the IDZ (100 m) is 219:1; and,
    - known effluent constituents will be within applicable water quality guidelines at the boundary of the IDZ (100 m).
- Fecal coliforms in the receiving environment (an indicator of microbiological contamination) were modelled for the proposed discharge. Fecal coliform concentrations were calculated with respect to distance from the outfall diffuser. With disinfection (effluent concentration of 200 MPN/100 mL), shellfish water quality guidelines are predicted to be achieved within 5 m of the point of discharge. Without disinfection, the initial fecal coliform concentration is estimated to be 1 x 10^5 (USEPA, 1986): Shellfish water quality guideline are predicted to be achieved within 1,200 to 6,300 m from the proposed diffuser location.
- A Stage II EIS is recommended and should including the following:
    - Comprehensive effluent characterization
    - Pre-discharge receiving environment monitoring with the elements as described in Section 10:
        - Water quality sampling at the boundary of the IDZ and receptor sites
        - Sediment chemistry and benthic community sampling
        - Bio-accumulation testing in sediments, benthic infauna and wild tissue.
    - *In-situ* current measurements and CTD profiles
    - Hydrodynamic modelling

13 Closure

Thank you for the opportunity to offer our services for this assignment. If you have any questions or require further details, please contact the undersigned at any time.

Respectfully submitted:
GreatPacific Consulting Ltd.

Original signed on 25-June-2015

Peter Howland. B.Sc.
Physical Oceanographer
Director

Original signed on 25-June-2015

Mercy Patterson, B.Sc
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Reviewed By:

Original signed and sealed on 25-June-2015

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Director

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Personal Communications

John Mackay. 2015. Director of Engineering and Operations. Municipality of North Cowichan.

Helen Reid, 2015. Cowichan Tribes

GreatPacific Engineering & Environment

Appendix 1 Discharge Permit

BRITISH COLUMBIA

MINISTRY OF ENVIRONMENT, LANDS AND PARKS

Vancouver Island Region
Pollution Prevention
2080-A Labieux Road
Nanaimo, British Columbia
V9T 6J9
Telephone: (250) 751-3100
Fax: (250) 751-3103

OPERATIONAL CERTIFICATE
ME-01497

Under the Provisions of the Waste Management Act

Duncan - North Cowichan Joint Utilities Board

PO Box 278, 7030 Trans Canada Highway

Duncan, British Columbia

V9L 3X4

is authorised to discharge effluent to the Cowichan River and to agricultural and forest land for irrigation, from a municipal sewerage system located in Duncan, British Columbia, subject to the conditions listed below. Contravention of any of these conditions is a violation of the *Waste Management Act* and may result in prosecution.

This operational certificate supersedes and amends all previous versions of permit PE-01497, issued under Part 2 Section 10 of the *Waste Management Act*.

1. AUTHORISED DISCHARGES

1.1 This subsection applies to the discharge of effluent to the Cowichan River from a MUNICIPAL SEWAGE TREATMENT FACILITY. The site reference number for this discharge is E100569.

1.1.1 The maximum authorised rate of discharge is 49,000 m^3/d. After June 30, 2005 the maximum authorised rate of discharge to the Cowichan River from July 1 to September 30 (inclusive) each year is 4,000 m^3/d.

1.1.2 The characteristics of the discharge shall not exceed:

5-day Biochemical Oxygen Demand	- 30 mg/L
Total Suspended Solids	- 40 mg/L
Fecal Coliform	- 200 CFU/100ml (median of 7 consecutive tests)
	- 800 CFU/100ml (in any sample)
Toxicity (LC_{50} - 96 hour)	- 100% effluent
pH	- 6.0 – 9.0

Date Issued: MAY 15 2001
Date Amended:
(most recent)
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Blake Medlar
Assistant Regional Waste Manager

1.1.3 The authorised works are a sewage collection system, influent pumping facilities, mechanical screens, grit removal tanks, one complete mix aerated lagoon, three polishing lagoons, chlorination and de-chlorination facilities, a biosolids storage lagoon, an outfall with diffuser, and related appurtenances approximately located as shown on attached Site Plan A.

1.1.4 The authorised works must be complete and in operation on and from the date of this operational certificate.

1.1.5 The location of the facilities from which the discharge originates is Lots 27-1-1, 27-A-1, 28-1-1, 26-1, 27-1 and 42-1, Sections 16 and 17, Range 8, Quamichan District, on the Cowichan Indian Reserve No. 1.

1.1.6 The location of the point of discharge is the Cowichan River.

1.2 This subsection applies to the discharge of reclaimed water to agricultural and forest land for irrigation, from a **MUNICIPAL SEWAGE TREATMENT FACILITY**. The site reference number for this discharge is E241964.

1.2.1 The rate of discharge will be in accordance with the approved operational plan required in Subsection 2.13.

1.2.2 The authorised discharge period is from April 1 to September 30 each year.

1.2.3 The characteristics of the discharge shall not exceed:

5-day Biochemical Oxygen Demand	- 30 mg/L
Total Suspended Solids	- 40 mg/L
Fecal Coliform	- 200 CFU/100ml (median of 7 consecutive tests)
	- 800 CFU/100ml (in any sample)
Toxicity (LC_{50} - 96 hour)	- 100% effluent
pH	- 6.0 – 9.0

1.2.4 The authorised works are a sewage collection system, influent pumping facilities, mechanical screens, grit removal tanks, one complete mix aerated lagoon, three polishing lagoons, chlorination and de-chlorination facilities, a biosolids storage lagoon, reclaimed water pumping station, a force main for seasonal irrigation, and related appurtenances approximately located as shown on attached Site Plan A.

Blake Medlar
Assistant Regional Waste Manager

1.2.5 The authorised works must be complete and in operation as follows:
- a sewage collection system, influent pumping facilities, mechanical screens, grit removal tanks, one complete mix aerated lagoon, three polishing lagoons, chlorination and de-chlorination facilities, a biosolids storage lagoon, on and from the date of this operational certificate;
- reclaimed water pumping station, and a force main for seasonal irrigation, on or before July 1, 2002.

1.2.6 The location of the facilities from which the discharge originates is Lots 27-1-1, 27-A-1, 28-1-1, 26-1, 27-1 and 42-1, Sections 16 and 17, Range 8, Quamichan District, on the Cowichan Indian Reserve No. 1.

1.2.7 The location of the points of discharge are as described in the Operational Plan required in Subsection 2.13.

1.3 This subsection applies to the discharge of effluent to the Cowichan River and reclaimed water to agricultural and forest land for irrigation from a **MUNICIPAL SEWAGE TREATMENT FACILITY.**

1.3.1 The combined average daily rate of discharge to the Cowichan River (authorised in Subsection 1.1) and to the agricultural and forest land irrigation sites (authorised in Subsection 1.2), based on an annual averaging period, is as follows:

Year	Average Daily Discharge m^3/d	Year	Average Daily Discharge m^3/d
2000	11,430	2010	14,490
2001	11,700	2011	14,840
2002	11,990	2012	15,190
2003	12,270	2013	15,560
2004	12,570	2014	15,930
2005	12,870	2015	16,310
2006	13,180	2016	16,700
2007	13,500	2017	17,110
2008	13,820	2018	17,520
2009	14,150		

Blake Medlar
Assistant Regional Waste Manager

2. GENERAL REQUIREMENTS

2.1 Maintenance of Works and Emergency Procedures

The Duncan - North Cowichan Joint Utilities Board shall inspect the authorised works regularly and maintain them in good working order. In the event of an emergency or condition beyond the control of the Duncan - North Cowichan Joint Utilities Board which prevents effective operation of the approved method of pollution control, the Duncan - North Cowichan Joint Utilities Board shall notify the Regional Waste Manager immediately and take appropriate remedial action. The Regional Waste Manager may reduce or suspend the operation of the Duncan - North Cowichan Joint Utilities Board to protect the environment until the approved method of pollution control has been restored.

2.2 Bypasses

The Duncan - North Cowichan Joint Utilities Board shall ensure that no waste is discharged without being processed through the authorised works unless prior written approval is received from the Regional Waste Manager.

2.3 Plans - New Works

Plans and specifications of the reclaimed water pumping station and force main for seasonal irrigation, authorised in Subsection 1.2.4 shall be certified by a qualified professional licensed to practice in the Province of British Columbia, and submitted to the Regional Waste Manager for review prior to the start of construction. A qualified professional licensed to practice in the province of British Columbia must certify that the works have been constructed in accordance with the submitted plans.

2.4 De-Chlorination

The effluent shall be de-chlorinated prior to discharge to reduce the total chlorine residual to less than 0.01 mg/L.

2.5 Sludge Reuse and Disposal

Sludge generated by the treatment plant shall be managed in a manner approved by the Regional Waste Manager and in accordance with the sludge management strategies developed in the Central Sector Liquid Waste Management Plan.

Blake Medlar
Assistant Regional Waste Manager

2.6 Posting of Outfall

The Duncan - North Cowichan Joint Utilities Board shall erect a sign along the alignment of the outfall above high water mark. The sign shall identify the nature of the works. The wording and size of the sign requires the approval of the Regional Waste Manager.

2.7 Outfall Inspection

The Duncan - North Cowichan Joint Utilities Board shall conduct an inspection of the outfall every five years or as may otherwise be required by the Regional Waste Manager.

2.8 Standby Power

The Duncan - North Cowichan Joint Utilities Board shall provide auxiliary power facilities to insure that during power outages, the discharge from the authorised works continue to meet the effluent criteria specified in this operational certificate.

2.9 Odour Control

Should objectionable odours, attributable to the operation of the sewage treatment plant, occur beyond the property boundary, as determined by the Regional Waste Manager, measures or additional works will be required to reduce odour to acceptable levels.

2.10 Effluent Upgrading

Based on receiving environment monitoring data and/or other information obtained in connection with this discharge, the Duncan - North Cowichan Joint Utilities Board may be required to provide additional treatment facilities.

2.11 Facility Classification and Operator Certification

The Duncan - North Cowichan Joint Utilities Board shall have the works authorised by this operational certificate classified (and the classification shall be maintained) by the Environmental Operators Certification Program Society (Society). The works shall be operated and maintained by persons certified within and according to the program provided by the Society. Certification must be completed to the satisfaction of the Regional Waste Manager. In addition, the Regional Waste Manager shall be notified of the classification level of the facility and certification level of the operators, and changes of operators and/or operator certification levels within 30 days of any change.

Blake Medlar
Assistant Regional Waste Manager

Alternatively, the works authorised by this operational certificate shall be maintained by persons who the Duncan - North Cowichan Joint Utilities Board can demonstrate to the satisfaction of the Regional Waste Manager, are qualified in the safe and proper operation of the facility for the protection of the environment.

2.12 Infiltration and Inflow Reduction

The Duncan - North Cowichan Joint Utilities Board shall take measures, in accordance with the strategies developed in the Central Sector Liquid Waste Management Plan, to reduce the inflow and infiltration into the sewage collection system. A report shall be submitted once every year to the Regional Waste Manager that provides details of the measures taken in the preceding year to reduce inflow and infiltration. The first report shall be submitted on or before June 30, 2001.

2.13 Operational Plan

The Duncan - North Cowichan Joint Utilities Board shall develop an Operational Plan, to be prepared by a qualified professional, which provides details for the proper operation and maintenance of sewage conveyance, treatment, disposal and reclaimed water reuse facilities, including the monitoring details. The plan shall provide details of the areas to be irrigated, irrigation schedule and application rates as determined by a registered professional Agrologist. The plan shall be certified by the qualified professional that it is adequate for the works being installed and the water reuse being proposed. The plan shall be submitted to the Regional Waste Manager for review by March 31, 2002.

2.14 Agricultural and Forest Land Irrigation

Construction and operation of the reclaimed water irrigation facilities shall be in accordance with the *Municipal Sewage Regulation Appendix 3 to Schedule 7 - Health and Safety Criteria for Use of Reclaimed Water.*

Surface ponding and/or runoff due to irrigation is prohibited. Irrigation using reclaimed water is only permitted during the period from April 1 to September 30 and only on the areas identified in the Operational Plan required in Subsection 2.13. Depending on local climatic conditions, the irrigation period may be reduced or extended by the Regional Waste Manager.

Blake Medlar
Assistant Regional Waste Manager

3. MONITORING AND REPORTING REQUIREMENTS

3.1 Discharge Monitoring

3.1.1 Sampling and Analysis

The Duncan - North Cowichan Joint Utilities Board shall install a suitable facility and obtain samples of the effluent for analysis as follows:

Parameter	Frequency	Sample Type
5-day Biochemical Oxygen Demand	monthly.	grab
Total Suspended Solids	monthly	grab
Ammonia Nitrogen (N)	monthly	grab
Ortho Phosphate Phosphorus (P)	monthly	grab
Total Phosphorus	monthly	grab
Fecal Coliform	monthly	grab
Toxicity	quarterly	composite

Additionally, during the discharge of reclaimed water to agricultural and forest land for irrigation, effluent samples shall be collected and analysed in accordance with the following schedule:

Parameter	Frequency	Sample Type
Fecal Coliform	weekly	grab
pH	weekly	grab

3.1.2 Flow Measurement

Provide and maintain a suitable flow measuring device and record once per day the effluent volume discharged to the Cowichan River and to the reclaimed water irrigation facilities over a 24-hour period.

3.2 Receiving Environment Monitoring

3.2.1 Sampling Stations

The permittee shall establish and maintain two Cowichan River monitoring stations as follows:

Station #1: Approximately 50 m upstream of outfall PE-01497;
Station #2: Approximately 200 m downstream of outfall PE-01497.

The exact sampling locations are subject to the approval of the Regional Waste Manager.

Blake Medlar
Assistant Regional Waste Manager

3.2.2 Sampling and Analyses

a) Substrate Sampling

The permittee shall collect a sample of the substrate at three sampling sites at each station once during the first 10 days of August each year, once during the third week of August each year and once during the first 10 days of September each year, commencing in the year 2001. Each sample shall be analyzed for Chlorophyll-a.

b) River Water Sampling

The permittee shall collect a sample of the river water at each station and a sample of the authorised discharge once during the first 10 days of August each year, once during the third week of August each year and once during the first 10 days of September each year, at the same time the substrate samples are collected, commencing in the year 2001.

Obtain analyses of the samples for the following:

Total Phosphorus (P);
Ortho Phosphorus (P);
Total Nitrogen (N);
Ammonia Nitrogen (N);
pH;
Temperature.

3.3 Monitoring Procedures

3.3.1 Sampling and Analytical Procedures

Flow Measurement shall be carried out in accordance with the procedures described in "Field Criteria for Sampling Effluents and Receiving Waters", April 1989, or by suitable alternative procedures as authorised by the Regional Waste Manager.

Copies of the above manual may be obtained from the Pollution Prevention Division, Ministry of Environment, Lands and Parks, P.O. Box 9342, Stn. Prov. Govt. Victoria, British Columbia V8W 9M1. The manual is also available for review at all Pollution Prevention Offices.

Blake Medlar
Assistant Regional Waste Manager

Sampling shall be carried out in accordance with the procedures described in the "British Columbia Field Sampling Manual for Continuous Monitoring Plus the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples. 1996 Edition (Permittee)", or by suitable alternative procedures as authorised by the Regional Waste Manager.

Analyses are to be carried out in accordance with procedures described in the "British Columbia Environmental Laboratory Manual for the Analysis of Water, Wastewater, Sediment and Biological Materials (March 1994 Permittee Edition)", or by suitable alternative procedures as authorised by the Regional Waste Manager.

Copies of the above manuals may be purchased from the Queen's Printer Publications Centre, P. O. Box 9452, Stn. Prov. Gov't. Victoria, British Columbia, V8W 9V7 (1-800-663-6105 or (250) 387-6409), and are also available for inspection at all Pollution Prevention offices.

3.4 Reporting

Maintain data of analyses and flow measurements for inspection and every quarter submit the data, suitably tabulated, to the Regional Waste Manager for the previous quarter. The first report is to be submitted by June 30, 2001. Based on the results of the monitoring program, the Duncan - North Cowichan Joint Utilities Board monitoring requirements may be extended or altered by the Regional Waste Manager.

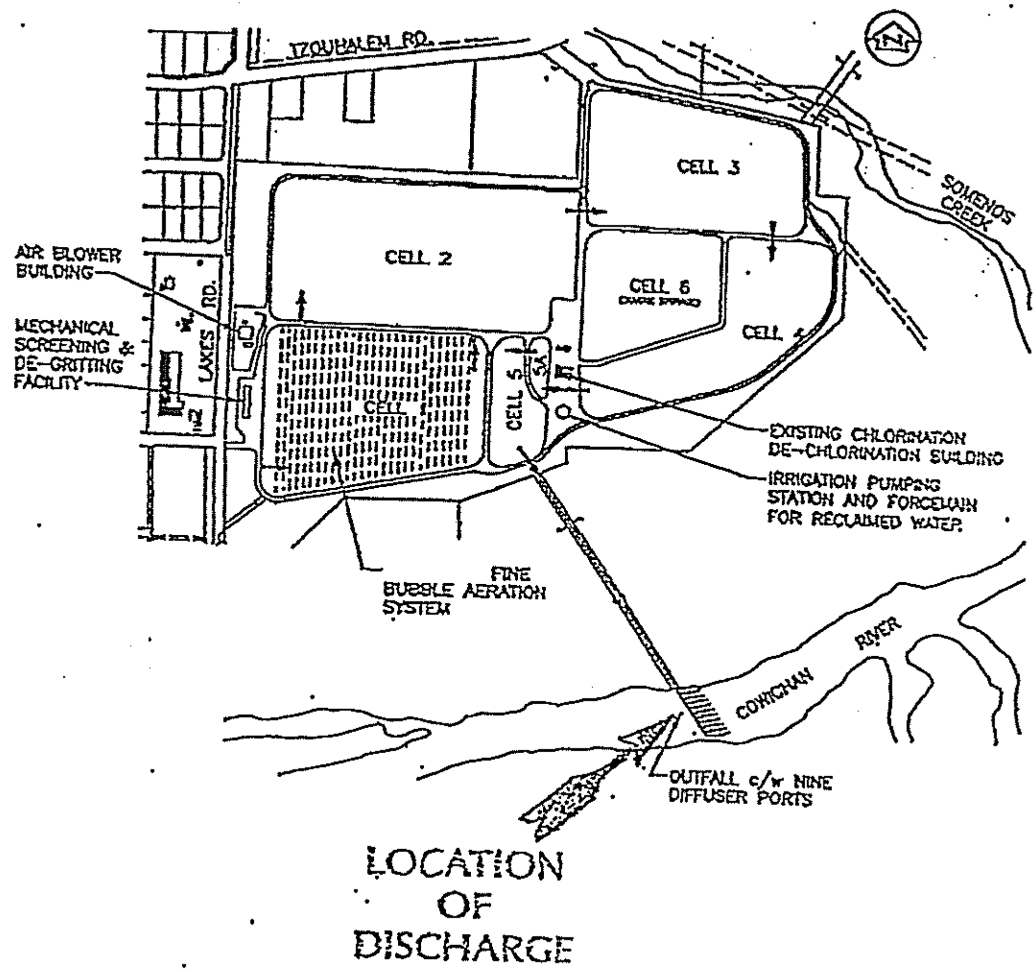
An annual report shall be prepared by an independent qualified professional which includes a summary and interpretation of the discharge and receiving environment monitoring results for the previous year. The report shall provide an assessment of the impact of this discharge on the receiving environment and recommended changes (if any) to the monitoring program. The first report shall be submitted by December 31, 2002.

Blake Medlar
Assistant Regional Waste Manager

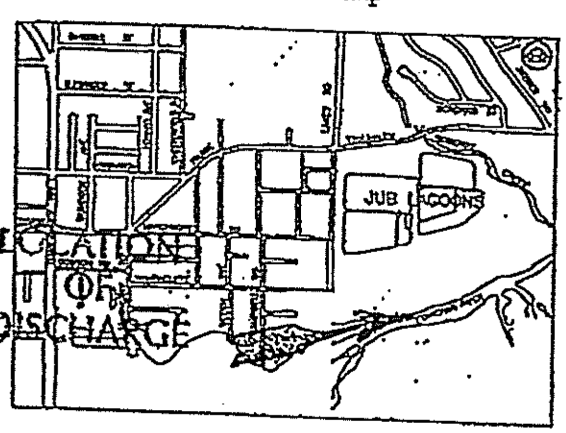
PROVINCE OF
BRITISH COLUMBIA

Pollution Prevention

SITE PLAN A



Location Map



Scale: Not to Scale

OPERATIONAL CERTIFICATE: ME-01497

Date: MAY 15 2001

Blake Medlar
Assistant Regional Waste Manager
Vancouver Island Region

Dmch 2001·05·01

Appendix 2 Relative Risk Comparison of the Proposed Marine Outfall versus Existing River Outfall

GREATPACIFIC
ENGINEERING & ENVIRONMENT

202-2780 Veterans Memorial Parkway
Victoria, BC V9B 3S6
Phone: 778.433.2672
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June 25, 2015

Cowichan Valley Regional District
175 Ingram St.
Duncan, BC V9L 1N8

Attention: Ms. Emily Doyle Yamaguchi

RE: JUB Effluent Disposal - Relative Risk Assessment of the Proposed Marine Outfall versus Existing River Outfall

1 Introduction

The purpose of this memorandum is to provide a comparison of the relative risks associated with the existing river outfall versus a deep water marine outfall for the Joint Utilities Board (JUB) Sewage Lagoon Treatment Plant in Duncan, BC. This comparison is intended as supplemental information to the Stage 1 Environmental Impact Study (EIS).

The scope of the comparison includes:

- Identify key fisheries and aquatic ecosystem issues and summarize how changes to the outfall could affect in-river aquatic values.
- Identify and compare the physical risks for each outfall (river vs. marine);
- Compare the risks to human health in the event of treatment system malfunction;
- Compare potential impacts of climate change;
- Compare emerging contaminants on the receiving environment;
- Identify potential impacts of cessation of the existing river discharge
- Compare regulatory compliance

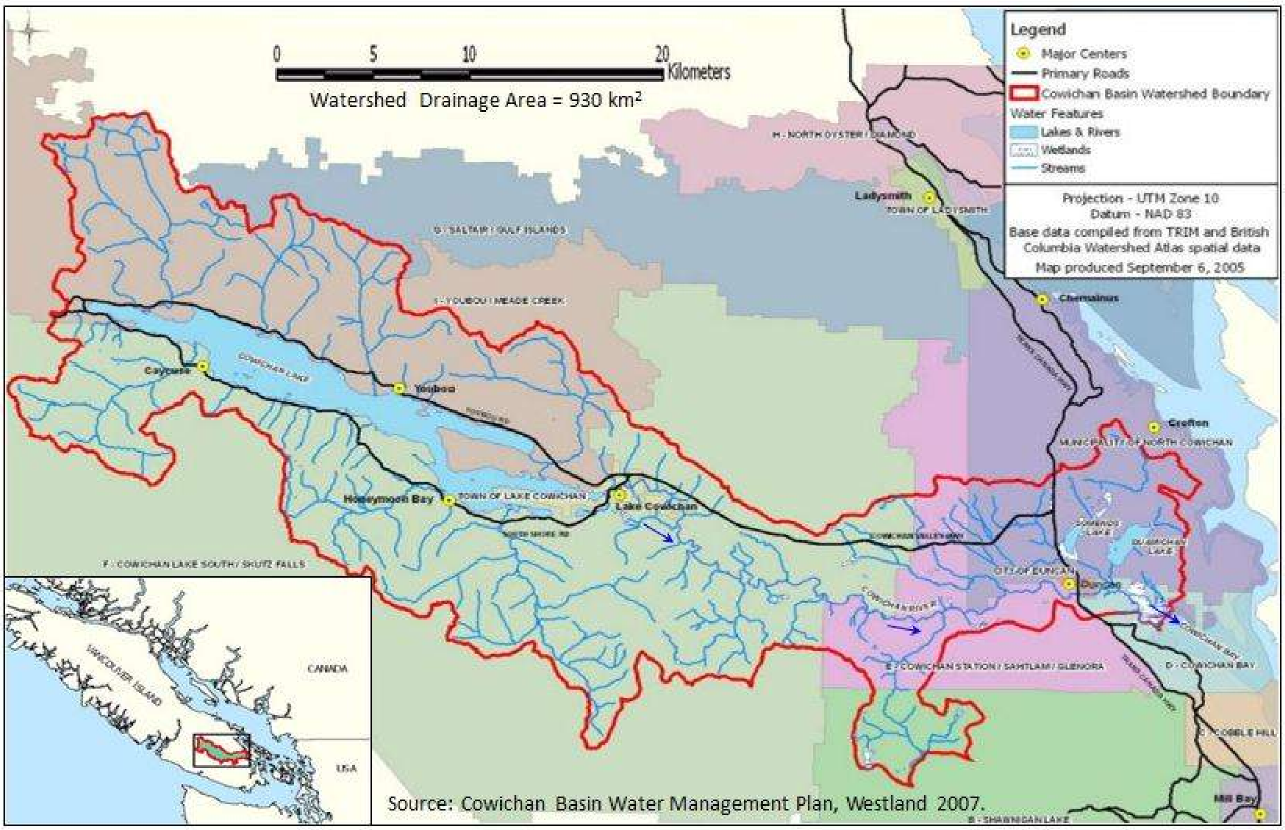
2 Background

The Cowichan River Watershed is located on south-eastern Vancouver Island. The river drains into an estuary that extends over 1,000 m into the coastal nearshore zone that exists in Cowichan Bay. The embayment is orientated in a south-east direction, and is approximately 5 km long, with a surface area of 4.7 km^2.

The Cowichan River Watershed has a total watershed area of 930 km^2 (Figure 1). It includes the 30 km long Cowichan Lake which dominates the western half of the watershed. The elevation difference from the watershed's headwaters in the north-west (at El Capitan Mountain) to its eastern drainage outlet is estimated at 1,520 m. The watershed region has a cool transitional climate associated with cool and wet fall and winter periods, followed by warmer, drier spring and summer seasons.

The present outfall for the Joint Utilities Sewage Lagoons Treatment Plant has been in place since the 1970's. The outfall is located along the lower Cowichan River, approximately 600 m upstream of the river's confluence with Somenos Creek and 5 km from Cowichan Bay. The outfall is positioned along the left bank of the Cowichan River, approximately 300 m south-east of the existing sewage lagoons.

Figure 1 Cowichan Basin Watershed



2.1 Identify known fisheries resources in existing discharge (river), identify key fisheries and aquatic ecosystem issues and summarize how changes to the outfall could affect in-river aquatic values.

The Cowichan River originates from Cowichan Lake, flows east approximately 47 km and drains to Cowichan Bay on the southeastern corner of Vancouver Island. Prior to discharging into the bay, the river forks into a north and south arm. The Cowichan watershed is known for its abundance and diversity of resident and anadromous fish populations. Because of this, the system is used for the US/Canada Pacific Salmon Treaty as an index river for the Georgia Basin (CVRD 2010). A search of the provincial Fisheries Inventory Data Queries (MOE 2015) identified numerous fish species that have been documented in the Cowichan River. Major anadromous species include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), chum salmon (*O. keta*) and steelhead (*O. mykiss*). Resident fish species in the system include rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*) and the introduced brown trout (*Salmo trutta*). Both resident and sea-run cutthroat trout (*O. clarkii*) have been documented in the Cowichan River.

Predominantly, anadromous fish migrate and spawn in the Cowichan during the fall and winter months. Chinook and coho salmon typically spawn in the system from November to December, with chinook utilizing the mainstem and coho accessing smaller tributaries to reproduce (MOE, 2015). The chum salmon migration and spawning period typically extends longer, beginning in November continuing into February. In the spring, steelhead spawning occurs in April and May. A spring run also occurs for Chinook salmon but it is small and not well documented (PSC, 2014).

The JUB wastewater treatment facility discharges effluent into the Cowichan River from an existing outfall south of the facility, approximately 5 km upstream from the bay. Tributaries that drain into the Cowichan River near this location include Somenos Creek and Quamichan Creek. These two creeks empty into the mainstem approximately 600 m downstream from the outfall. Known fish distributions in Semenos and Quamichan creeks are similar to the mainstem, and include coho and chum salmon, steelhead, rainbow trout, cutthroat trout and brown trout (MOE, 2015). Near the outfall, a total of three fish passage obstacles are documented in the mainstem and in the two tributaries. One barrier is located on the southern arm of the mainstem where the river drains into the bay (Obstacle ID 22776; MOE, 2015). The other two obstacles are in Quamichan Creek (falls, Obstacle ID 18673) and in Somenos Creek (beaver dam, Obstacle ID 31723), approximately 450 m upstream and 200 m upstream from the Cowichan River mainstem, respectively (MOE, 2015).

Within the Cowichan watershed, population declines have been observed for chinook, coho and steelhead (CVRD 2010). Key factors affecting fisheries resources in the Cowichan River, as identified in the 2010 State of the Environment by the Cowichan Valley Regional District, include:

- low water levels from low precipitation and flow alteration (i.e. weir on Cowichan Lake and intakes for the Crofton Mill and the City of Duncan);
- poor water quality (i.e. high water temperatures and sedimentation); and
- loss of spawning and rearing habitat due to development.

During low flows, effluent discharged from the outfall mixes poorly with the river and has a lower dilution ratio (Reitsma, 2014). Rerouting the discharge from the Cowichan River would decrease the risk of water quality exceeding provincially approved guidelines for the protection of aquatic life.

3 Physical Risks

If the existing river outfall were to remain at its current location along the Cowichan River, then erosion and scour processes would be expected to continue to cause localized channel shifting during moderate-to-high flow events. Channel bed forms will continue to develop (i.e., gravel bar complexes and alluvial islands) and channel patterns will likely change over time. Changes in the channel patterns could cause the outfall to discharge into an un-wetted portion of the river. Poor effluent mixing and dilution would likely result during extended low flow periods when surface water areas and flow volumes reduce. Concentrated effluent discharge levels would likely occur if the relative position of the channel's thalweg shifts further away from the existing outfall location.

Scouring and erosion of the river may expose or compromise the outfall, diffusers and protection works. This can result in damage such as leaks or blockages of the diffuser comprising the ability of the diffuser to function as intended.

By comparison, the potential risks to a deep water outfall location in Satellite Channel would be from anthropogenic sources such a vessel anchors. Cowichan Bay and Satellite Channel are used for anchorage by ocean going freighters. Should one of these vessels strike or snag the outfall pipeline the outfall could become damaged, dragged from its alignment or kinked. A hole or break in the outfall would result in the discharge of effluent in an unintended location, albeit in a deeper water environment with good dilution as compared with a river. If the outfall pipeline was dragged or pulled off the seabed the pipe could be kinked resulting in partial or full blockage of the outfall. The proposed outfall terminus location (as discussed in the EIS) is intended to have sufficient setback from existing anchor berths as to reduce the likelihood of an anchor strike.

Sediment transport processes from waves and currents may also pose a risk to the proposed outfall. Cowichan Bay is not within high wave energy zones, is not subjected to excess nearshore sediment depositional processes. Subtidal sediment processes may also result in burial of the outfall and/or scouring. The potential rate of sediment deposition or scour in the marine environment is significantly lower than in the river. The anticipated risk to the outfall from sediment movement in Cowichan Bay would be addressed in the engineering of the outfall.

4 Malfunction Risks

Malfunctions of the JUB lagoons may include:

- no or improper disinfection of the effluent; or,
- failure of lagoon components (such as the aeration system) may result in the discharge of lower quality effluent.

The discharge of un-disinfected effluent to the Cowichan River would result in the exceedance of recreational water quality guidelines downstream of the discharge posing a risk to human health. For the marine discharge, dilution modelling suggests that the effluent plume will remain trapped below the water surface and therefore the likelihood of recreational users coming into contact with the diluted effluent plume is low. There is a greater potential to exceed shellfish harvesting guidelines, and therefore a failure of the disinfection system could result in a closure to shellfish harvesting.

Potential failures of the wastewater treatment system and the temporary discharge of lower than anticipated or permitted effluent quality is likely to have a greater impact to a river discharge than to the marine discharge particularly during periods of low river flow. The minimum dilution of the effluent in the river is predicted to be 11.4:1[1] whereas the minimum dilution of 219:1 is

[1] Delcan. 2010. Wastewater Treatment Plant Site Selection Study (Phase 1). Central Sector Liquid Waste Management Plan.

predicted for the marine discharge. Possible impacts from degraded effluent quality therefore pose a greater risk to aquatic life with a discharge to the river than to a marine discharge.

The Cowichan River and estuary are highly productive and important habitat for a variety of fish and wildlife species. In the event of a malfunction, increased nutrient (phosphorus) levels may result in increased adverse biological production downstream of the discharge or may result in effluent that is deemed deleterious to aquatic life.

5 Climate Change Affects

Impacts due to climate change were assessed by first reviewing the technical literature related to climate change projections for the Cowichan River Watershed region. The review also included forecasts from the Pacific Climate Impacts Consortium's (PCIC) on-line Plan2Adapt Regional Analysis tool.

For the existing river outfall, the potential climate change effects were considered in terms of changes in water discharges, channel stability and sedimentation processes, as well as impacts from the downstream transport of large woody debris. For a potential marine outfall location, the risks were considered in terms of factors affecting relative tidal circulations, wave climate and potential sea level changes in Cowichan Bay.

Impacts to the existing discharge are expected to be linked primarily to changes in the hydrology of the Cowichan River. The science of climate change and its hydrologic effects on the Cowichan River is broad and complex. The Pacific Climate Change Impacts Consortium (PCIC) has provided a hydro-climatic overview of the expected changes for the province (Rodenhuis *et al*., 2009). For British Columbia, the range of average annual temperature is projected to increase by 1^{o}C to 3^{o}C, with a variation in average annual precipitation extending from 3% to 11% across the province. The PCIC regional analysis models indicate that by the fifth decade of the 21st century, the Cowichan Watershed region will likely be warmer and wetter. These trends are also projected by the PCIC's Plan2Adapt Analysis Tool (Figure 2-4).

Figure 2 A projection of percent change in Annual Precipitation by PCIC's Plan2Adapt Regional Analysis tool for 2020s, 2050s and 2080s

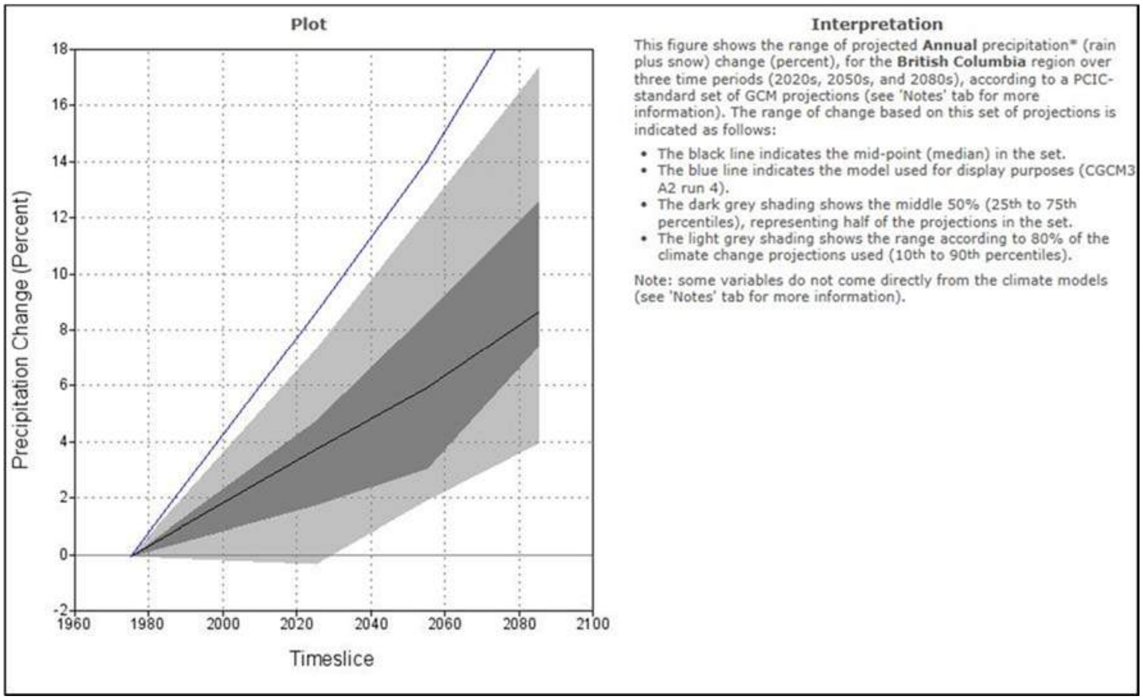


Figure 3 A projection of Change in Mean Temperature by PCIC's Plan2Adapt Regional Analysis tool for 2020s, 2050s and 2080s

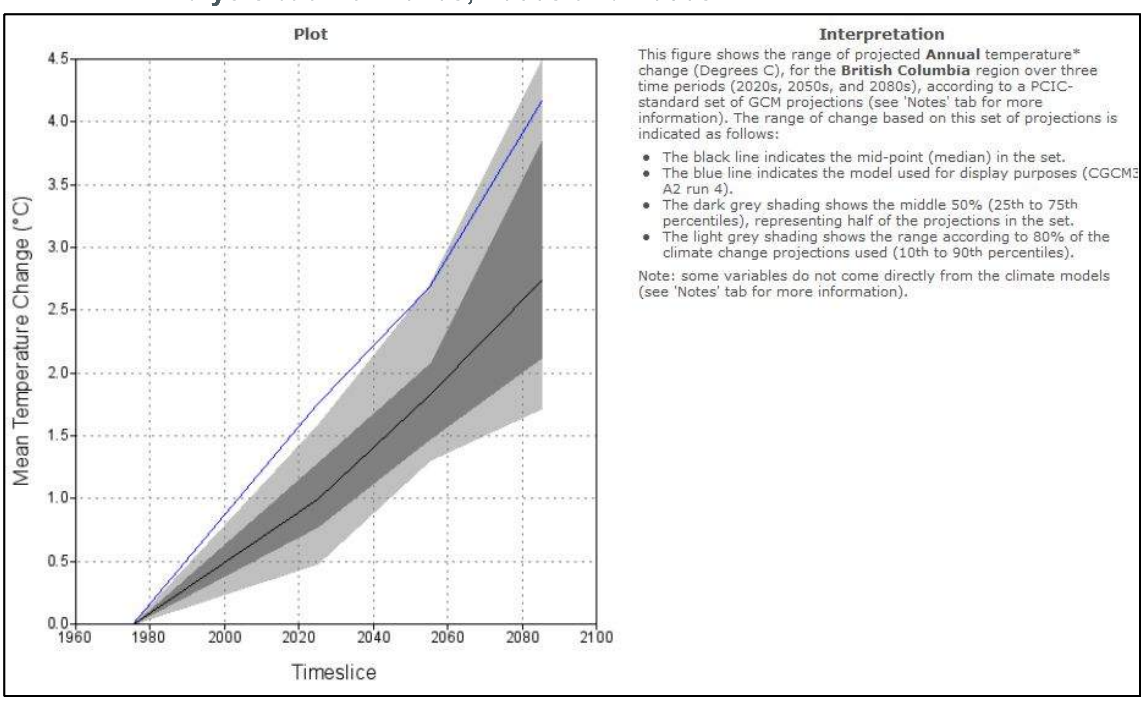


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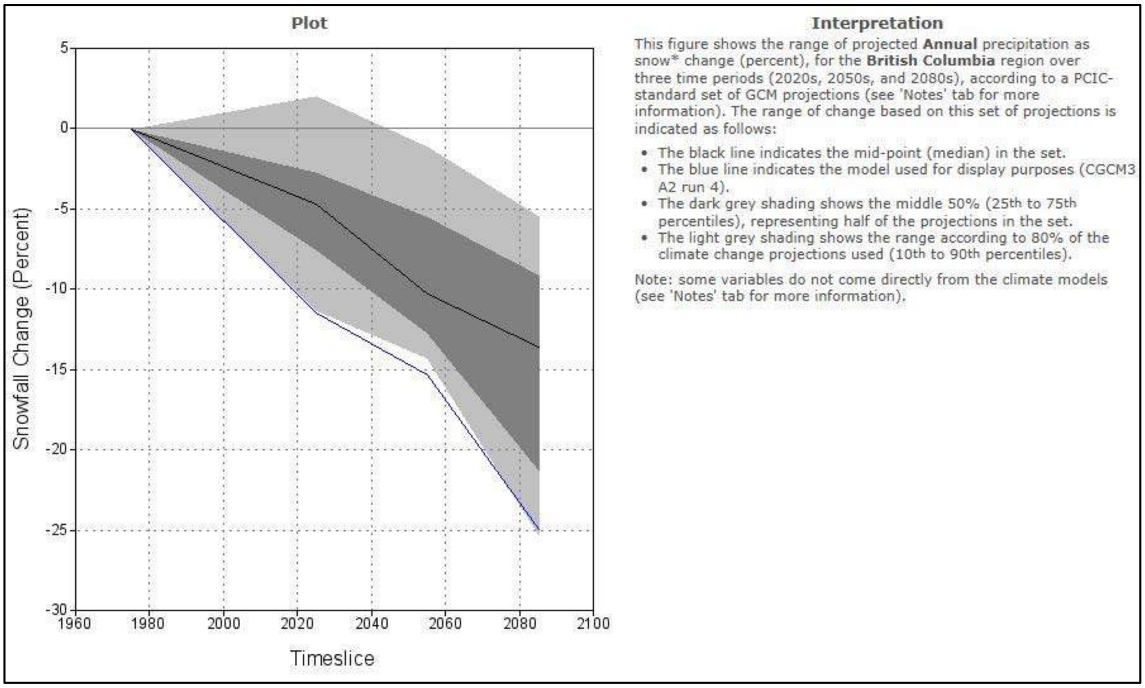
Figure 4 : A projection of Snowfall Change in percent by PCIC's Plan2Adapt Regional Analysis tool for 2020s, 2050s and 2080s



Recent studies by the Cowichan Basin Water Management Forum (Westland, 2007), BC River Forecast Centre (Chapman, 2010), the BC Conservation Foundation (KWL, 2011; 2012), and the BC Ministry of Agriculture (2014) for the Cowichan Watershed region indicates that annual average temperatures will likely increase from 0.7^{o}C to more than 1.1^{o}C by 2020s. They are expected to further elevate between 1.3^{o}C and 1.9^{o}C by the 2050's. The hydrologic response of the Cowichan Watershed was assessed by the BC Conservation Foundation (KWL, 2011) by using a monthly water balance model that considered monthly precipitation and temperature forecasts. The reported results indicate that by the 2050's the average annual runoff for Cowichan River at Lake Cowichan and at Duncan, BC will rise by 11% and 14%. But, the increase in annual runoff will occur during the wetter fall and winter periods. Monthly streamflows will be less during the spring and summer due to less precipitation received during these annual seasons. At Lake Cowichan, the average reduction in runoff during the spring and summer periods are forecasted to be -13% and -5%. At Duncan, the runoff decreases elevate incrementally to - 14% in the spring and -10% during the summer months. It should be noted that the study does caution that some uncertainty exists in the hydrologic model results due to lack of information concerning land cover and land use changes in the future.

Lower river flows in combination with a projected increase in effluent flow will result in lower dilution of the effluent in the river. The minimum dilution of the effluent plume is anticipated to be 11.4:1. Should river flows decrease below present levels, the dilution ratio may fall below the minimum allowable dilution of 10:1 as specified in the Municipal Wastewater Regulation.

Risks due to climate change for a marine outfall are anticipated to be limited. Sea level rise would not adversely affect the dilution and dispersion of the effluent plume, but could result in decreased hydraulic capacity of the outfall.

6 Emerging Contaminants

Emerging contaminants are described in the complementary memorandum (Emerging Contaminants of Concern). The relative risk of emerging contaminants in the river environment versus the marine environment is primarily related to the available dilution for each scenario and the relative sensitivity of the receiving environment.

As previously discussed, the minimum dilution of the effluent in the Cowichan River is predicted to be 11.4:1 with no additional dilution feasibly until the river (and effluent) reach Cowichan Bay. Whereas the minimum dilution in the marine environment 219:1 is predicted for the marine discharge at 100 m from the point of discharge with additional dilution beyond the initial dilution zone.

Relative concentrations of emerging contaminants (assuming identical wastewater treatment) will be on the order of 20 times greater in the Cowichan River versus the marine environment. The risk of potential impacts to aquatic life is therefore deemed greater for a river discharge than the marine discharge.

7 Cessation of Discharge from Existing Outfall

Given the future projection that stream flows will likely be less along the Cowichan River during the spring and summer by up to -14% in the spring and -10% during the summer months, the removal of the outfall and the cessation of effluent discharge from the Joint Utilities Sewage Lagoons Treatment Plant will provide a net overall benefit to the river's existing water quality because it will eliminate the nutrient loading from the treatment plant and the loading of higher temperature waters to the river.

The Cowichan Valley Regional District (CVRD) has reported that discharges from the treatment plant have caused seasonal increases in nutrient levels despite significant improvements in phosphorus reduction in recent years (CVRD 2010). During low flow conditions in 2014, the Municipality of North Cowichan reported to BC Environment that water temperature, nitrite (NO_2), fecal coliforms and Escherichia coliforms exceeded BC Water Quality Guidelines along the lower Cowichan River. The elevated nitrite levels were from the treatment plant, with corrective actions undertaken after the event. However, a general concern was raised that if extended low flow periods persist and stream flows continue to decrease, the treatment plant would likely not be able to meet the provincial water quality guidelines in the future (Reitsma, 2014).

Given the current channel geomorphic conditions and the migration of the river's thalweg away from existing outfall location, the use of temporary pipeline hoses to extend the outfall diffusers out into the active water flow area during extended low flow periods may likely be required again in order to achieve acceptable downstream effluent mixing and dilution ratios along the lower Cowichan River. Without maintaining or elevating the regulated flow discharge levels from the

Lake Cowichan weir, then extended low flow periods will likely negatively impact fisheries and habitat conditions along the lower Cowichan River.

8 Regulatory Compliance

A comparison of regulatory compliance for both the river and marine discharge options are presented in Tables 1 and 2. Table 1 outlines the effluent quality requirement specified in the *Wastewater Systems Effluent Regulations* (Government of Canada, 2015*)*, while Table 2 outlines the requirement related to the *Municipal Wastewater Regulation* (Queen's Printer, 2012*)*.

Regulatory criteria specific to the design of the wastewater treatment (i.e. effluent quality) and discharge are presented. Regulatory criteria for operations and maintenance (i.e. monitoring of the effluent and receiving environment have not been presented.

The *Wastewater Systems Effluent Regulations (WSER)* provides minimum effluent criteria for discharges for the protection of aquatic life. No distinction is provided for the point of discharge and therefore both discharge options will have identical effluent and monitoring requirements under the WSER. The primary differentiator is that Environment Canada has issued a transitional authorization for the existing wastewater system until the year 2030. It is unclear if the point of discharge is moved to the marine environment if that authorization can be transferred or amended.

Regulatory criteria specified in the *Municipal Wastewater Regulation* relate to both the effluent quality and the design of the outfall. The existing discharge is authorized under ME-01497, however the limits outline in the operational certificate do not align with current requirements under the MWR. For a discharge to rivers with a dilution ratio greater and 10:1 and less than 40:1 maximum concentrations of $BOD_5 \leq 10$ mg/L and TSS ≤ 60 mg/L lagoon systems are required in comparison to BOD_5 of ≤ 45 mg/L and TSS of ≤ 60 mg/L for marine discharge. Given the proximity of the existing discharge to recreational waters downstream of the outfall, then the reliability category of the existing system should be Category I. In comparison, the effluent plume is predicted to be trapped at a depth of over 39 m. The effluent plume is therefore unlikely to reach the water surface and would not cause immediate human health concerns in the event of a failure. The marine option would therefore be categorized as a Category II system.

Table 1 Regulatory Compliance – WSER

Regulation Section		River Outfall		Marine Outfall	
		Criteria	**Compliant**	**Criteria**	**Compliant**
6 (1)	Effluent Quality				
	Acute Lethality	Effluent is not cutely lethal	Yes	Effluent is not cutely lethal	Yes
	Average CBOD	25 mg/L	Yes	25 mg/L	Yes
	Average Suspended Solids	25 mg/L	Yes	25 mg/L	Yes
	Average Total Residual Chlorine	0.02 mg/L	Unknown	0.02 mg/L	Unknown
	Maximum un-ionized ammonia	1.25 mg/L at 15°C	Yes (0.05 mg/L)	1.25 mg/L at 15°C	Yes (0.05 mg/L)
15					
23 (1)	Transitional Authorization	Transitional Authorization is in place until 2030	Yes	Environment Canada should be consulted to determine if the existing transitional authorization will be valid with new discharge.	Unknown

Table 2 Regulatory Compliance – Municipal Wastewater Regulation

Regulation Section	Criteria	River Outfall	Compliant	Marine Outfall	Compliant
7 (3)	Municipality must not accept non-domestic waste.	City of Duncan and CVRD Sewer Service Bylaws	Yes	City of Duncan and CVRD Sewer Service Bylaws	Yes
34 (2)	Reliability	Category I (Short term degradation of effluent quality could cause unacceptable damage to recreational waters)	TBD	Category II (long term effluent degradation could cause unacceptable damage to recreational or shellfish waters)	TBD
52 (1)	Disinfection	Required	Yes	Required	Yes
52 (2)	Chlorination (A dischargers must nor use chlorination without authorization from a director)	Authorized under ME-01497	Yes		TBD
58	Toxicity	Monitoring Required	Yes	Monitoring not required (predicted dilution >100:1 at IDZ boundary)	Yes
91	Initial Dilution Zone				
91(2)	IDZ must be 300 m from:				
	(b) Recreational Areas	No public access within 400 m	Yes	Point of discharge 400 m from the shore	Yes
	(b) Shellfish Harvesting	n/a		Point of discharge 400 m from possible shellfish waters	Yes
91 (3)	Combined Effects	The river is impacted by forestry, agriculture, on-site sewage disposal and urbanization, several water quality objectives		The Lambourn outfall discharges in close proximity to the proposed location. Die to the high quality effluent and low	

Regulation Section	Criteria	River Outfall	Compliant	Marine Outfall	Compliant
		for the river have historically been exceeded (MOE, 2011).		flow combined effects are not anticipated.	
92	Initial Dilution Zone (Marine)			100 m Radius from individual diffuser ports	Yes
93	Initial Dilution Zone (River)	25% of width of stream (~10 m) and lesser of 100 m downstream or where effluent plume equals the width of IDZ)	Yes		
94	Effluent Quality	BOD_5 ≤ 10 mg/L	No	BOD_5 ≤ 45 mg/L	Yes
		TSS ≤ 10 mg/L (60 mg/L for lagoon systems)	No	TSS ≤ 45 mg/L (60 mg/L for lagoon systems)	Yes
		pH 6-9	Yes	pH 6-9	Yes
		total phosphorous, < 1 mg/L	No (1.2 mg/L)	total phosphorous n/a	Yes
		ortho-phosphate, < 0.5 mg/L	Unknown	ortho-phosphate < 0.5 mg/L	Unknown
95	Effluent Quality	Ammonia, (11.4:1 Dilution – Declan 2013)	Yes	(See EIS)	Yes
96	Fecal Coliform	Fecal coliform (End of Pipe 200 CFU/100 mL)	Yes	(See EIS)	Yes
97	Advanced Treatment	Average Phosphorus ≤ 0.25 mg/L		n/a	n/a

Regulation Section	Criteria	River Outfall	Compliant	Marine Outfall	Compliant
98	Enhanced Environmental Impact Study	n/a	n/a		n/a
99 (1)	(a) Initial Dilution Zone requirements are met	Modelling and detailed assessment has not been completed	TBD		Yes
	(b) air entrapment is prevented	(assumed)	Yes	To be verified in detailed design	Yes
	(c) adequate weighting	(assumed)	Yes	To be verified in detailed design	Yes
	(d) the outfall is protected from corrosion	(assumed)	Yes	To be verified in detailed design	Yes
99 (2)	(a) trapping of effluent plume is maximized	Trapping of the effluent plume is unlikely in a river scenario	No	See EIS (Worst Case 39m)	Yes
	(b) Intercept the predominant current		n/a	To be confirmed with current study and 3D modelling	Yes
	(c) minimum 10:1 dilution and water quality parameters are met at boundary of IDZ	Modelling and detailed assessment has not been completed	TBD	Preliminary dilution modelling suggest minimum of ### :1 dilution	Yes
	(d) locate in the channel in which most of the water flows	Located in main channel of river.	Yes		n/a
99 (3)	(a) protected from wave, boat and marine activity		n/a	Located approximately 1 km from anchor berths	Yes
	(b) Minimum depth of 10 m below low water		n/a	60 m below low water	Yes
100	Depth and distance of diffuser to be determined by EIS		n/a	See EIS	Yes

Regulation Section	Criteria	River Outfall	Compliant	Marine Outfall	Compliant
101	Outfall to be marked with a sign		TBD	The proposed outfall will include a sign.	Yes

9 Conclusion

The marine outfall location will provide a higher degree of risk management for the environment and human health over the river outfall, including being more robust under treatment system upset conditions if those conditions were to occur. The marine outfall will also be able to achieve present day regulatory requirements for a municipal effluent discharge.

10 Closure

If you have any questions or require further details, please contact the undersigned at any time.

Sincerely,

Original Signed on 25-June-2015

Jason Clarke, P. Eng.
Director

11 References

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GreatPacific Engineering & Environment

Appendix 3 Dayton Knight Report, 1993

DUNCAN NORTH COWICHAN JOINT UTILITIES BOARD

PRELIMINARY OCEANOGRAPHIC AND EFFLUENT DISPOSAL STUDIES IN COWICHAN BAY AND SATELLITE CHANNEL

JANUARY 1993

Dayton & Knight Ltd.
626 Clyde Avenue
P.O. Box 91247
West Vancouver, B.C.
V7V 3N9

DUNCAN NORTH COWICHAN JOINT UTILITIES BOARD
COWICHAN BAY
OCEANOGRAPHIC AND EFFLUENT DISPOSAL STUDIES

CONTENTS

DUNCAN NORTH COWICHAN JOINT UTILITIES BOARD
COWICHAN BAY
OCEANOGRAPHIC AND EFFLUENT DISPOSAL STUDIES

1.0 INTRODUCTION

1.1 Background

The Duncan North Cowichan Joint Utilities Board provides sewerage service to the City of Duncan, the southern part of the District of North Cowichan, the Eagle Heights area in the Cowichan Valley Regional District and to the Boy's Road area in the Cowichan Indian Reserve.

The system presently services about 18,000 people. Aerated lagoons located on Cowichan Band land adjacent to the City of Duncan provide secondary treatment and an outfall is used to dispose of effluent to the adjacent Cowichan River.

A review[1] of treatment and disposal options carried out in 1988/89 concluded that the Cowichan River discharge should be abandoned and the outfall should be extended to Satellite Channel at the mouth of Cowichan Bay. A staged program was recommended that would initially discharge at the 40 m depth within Cowichan Bay and later, as sewage loads grew, the outfall would be extended to Satellite Channel. The report noted that the existing lagoons could be upgraded to serve about 18,000 people but eventually a new site would have to be located for a treatment plant. The report also recommended an expansion of the service area to include Maple Bay, Shawnigan Lake and the Mill Bay areas.

In 1991 the Board commissioned a pre-design study[2] for trunk sewer routing and treatment plant siting. Two sites were evaluated for a new treatment plant, one at the head of Cowichan Bay and the second in the vicinity of the Island Highway and CN Rail R/W just south of Indian Reserve No. 1. Trunk sewer alignments between the existing lagoons and the proposed new treatment plant sites were advanced to a pre-design stage. Both sites were considered technically suitable for treatment plant use.

The Cowichan Bay Estuary Plan serves to restrict activity within the Plan area. The proposed treatment plant site at the head of Cowichan Bay is situated within the Plan area. The proposed initial stage outfall terminus at the 40 m depth is also within the Plan area. B.C. Environment in a June 17/91[8] letter advised that the Cowichan Bay Estuary Committee opposed an initial stage outfall within Cowichan Bay. It was suggested that the outfall be extended to Satellite Channel using an alignment along the Wescan Terminal causeway and the south shoreline of Cowichan Bay. It was also pointed out that a plant site within the estuary may not be the best location to serve the long term needs of the service area.

1.2 Objective and Scope

The objective is to undertake a preliminary assessment of effluent disposal at the mouth of Cowichan Bay.

Study terms of reference are outlined in a Dayton & Knight Ltd. letter dated November 3/89. In summary, the study tasks included:

1. Data assembly including existing oceanographic data, charts, foreshore leases, fisheries resources, recreational uses.

2. Data analysis including outfall criteria, sizing and outfall alignment.

3. Oceanographic study including drogue tracking over flood and ebb tides and conductivity, temperature, depth (CTD) measurements (at 40 m depth, midway and seaward end of Cowichan Bay).

4. Report to summarize study findings.

The scope was modified to eliminate oceanographic study at the 40 m depth within Cowichan Bay in order to comply with direction received from B.C. Environment.

By letter of July 25/91, the Board authorized the study to proceed.

1.3 Conduct of Study

Data gathering commenced in August 1991.

Seakem Oceanography Ltd. (now AXYS Environmental Consulting Ltd.) of Sydney, B.C. was retained to carry out the oceanographic work. A three day study was carried out on September 18, 19 and 20, 1991.

The Cowichan Bay south foreshore (from Cowichan Bay to Cherry Point) was walked on September 18, 1991 and photographs were taken during the morning low tide.

A meeting was held with Mr. Trevor Field of Fisheries and Oceans in Duncan on October 1, 1991 to identify fisheries resources in the Cowichan Bay area.

The Seakem report was submitted in mid October and was reviewed by month's end. Review comments were provided on October 29, 1991. A supplementary letter report with illustrations was provided on January 9, 1992 to complete the oceanographic portion of the assignment.

Effluent disposal analysis commenced in late January, 1992. Drawings were prepared to illustrate the proposed outfall alignment, the predicted travel of the effluent plume and the estimated dilutions at various locations along the shoreline.

A draft report was submitted for review in July 1992.

Review comments were received in mid October 1992 and the report was finalized in December 1992.

1.4 Study Team

Mr. Brian Walker, P. Eng., acted as principal-in-charge and report author. Mr. John Boyle, P. Eng., was responsible for dilution modelling and was assisted by Mr. Ralph Beyer, P. Eng.

Oceanographic study and report writing were under the direct supervision of Mr. Randolph Kashino, B.Sc., of Seakem Oceanography Ltd.

Mr. John MacKay, P. Eng., of the District of North Cowichan and Mr. Paul Douville of the City of Duncan provided study guidance and draft report review comments.

1.5 Definitions and Abbreviations

ADWF	-	average dry weather flow
AWWF	-	average wet weather flow
Peak Flow	-	instantaneous flow which includes maximum inflow and infiltration coincident with peak sewage flow
BOD_5	-	biochemical oxygen demand
SS	-	suspended solids
P	-	phosphorus
NH_3	-	ammonia
MPN/100 mL	-	most probable number per 100 millilitres

2.0 OCEANOGRAPHIC STUDY

The oceanographic study reports are attached as Appendix 1. The purpose of the study was to provide background oceanographic data for a proposed effluent outfall in the general vicinity of the mouth of Cowichan Bay. A summary of the oceanographic study findings is presented in the following sections.

2.1 Previous Studies

Previous oceanographic studies were primarily concerned with circulation in the Satellite Channel - Saanich Inlet systems. These include:

- Canadian Hydrographic Service (1966)
- Herlinveaux (1968)
- Coastal Zone Oceanography (1980)
- Byers (1980)
- Narayanan (1981)
- Woods and Shaw (1981)

The Narayanan study was undertaken for the Hatch Point Marine Assessment and overlaps this work. It was primarily concerned with oil apills. The Woods and Shaw work concentrated on biological oceanography for the Hatch Point area.

Known environmental studies include:

- Bell and Kalloran (1976)

This report presents a status of environmental knowledge to 1975 for the Cowichan and Chemainus River estuaries. The study focused primarily on the Stuart Cbannel area with only limited information presented for Cowichan Bay.

These previous studies provide useful information but add little detail on tbe actual circulation patterns within Cowichan Bay and Satellite Cbannel.

2.2 Drogue Studies

Current following drogues were deployed on September 18, 19 and 20, 1991. Five shallow drogues (2 m x 2 m sails set at the surface) and five deep drogues (3 m x 2 m sails set 10 m below water) were used and tracked by boat using a sextant.

Wind measurements were made during the work using a hand held anemometer. During the study the winds were ligbt, not exceeding 8 knots. This means the wind bad little effect on the movement of the drogues.

The drogue tracks are presented on Figures 3 to 14 in the Seakem report. Tbe drogues were deployed at the mouth of Cowichan Bay (at Satellite Channel) on September 18 and within Cowichan Bay (mid point) on September 19 and 20. Tbe following results are noted and are illustrated on Figures 2-1, 2-2 and 2-3.

- At Satellite Cbannel the circulation pattern is complex with eddies being set up on both ebb and flood tides and circulation varying with depth. On the flood surface water will be directed into Sansum Narrows and Cowichan Bay with a back eddy being formed at Separation Point (Figure 2-1). On an ebb tide water discharges from Cowichan Bay and Sansum Narrows into Satellite Channel, causing a large back eddy off Separation Point. On the ebb water also discharges from Saanich Inlet and is eitber forced along the Saltspring Island shoreline of Satellite Channel to cause a second back eddy near Cberry Point (Figure 2-2) or it discharges into Satellite Channel (Figure 2-3).

- Within Cowicban Bay the surface circulation pattern is less complex and is more typical of an estuarine bay. Surface water flows out of the Bay on an ebb tide while deep water flows into the Bay. On the flood surface water flows into the Bay while deep water exits. On the ebb, tbe large back eddy off Separation Point causes the surface water to flow out of the Bay along tbe south sboreline.

Witb respect to a possible discharge of effluent the following generalized conclusiona are drawn.

- For a discharge in the middle of Cowichan Bay, flood currents will direct the effluent field toward the head of the bay and on an ebb tide effluent will be directed along the south sbore toward the moutb of tbe Bay.

- For a discharge at the mouth of tbe Bay flood currents will be primarily into the Bay with a fraction into Sansum Narrows. On the ebb tide, effluent will be directed eitber into Satellite Channel or into a back eddy off Cherry Point.

The drogue travels were used to estimate near surface current velocity as summarized in Table 2-1.

TABLE 2-1
CURRENT VELOCITIES

Current cm/s	Satellite Channel		Cowichan Bay	
	Surface	10 m Depth	Surface	10 m Depth
Average	26.7	34.5	26.2	14.7
Maximum	79.7	81.0	130.9	48.0
Minimum	5.5	7.4	0.7	2.8

2.3 Water Structure

Conductivity, temperature, depth (CTD) measurements were taken at 12 stations over the three days of drogue study. Station locations are shown on Figure 2 of the Seakem report. Figures 25 to 50 in the Seakem report show the results in terms of temperature, salinity and density (expressed as sigma-T) profiles at each station.

The vertical profiles show that four layers of water exist in Cowichan Bay and Satellite Channel:

0 - 5 m	- surface layer, Sigma-T = 20.5 to 21.0
5 - 20 m	- mid layer, Sigma-T = 21.0 to 22.0
20 m - near bottom	- deep layer, Sigma T = 22.0 to 23.0
Bottom - 5 m above bottom	- bottom layer, Sigma T = 23.0 to 23.5

There is strong stratification on ebb tide and weaker stratification on a flood tide in both Cowichan Bay and Satellite Channel. Generally water density increases from the head of the Bay toward Satellite Channel.

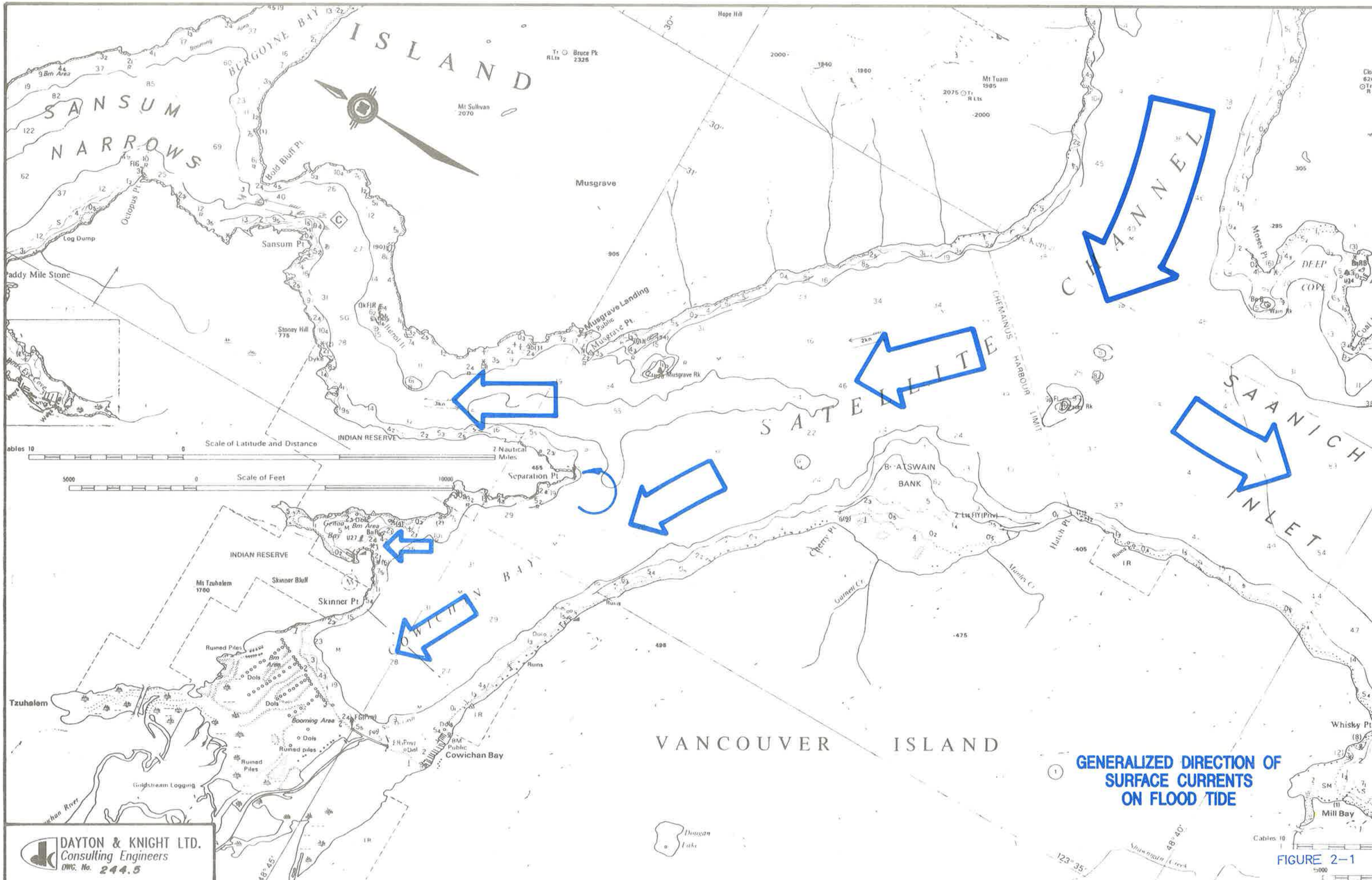
The CTD results also indicate an estuarine movement within Cowichan Bay. That is, on a flood surface waters enter the Bay while deep water exits and on an ebb the surface waters exit (favouring the south side) and deep waters enter.

The river discharge is an integral part of estuarine circulation in Cowichan Bay. Maximum flows occur during winter rains and not during spring snow melt. The study period coincided with low river flows and a corresponding low impact from the estuarine circulation. The CTD results, however, still show the estuarine effect and this can be expected to be more pronounced in winter months.

2.4 Wind

Winds during the study period were light and did not materially affect the surface currents. A general rule is that wind will cause surface currents at about 3% of wind velocity. Thus a 30 knot wind will drive surface currents at 1 knot.

Victoria airport records show prevailing westerly winds in summer and south-east winds in winter. Thus, if a strong westerly is blowing, surface water outflow during an ebb will be enhanced and conversely, during a strong south-east blow, the surface water outflow will be stalled.



GENERALIZED DIRECTION OF SURFACE CURRENTS ON FLOOD TIDE

FIGURE 2-1

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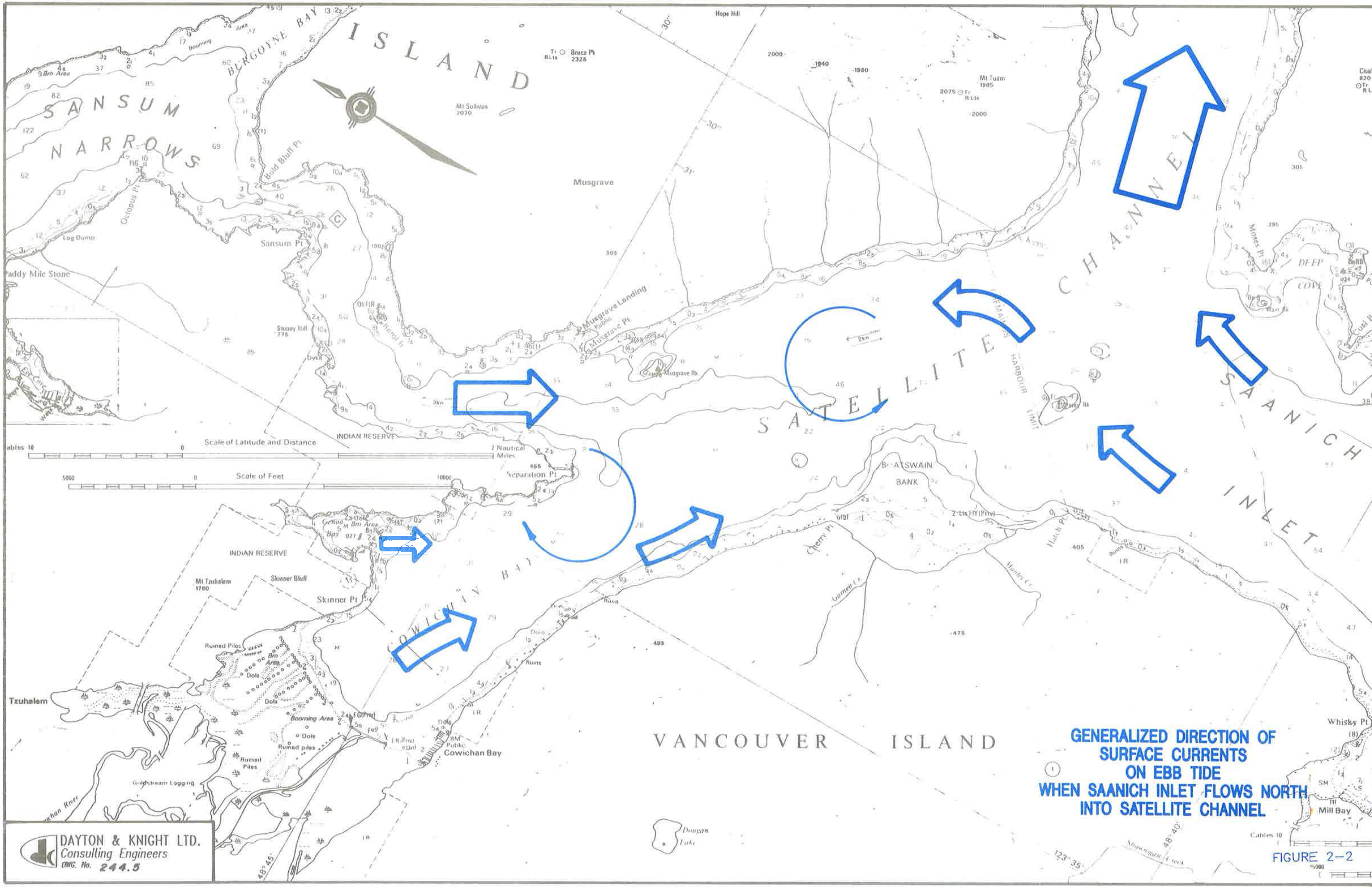
GENERALIZED DIRECTION OF
SURFACE CURRENTS
ON EBB TIDE
WHEN SAANICH INLET FLOWS NORTH
INTO SATELLITE CHANNEL
SATELLITE CHANNEL
SAANICH INLET
COWICHAN BAY
VANCOUVER ISLAND
ISLAND
SANSUM NARROWS
BURGOYNE BAY
Musgrave
Musgrave Landing
Sansum Pt
Separation Pt
Skinner Pt
Skinner Bluff
Mt Tzuhalem
Tzuhalem
Cowichan Bay
Mill Bay
Whisky Pt
DEEP COVE
Moses Pt
BOATSWAIN BANK
INDIAN RESERVE
Scale of Latitude and Distance
Scale of Feet
DAYTON & KNIGHT LTD.
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FIGURE 2–2

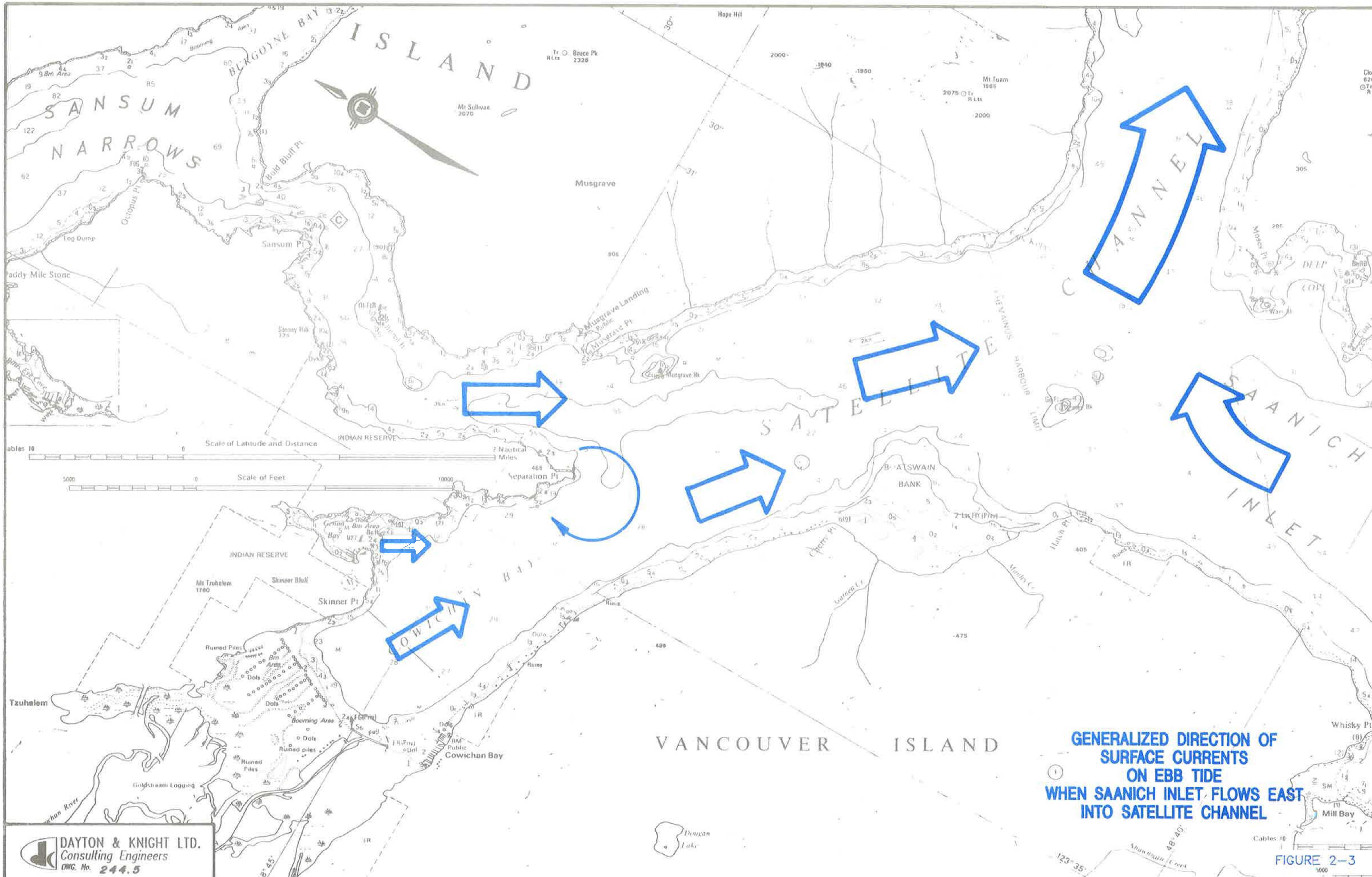

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FIGURE 2–3

3.0 EFFLUENT DISPOSAL

3.1 Sewage Treatment and Disposal Criteria

The outfall pipeline alignment and the impact of the effluent discharge on the receiving waters are tbe primary concerns of this study. The present aerated lagoon system provides a secondary level of treatment. The Province's effluent disposal Objectives[3] permit a primary level of treatment for disposal to open marine waters sucb as Satellite Channel. These Objectives are under review and it is likely tbat secondary treatment will become mandatory for all discharges to tbe Strait of Georgia. For this study it is assumed existing and future treatment will be to a secondary level whicb, can be generally characterized as follows:

BOD_5	30 mg/L
SS	40 mg/L
NH_3	20 mg/L
P	4 mg/L
Fecal Coliform	20,000 to 60,000 MPN/100 ml

Population and flow criteria were set out in the 1989 report[1] as follows:

TABLE 3-1
POPULATION AND FLOW CRITERIA

	1989	2011	2041
Population	12,000	40,000	100,000
ADWF (m^3/d)	5,800	18,000	45,000
AWWF (m^3/d)	12,200	24,000	60,000
Peak (m^3/d)	20,900	40,300	113,500

3.2 Effluent Pipeline and Outfall Pre-Design

3.2.1 Alignment

The B.C. Environment letter of June 17, 1991[4] suggested a pipeline alignment along the Wescan causeway and south shore of Cowichan Bay. The majority of this route was inspected during the low daytime tide on September 18/91. The causeway and the shoreline from the west end of Cowichan Bay Village to Cherry Point were inspected on foot. Only the water section between the end of the causeway and Cowichan Bay Village could not be inspected (diving will be necessary to view this section).

Representative photographs are attached as Figures 3-1 to 3-3

The section from the causeway to the Hecate Park (500 m) was below tide at the time of inspection. The charts indicate that this area is mud and dries at low tide. It may be possible to excavate a trench at low tide for a pipeline, or alternatively, dredging or jetting could be employed to create a trench for the pipeline.

The section from Hecate Park to the east end of the Government Wharf in Cowichan Bay Village (500 m) is largely commercialized waterfront with numerous wharves. It will be necessary to temporarily remove sections of wharf to allow excavation equipment to trench. Generally the beach in this section is mud to cobble. Construction of a buried pipeline is feasible, but will be difficult.

Alternatively, the pipeline could be laid in a straight line on the ocean bottom from the end of the causeway to the east end of the Government Wharf. This will avoid the difficult construction through the commercial foreshore area. The chart indicates a mud bottom. The pipeline can be trenched or jetted into the sea bottom to provide cover and protection.

The section from Cowichan Bay Village government wharf to Cherry Point Marina (2000 m) is generally sand to cobble beach with some sections of mud where small creeks discharge. During the inspection there was generally a minimum of 10 to 15 m of beach above the 1.2 m (4 ft.) tide level. Pipeline construction in this section will be easy.

At Cberry Point Marina (100 m) there are a few wharves that must be crossed. Temporary removal of wharf sections will be necessary. Pipeline construction is feasible, but will be difficult.

From Cherry Point Marina to the abandoned wharf due soutb of Separation Point (1900 m), the beach is sand to cobble with generally 10 to 15 m exposed at a 1.5 m (5 ft.) tide. Pipeline construction in this section will also be straightforward.

Beyond the abandoned wharf to Cherry Point (1400 m) the beach is also sand and cobble with 10 to 15 m exposed at a 1.5 m (5 ft.) tide. Construction will be easy.

3.2.2 Pipeline Size

The pipeline will initially allow lagoon effluent discharge to Satellite Channel. It could also be converted in the future to a raw sewage forcemain should a treatment plant be located in the vicinity of Cherry Point to Hatch Point. The pipeline size, accordingly, should be suitable for both uses.

The existing lagoons are at about elevation 7.3 m and the distance to Satellite Cbannel is over 10 km. High tide in Satellite Channel is about elevation 3.9 m. There is not enough head for gravity flow. Effluent pumping is necessary.

The Site 1 and Site 2 treatment plant locations that were evaluated in tbe October, 1991 report[2] are respectively 8.3 km and 9.9 km from Satellite Channel. Site 1 is at elevation 1.0 m and Site 2 is at elevation 4-5 m. Effluent pumping is also necessary from these possible future treatment plant sites.

For this study it is assumed effluent pumping will be located at the Site 2 treatment plant location. The effluent pipeline length from Site 2 to the embayment line in Satellite Channel is 9900 m (32,500 ft.).

Important criteria for pipeline sizing include:

- Design for peak flow.
- Limit total dynamic head (TDH) to about 50 m (165 ft.) for possible future raw sewage pumping.
- For secondary effluent, maintain minimum velocity of about 0.30 m/s (1 fps) and for raw sewage about 0.76 m/s (2.5 fps).
- Pipeline should serve a minimum 20 year period (the normal financing period).

Two pipeline sizes have been considered as compared in Table 3-2.

TABLE 3-2
EFFLUENT PIPELINE CRITERIA

Population	12,000	40,000	100,000
Peak Flow (m^3/d)	20,900	40,300	113,500
ADWF (m^3/d)	5,800	18,000	45,000
750 mm (30 in.)			
Velocity (Peak) (m/s)	0.55	1.04	2.90
TDH (m)	4.00	15.00	119.00
Velocity (Minimum) assuming 2 - 20,000 m^3/d pumps = 0.50 m/s			
900 mm (36 in.)			
Velocity (Peak) (m/s)	0.38	.73	1.98
TDH (m)	2.00	6.10	45.70
Velocity (minimum) assuming 2 - 20,000 m^3/d pumps = 0.37 m/s			

The 750 mm (30 in.) option has capacity for about 60,000 people before a duplicate pipeline is needed. Preliminary analysis favours use of a 900 mm (36 in.) pipeline which will be suitable for 100,000 people.

3.2.3 Outfall Design Criteria

The outfall and diffuser should be designed to incorporate tbe following design criteria.

- Bury pipeline witb 1 m cover in the intertidal zone to 3 m below low water to provide protection from wave action and for aestbetic effects.
- Beyond the intertidal zone the outfall will rest on the channel/ocean bottom.
- Align outfall in a straight line (ease of construction) and constant downhill grade (avoid entrapment of air).
- Diffuser section to be an extension of the outfall for ease of installation.
- Locate diffuser in a minimum of 30 m (100 ft.) of water to ensure good initial dilution and trapping of tbe effluent plume when stratification exists.
- Use either polyethylene or mild steel pipe.
- Design outfall to prevent uplift or movement with a factor of safety of 1.5. For polyethylene pipe this will require the addition of some external weighting (typically concrete). For steel pipe tbe external weighting, if any, will be lesa than for polyethylene pipe.
- Apply for construction approval from the Coast Guard.
- Post the outfall with a sign facing seawards.

3.2.4 Marine Outfall and Diffuser Section

The marine outfall will extend from the effluent pipeline in the south sbore of Cowichan Bay to the selected point for the outfall terminus. Two outfall terminii locations have been considered; one just outside the Cowichan Estuary Plan boundary within Cowichan Bay and the second at the embayment line in Satellite Cbannel. Figure 3-4 illustrates.

1) Cowichan Bay Terminus

This discharge location is considered for possihle initial stage construction to minimize cost. Tbe marine outfall will be sized at 600 mm (24 in.) to serve a maximum 40,000 people. In future, the 600 mm outfall will be abandoned and the effluent pipeline will be extended to discbarge at Satellite Channel.

The 600 mm diameter outfall will be 850 m long and discharge at the 55 m deptb. The diffuser section will be 19 m long, 600 mm diameter witb 20 - 100 mm diameter horizontal ports at 1 m spacing.

2) Satellite Channel Terminus

This discbarge location is the desirahle long term terminus for an outfall. The outfall will be 900 mm diameter, 1000 m long and discharge at the 55 m depth. The diffuser section will also be 900 mm diameter with 20 - 100 mm diameter horizontal ports (1 m spacing) suitable initially for peak flow of 40,300 m^3/d (40,000 people). In future the diffuser section will need to be extended to service up to 100,000 people.

3.2.5 Cost Estimates

Preliminary estimates of cost bave utilized tbe following unit prices:

- Effluent pipeline, land and beach sections $0.71/m/mm dia ($5.50/ft/in dia)
- Outfall, marine section $0.89/m/mm dia ($7.00/ft/in. dia)

1) Cowichan Bay Terminus:

• Site #2 to Causeway	
- 900 mm, 4500 m x $640	$2,880,000
- river crossing; extra, allow	50,000
• Causeway to Cowichan Bay Govt. Wharf (across Bay)	
- 900 mm, 1000 m x $800	800,000
• Cowichan Bay Govt. Wharf to outfall	
- 900 mm, 500 m x $640	320,000
• Marine outfall	
- 600 mm, 850 m x $535	455,000
- Diffuser Section; extra, allow	30,000
Sub-Total	$4,535,000
• 25% Engineering and Contingency	1,134,000
Sub-Total	5,669,000
• 3% GST (net)	170,000
TOTAL	$5,839,000

2) Satellite Channel Terminus:

• Site #2 to Causeway	
- 900 mm, 4500 m x $640	$2,880,000
- river crossing; extra, allow	50,000
• Causeway to Cowichan Bay Govt. Wharf (across Bay)	
- 900 mm, 1000 m x $800	800,000
• Cowichan Bay Govt. Wharf to outfall	
- 900 mm, 3700 m x $640	2,368,000
• Marine outfall	
- 900 mm, 1000 m x $800	800,000
- Diffuser Section; extra, allow	40,000
Sub-Total	$6,938,000
• 25% Engineering and Contingency	1,735,000
Sub-Total	$8,673,000
• 3% GST (net)	260,000
TOTAL	$8,933,000

3.3 Effluent Dilution

Effluent discharged from an outfall undergoes physical and chemical dilution processes. These processes can be categorized into three principal phases of dilution; initial dilution, dispersion dilution and chemical (or waste decay) dilution. Tbese processes are illustrated on Figure 3-5.

3.3.1 Physical Dilutions

Initial Dilution: The most important force in the first pbase of physical dilution is exerted by tbe relatively static ocean water mass wbicb attempts to slow down the discharge stream from an outfall or diffuser system. A second force is exerted by tbe relative buoyancy of the discharged effluent in relation to the seawater. This relative buoyancy deflects the effluent upwards towards the surface of the sea. As the buoyant effluent is deflected towards tbe surface it is slowed down by the static water mass and during the slowing down process violent mixing takes place. This mixing dilutes tbe effluent which in turn decreases the magnitude of the buoyant force. Tbere is finally a stage where the seawater and effluent densities are equal. The location where this occurs is referred to as the trapping level. Thereafter, the plume usually spreads horizontally. In unstratified water the trapping heigbt will be at the ocean surface while in stratified locations the plume will reach the point of neutral buoyancy before surfacing.

The mixing which has occurred between the discharge and the trapping height is called the **Initial Dilution** (D1) and the initial dilution value used in dilution calculations is the D1 value at the trapping height.

Dispersion Dilution: Once stationary conditions are achieved, tbe seawater effluent mixture moves with tbe ocean currents at a given depth. Further dilution is caused by ocean turbulence. This second phase in the physical dilution process occurs mainly near the edges of the mixture field and is predominantly in the horizontal direction. It is referred to as **Dispersion Dilution** (D2).

3.3.2 Chemical Dilution

Starting immediately after discharge and progressing throughout the two phases of physical effluent dilution, the seawater-effluent seawater mixture undergoes continuous purification. The purification, commonly referred to as chemical or decay dilution, consists of a natural die-off of bacteria and other biological organisms, settlement to the ocean floor of suspended matter, transformation of dissolved solids to suspended matter, and satisfaction of oxygen demand in the seawater. The chemical dilution is commonly referred to as **Waste Decay Dilution** (D3).

3.3.3 Computer Models

Initial Dilution: From a review of available computer models a program called "UMERGE" was judged appropriate for calculating initial dilution because it models a multi-port diffuser in a variable current condition with or without a stratification condition. These conditions apply in Cowichan Bay.

The UMERGE program was developed by Teeter and Baumgartner at the Corvallis Environmental Research Laboratory (Reference 2) and this model calculates average volumetric dilutions of a single plume in either a single or a multiport system. The UMERGE model incorporates criteria and formulae originally established by Rawn, Bowerman and Brooks. Teeter and Baumgartner advise that the 10 percentile current should be used with UMERGE to simulate worse case conditions. The UMERGE program terminates either when the density difference between the effluent and the ambient (the surrounding ocean) has become zero and the plume is referred to as "trapped", or alternatively, at the surface if the plume reaches there before becoming trapped.

In the operation of an outfall it is desirable to achieve an adequate flushing velocity through the diffuser port(s). If this does not occur, seawater may enter the ports and marine organisms may prosper in the nutrient ricb environment of the pipeline, with a possible gradual reduction of the cross sectional area and flow capacity. Seawater intrusion can be prevented if the Froude number (Fd) is greater than 2. The Froude number is defined as follows:

$$Fd = \frac{v}{\sqrt{g'd}}$$

where:

v	=	port velocity in metres per second
d	=	port diameter in metres
g'	=	$g\,\frac{(Pa - Pe)}{Pa}$
Pa	=	receiving water density in grammes per cubic centimetre (g/cm^3)
Pe	=	effluent density in g/cm^3

Dispersion (D2) and Decay Dilutions (D3) The dispersion and decay dilutions were calculated using a program called "DISPERS" wbich is based on formulae presented in Metcalfe and Eddy (Ref.3).

Although the 10 percentile current is generally accepted as tbe current to use for estimating a worst case initial dilution, no specific value is commonly adopted for calculating the decay and dispersion dilution. Some adopt a range of values based on the 10 and 90 percentile currents. For this study the 50 percentile current value has been adopted.

For decay dilution, a T-90 decay time of 4 to 5 hours is generally used by most authorities. This rate represents the time for 90% of bacteria to die in seawater. Generally, the decay rate is less if the effluent-seawater mixture surfaces and sunlight assists the die-off compared with a trapped discharge at depth. The shorter the decay time, the greater the decay dilution.

3.3.4 Total Dilutions

The product of Dispersion Dilution (D2) and Waste Decay Dilution (D3) is generally referred to as **Subsequent Dilution**.

The product of Subsequent Dilution and Initial Dilution (D1) is generally referred to as **Total Dilution**. Thus Total Dilution can be expressed as follows:

$$\text{Total Dilution} = D1 \times D2 \times D3$$

3.3.5 Calculated Dilutions

Effluent dilutions were calculated using the data obtained from tbe oceanographic study.

Initial Dilutions

Initial dilutions were calculated for future average and peak rates of flow (40,000 population) for summer and winter discharge conditions for outfalls in Cowichan Bay and in Satellite Channel.

Copies of the UMERGE computer printouts for the above conditions are included in Appendix 2. In all cases the effluent plume reached the trapping level below the surface. This is a desirable condition as it means that by the time the plume reaches the surface under the subsequent dilution stage, considerable further dilution will have occurred.

Surface currents for summer conditions were calculated based on drogue current velocities. For the purpose of these preliminary studies, similar currents were adopted for the winter analyses. Summer temperature and salinity values were obtained from measurements recorded by AXYS and typical winter data were obtained from records provided by the Institute of Ocean Sciences[5].

The initial dilution values at the trapping depths for the above conditions are tabulated in Table 3-3. Trapping depths are measured from the surface.

TABLE 3-3
INITIAL DILUTIONS

Discharge Location	Flow	Summer		Winter	
		Dilution	Trapping Depth (m)	Dilution	Trapping Depth (m)
Cowichan Bay	Average	84:1	33.6	152:1	21.0
	Peak	62:1	29.3	109:1	13.0
Satellite Channel	Average	105:1	29.7	152:1	21.0
	Peak	75:1	24.6	109:1	13.0

From Table 3-3 the effluent plume is shown to be trapped at greater depth during summer than in winter for both outfall locations. As previously explained this is a desirable condition. The trade-off is that the initial dilution values are predicted to be slightly lower in summer than in winter as shown in Table 3-3.

Subsequent Dilutions

Subsequent dilutions were calculated using the "DISPERS" program and copies of the computer printouts for the same conditions considered for initial dilution are included in Appendix 2.

The subsequent dilution calculations also refer to conditions from future average and peak flows from a 40,000 population.

Tables 3-4 and 3-5 summarize some of the DISPERS output data for various discharges at Cowichan Bay and Satellite Channel respectively.

TABLE 3-4
SUBSEQUENT DILUTIONS
COWICHAN BAY

Distance from Diffuser (m)	Season	Flow	Dispersion Dilution	Decay Dilution	Subsequent Dilution
500	Summer	Average	2.6:1	1.7:1	4.4:1
		Peak	2.5:1	1.6:1	4.0:1
	Winter	Average	2.2:1	1.6:1	3.5:1
		Peak	2.1:1	1.6:1	3.3:1
1000	Summer	Average	5.2:1	2.8:1	14.6:1
		Peak	4.7:1	2.7:1	12.7:1
	Winter	Average	4.1:1	2.6:1	10.6:1
		Peak	4.0:1	2.6:1	10.4:1
1500	Summer	Average	8.2:1	4.7:1	38.5:1
		Peak	7.5:1	4.4:1	33:1
	Winter	Average	6.5:1	4.1:1	26.7:1
		Peak	6.2:1	4.1:1	25.4:1
2000	Summer	Average	11.8:1	7.9:1	93.2:1
		Peak	10.6:1	7.2:1	76.3:1
	Winter	Average	9.0:1	6.5:1	58.5:1
		Peak	8.6:1	6.5:1	55.9:1

TABLE 3-5
SUBSEQUENT DILUTIONS
SATELLITE CHANNEL

Distance from Diffuser (m)	Season	Flow	Dispersion Dilution	Decay Dilution	Subsequent Dilution
1000	Summer	Average	4.7:1	2.7:1	12.7:1
		Peak	4.4:1	2.6:1	11.4:1
	Winter	Average	4.1:1	2.6:1	10.7:1
		Peak	4.0:1	2.6:1	10.4:1
2000	Summer	Average	10.6:1	7.2:1	76.3:1
		Peak	9.6:1	6.5:1	62.4:1
	Winter	Average	9.0:1	6.6:1	59.4:1
		Peak	8.6:1	6.5:1	55.9:1
3000	Summer	Average	17.8:1	19.4:1	345:1
		Peak	16.1:1	16.8:1	271:1
	Winter	Average	15.1:1	16.8:1	253:1
		Peak	14.4:1	16.8:1	242:1
4000	Summer	Average	26.3:1	52.1:1	1370:1
		Peak	23.6:1	42.9:1	1012:1
	Winter	Average	22.0:1	42.9:1	944:1
		Peak	21.0:1	42.9:1	901:1

Tables 3-4 and 3-5 data indicate slightly greater values of subsequent dilution for summer conditions compared to winter. This is due to the lower temperature and salinity gradients which exist during winter. Subsequent dilutions are about the same in Cowichan Bay and Satellite Channel.

Total Dilutions

Total dilutions at various distances from discharges in Cowichan Bay and Satellite Channel are presented in Tables 3-6 and 3-7 respectively. Total dilutions are predicted to be similar at both discharge locations.

TABLE 3-6
TOTAL DILUTIONS
COWICHAN BAY

Distance from Diffuser (m)	Season	Flow	Dispersion Dilution	Decay Dilution	Subsequent Dilution
500	Summer	Average	84:1	4.4:1	370:1
		Peak	62:1	4.0:1	250:1
	Winter	Average	152:1	3.5:1	530:1
		Peak	109:1	3.3:1	360:1
1000	Summer	Average	84:1	14.6:1	1220:1
		Peak	62:1	12.7:1	790:1
	Winter	Average	152:1	10.6:1	1610:1
		Peak	109:1	10.4:1	1130:1
1500	Summer	Average	84:1	38.5:1	3220:1
		Peak	62:1	33:1	2040:1
	Winter	Average	152:1	26.7:1	4050:1
		Peak	109:1	25.4:1	2760:1
2000	Summer	Average	84:1	93.2:1	7800:1
		Peak	62:1	76.3:1	4720:1
	Winter	Average	152:1	58.5:1	8870:1
		Peak	109:1	55.9:1	6070:1

TABLE 3-7
TOTAL DILUTIONS
SATELLITE CHANNEL

Distance from Diffuser (m)	Season	Flow	Dispersion Dilution	Decay Dilution	Subsequent Dilution
1000	Summer	Average	105:1	12.7:1	1330:1
		Peak	76:1	11.4:1	860:1
	Winter	Average	152:1	10.7:1	1630:1
		Peak	109:1	10.4:1	1130:1
2000	Summer	Average	105:1	76.3:1	7980:1
		Peak	76:1	62.4:1	4710:1
	Winter	Average	152:1	59.4:1	9040:1
		Peak	109:1	55.9:1	6090:1
3000	Summer	Average	105:1	345:1	36,120:1
		Peak	76:1	271:1	20,460:1
	Winter	Average	152:1	254:1	38,590:1
		Peak	109:1	242:1	26,350:1
4000	Summer	Average	105:1	1370:1	143,300:1
		Peak	76:1	1012:1	76,410:1
	Winter	Average	152:1	944:1	143,550:1
		Peak	109:1	901:1	98,120:1

3.4 Fecal Coliform Concentrations

The Waste Management Branch Pollution Control Objectives require a maximum 200 MPN/100 mL and 14 MPN/100 mL fecal coliform concentrations in the waters of Cowichan Bay and Satellite Channel to satisfy recreational and shellfish requirements respectively. The normal range of fecal coliform organisms in wastewater is typically:

	Fecal Coliform MPN/100 mL
Raw Sewage	2,000,000 to 6,000,000
Primary Treatment	200,000 to 600,000
Secondary Treatment	20,000 to 60,000
Secondary Treatment (with disinfection)	0 to 600

For the proposed effluent discharge locations in Cowichan Bay and in Satellite Channel the calculated fecal coliform concentrations for an effluent seawater mixture are as shown in Tables 3-8 and 3-9. The case considered is for secondary treatment without disinfection which is the minimum allowable by the Waste Management Branch.

TABLE 3-8
CALCULATED FECAL COLIFORM CONCENTRATION (MPN/100 mL
COWICHAN BAY

Distance from Diffuser (m)	Season	Flow	Total Dilution	Concentration
500	Summer	Average	370:1	54 to 162
		Peak	250:1	80 to 240
	Winter	Average	530:1	38 to 113
		Peak	360:1	56 to 167
1000	Summer	Average	1220:1	16 to 49
		Peak	790:1	25 to 76
	Winter	Average	1610:1	12 to 37
		Peak	1130:1	18 to 53
1500	Summer	Average	3220:1	6 to 19
		Peak	2040:1	10 to 29
	Winter	Average	4050:1	5 to 15
		Peak	2760:1	7 to 22
2000	Summer	Average	7800:1	3 to 8
		Peak	4720:1	4 to 13
	Winter	Average	8870:1	2 to 7
		Peak	6070:1	3 to 10

TABLE 3-9
CALCULATED FECAL COLIFORM CONCENTRATION (MPN/100 mL)
SATELLITE CHANNEL

Distance from Diffuser (m)	Season	Flow	Total Dilution	Concentration
1000	Summer	Average	1330:1	15 to 45
		Peak	860:1	23 to 70
	Winter	Average	1630:1	12 to 37
		Peak	1130:1	18 to 53
2000	Summer	Average	7980:1	3 to 8
		Peak	4710:1	4 to 13
	Winter	Average	9040:1	2 to 7
		Peak	6090:1	3 to 10
3000	Summer	Average	36,120:1	<1 to 2
		Peak	20,460:1	<1 to 3
	Winter	Average	38,590:1	<1 to 2
		Peak	26,350:1	<1 to 2
4000	Summer	Average	143,300:1	<1
		Peak	76,410:1	<1
	Winter	Average	143,550:1	<1
		Peak	98,120:1	<1

- Cowichan Bay Discharge

The proposed location for this outfall has a discharge depth of 55 metres of water and is located 850 metres from shore. From Table 3-8 the recreational requirement of 200 MPN/100 mL is achievable at the shoreline during both summer and winter conditions for both average and peak flows. For average flows the shellfish requirement of 14 MPN/100 mL is calculated to be achieved within approximately 1430 m from the outfall terminus during summer conditions and within approximately 1310 m during winter conditions. For peak flows the shellfish requirement is calculated to be achieved within approximately 1700 metres from the outfall terminus during summer conditions and within approximately 1520 meters from this terminus during winter conditions.

- Satellite Channel Discharge

The proposed location for this outfall has a discharge depth of 55 metres of water and is located 1000 metres from shore. From Table 3-9, the recreational requirement of 200 MPN/100 mL is achievable at the shoreline during both summer and winter conditions. For average flows the shellfish requirement is achievable at approximately 1400 metres from the outfall terminus during summer and at approximately 1310 metres from the outfall terminus during winter. For peak flows the shellfish condition is achievable up to approximately 1680 metres from the outfall terminus during summer and up to approximately 1520 metres from the outfall terminus during winter.

3.5 Impact on Receiving Waters

Adequate treatment must be provided to ensure that an effluent dishcarge is non-toxic and that the long term impact will not cause harm to the receiving environment. The Province's objective of "zero pollution" recognizes that the natural environment is capable of assimilating effluent resulting from adequate treatment of municipal sewage. These principles should guide the planning for treatment and disposal of municpal sewage from the Duncan North Cowichan area.

For an effluent discharge to water, both the fisheries resource and the recreational users of the waters and shorelines need to be considered. No environmental studies have been undertaken at this conceptual design phase. However, the preliminary assessment which follows provides an indication of the impact that the effluent discharge will have on the receiving waters.

Fisheries and Oceans have provided a summary of the fisheries resources in the Cowichan Bay Area. These are illustrated on Figure 3-4. Within Cowichan Bay crab, oysters, and clams are harvested as a recreational activity. The waters off the south shoreline are frequented by salmon smolt. In Satellite Channel a commercial crab, scallop, shrimp, geoduck, salmon and rock fishery exists. Sport fisherman also take salmon and rockfish. Clams are located along the south shoreline.

Recreational uses include, fishing, boating, shellfish and crab harvesting and beachcombing.

The potential impact on fisheries and recreational water use can be quantified using tbe fecal coliform standards set by the Ministry of Environment. The effluent modelling provides an estimate of the fecal coliform concentrations at a 40,000 population development and under various conditions of flow (average, peak, summer, and winter).

The wastewater will undergo secondary treatment. Predicted effluent quality without disinfection is set out in Table 3-10.

TABLE 3-10
PREDICTED EFFLUENT QUALITY

Flow - Average (m^3/d) - Peak (m^3/d)	 18,000 40,300
BOD_5 - Average (mg/L) - Maximum (mg/L)	 20 45
SS - Average (mg/L) - Maximum (mg/L)	 20 60
Fecal Coliform - Range (MPN/100 mL)	 20,000 to 60,000

The BOD and SS loads will have negligible impact on the receiving waters.

MOE standards for shellfish are 14 fecal coliform/100 mL and for recreational water use are 200 fecal coliform/100mL.

The predicted concentrations of fecal coliform in the seawater following discharge and under worst case conditions of direct onshore movement are presented in Table 3-11.

TABLE 3-11
PREDICTED WORST CASE FECAL COLIFORM CONCENTRATIONS

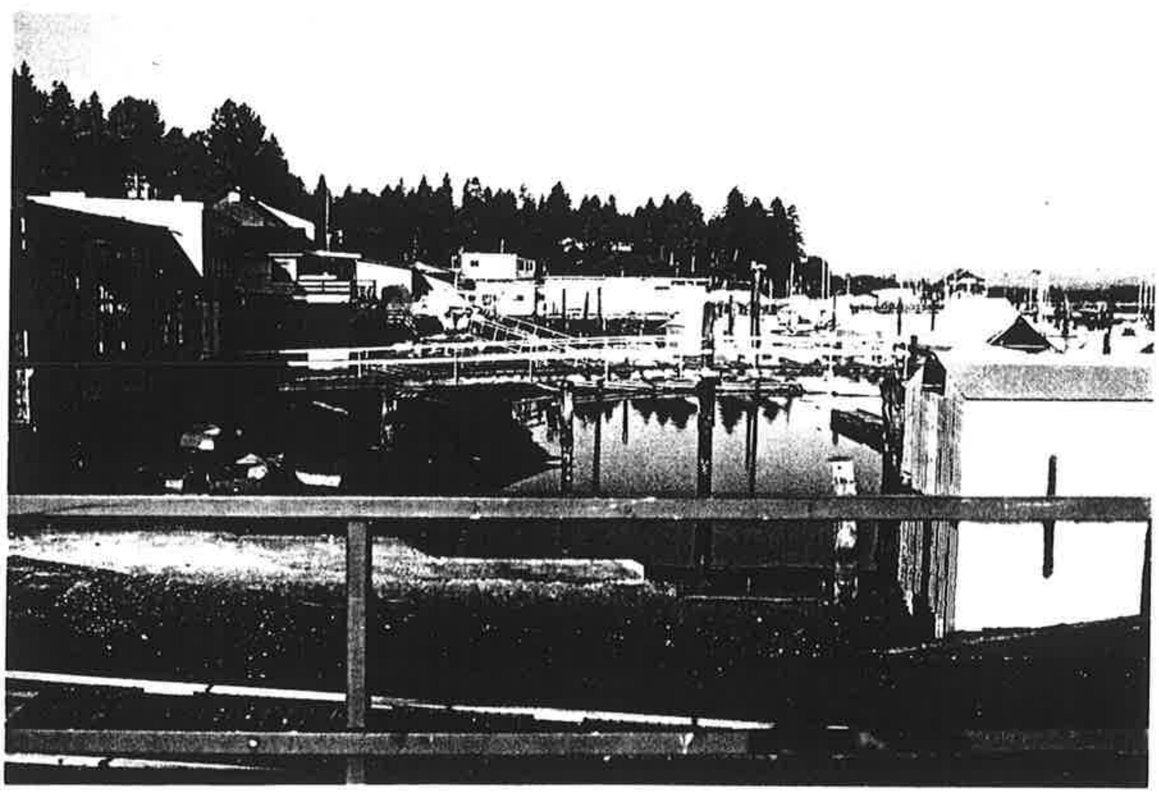
Discharge Location	Distance to Shore (m)	Flow Condition	Summer	Winter
Cowichan Bay	850	Average Peak	22-68 38-120	15-45 23-70
Satellite Channel	1000	Average Peak	15-45 23-70	12-37 18-53

Generally, the discharge at Satellite Channel is predicted to have slightly better effluent integration capacity than a discharge in Cowichan Bay.

In summer and winter and under both average and peak rates of flow, the recreational use criteria of 200 MPN/100 mL is estimated to be achieved for either discharge location without effleunt disinfection.

The shellfish criteria of 14 MPN/100 mL however, is estimated to be slightly exceeded under both average and peak conditions of flow. With effluent disinfection, the fecal coliform concentrations would be reduced to easily meet the shellfish criteria.

HECATE PARK, LOOKING AT WESCAN CAUSEWAY, SEPT. 18/91, 4 FT. TIDE.



COWICHAN BAY VILLAGE, GOVERNMENT WHARF, LOOKING WEST, SEPT. 18/91, 4 FT. TIDE.

DAYTON & KNIGHT LTD.
Consulting Engineers
DWG. NO. 244.5

FIGURE 3-1

COWICHAN BAY VILLAGE, GOVERNMENT WHARF, LOOKING EAST,
SEPT. 18/91, 4 FT. TIDE, COBBLE BEACH.

APPROXIMATELY 1 KM. WEST OF CHERRY POINT MARINA, LOOKING WEST,
SEPT. 18/91, 4 FT. TIDE, COBBLE BEACH.

FIGURE 3-2

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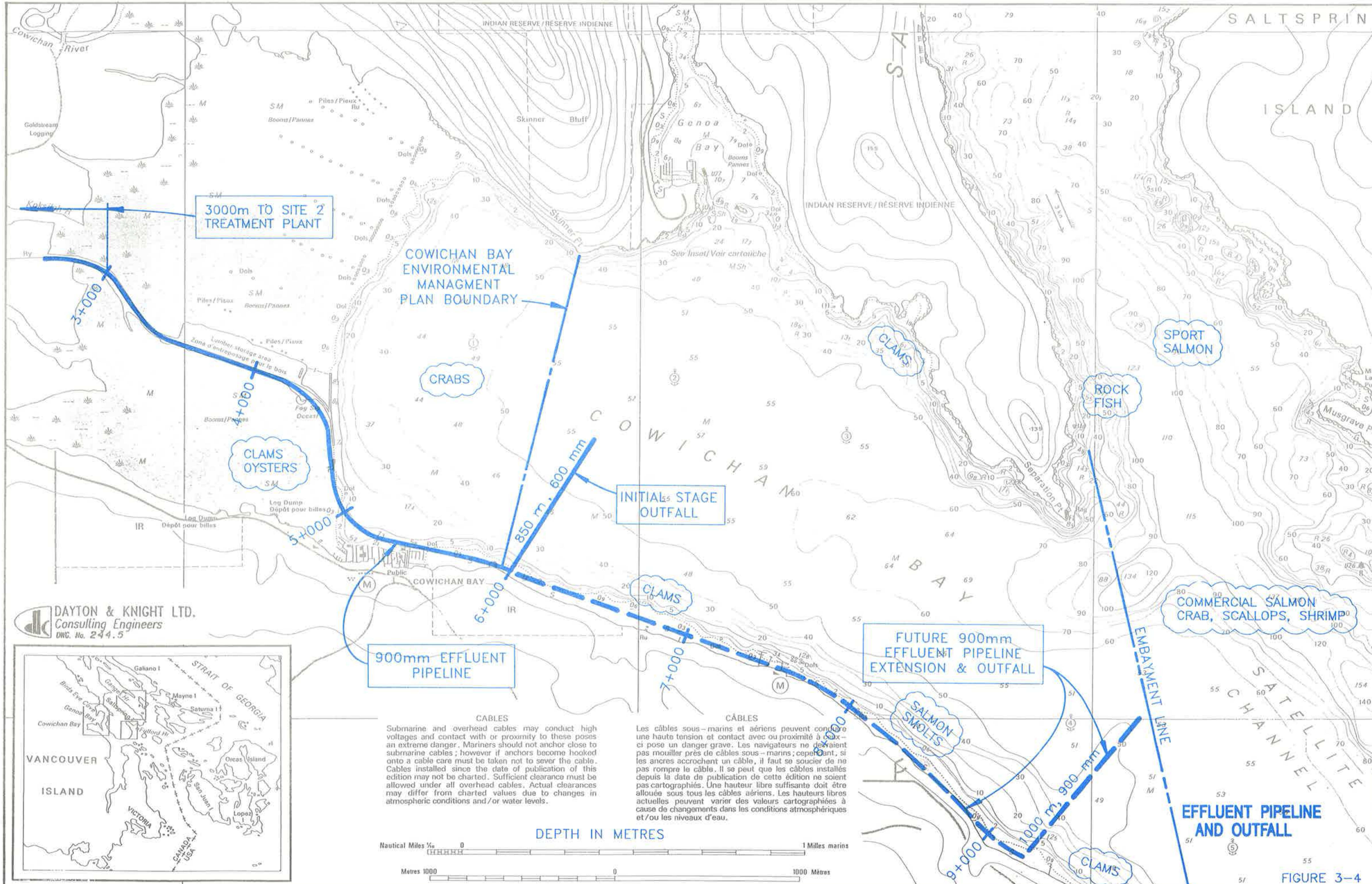
LOOKING WEST AT CHERRY POINT MARINA,
SEPT. 18/91, 5 FT. TIDE, COBBLE AND SAND BEACH.

APPROXIMATELY 1 KM. EAST OF CHERRY POINT MARINA, LOOKING EAST,
SEPT. 18/91, 5 FT. TIDE, COBBLE BEACH.

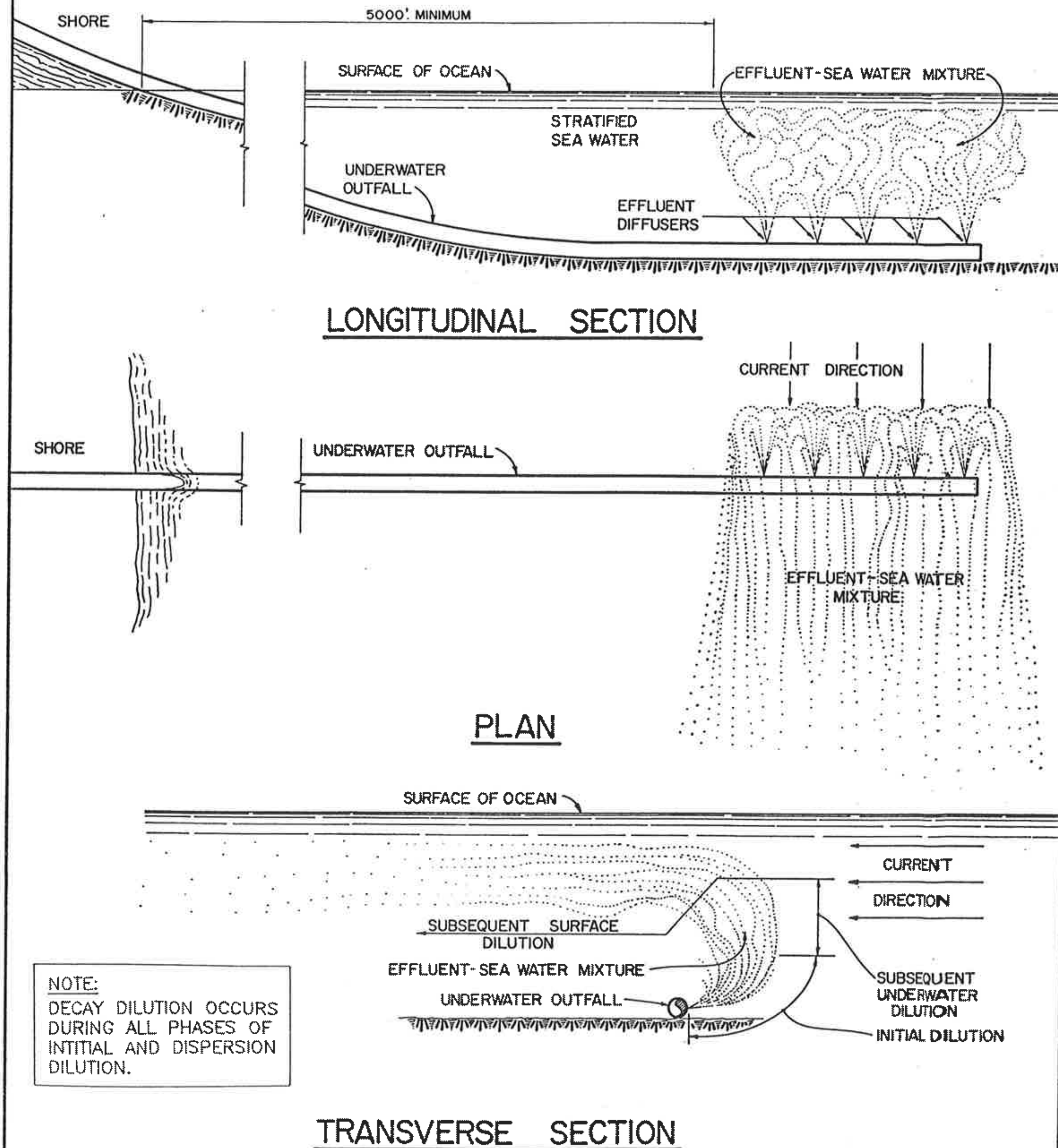
DAYTON & KNIGHT LTD.
Consulting Engineers
DWG. NO. 244.5

FIGURE 3–3



EFFLUENT PIPELINE AND OUTFALL

FIGURE 3-4



PATTERN OF EFFLUENT DILUTION FOLLOWING OCEAN DISCHARGE

DWG. No. 244.5

FIGURE 3—5

4.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A summary of the study findings followed by conclusions and recommendations are set out in this Chapter.

4.1 Summary

1. The Board currently provides aerated lagoon treatment for about 18,000 people located in the City of Duncan, southern portion of North Cowichan, the Eagle Heights area in the Regional District and the Boys Road subdivision within the Cowichan Indian Reserve.

2. Previous studies have identified the desirability for the Joint Utilities Board to discontinue its effluent discharge to the Cowichan River and to relocate the discharge into marine waters in the vicinity of Satellite Channel at the mouth of Cowichan Bay.

3. The objective of this study is to provide a preliminary assessment of the impact of effluent disposal at the mouth of Cowichan Bay.

4. Oceanographic studies were carried out in September 1991 near the mid point within Cowichan Bay and at Satellite Channel.

5. Circulation patterns are complex in Satellite channel with eddies forming on both flood and ebb tides. A less complex estuarine flow exists within Cowichan Bay. Back eddies at Separation Point cause the surface waters to flow out of Cowichan Bay along the south shore on an ebb tide.

6. With respect to a possible discharge of effluent the following generalized conclusions are drawn.

- For a discharge in the middle of Cowichan Bay, flood currents will direct the effluent field towards the bead of the bay and on an ebb tide effluent will be directed along the south shore toward the mouth of the Bay.

- For a discharge at the mouth of the Bay, flood currents will be primarily into the Bay with a fraction into Sansum Narrows. On the ebb tide, effluent will be directed either into Satellite Channel or into a back eddy off Cherry Point.

7. In September 1991, the water column was stratified under both ebb and flood conditions and both within Cowichan Bay and in Satellite Channel. This means an effluent discharge will remain trapped below the water surface.

8. Two possible outfall locations were investigated.

- Cowichan Bay just outside the Environmental Management Plan boundary in 55 m of water.

- Satellite Channel in 55 m of water.

9. Previous studies (Ref. 2) identified a possible future treatment plant site (Island Highway and CN Rail R/W) which was referred to as Site 2.

10. B.C. Environment bave recommended the Wescon causeway and the south shore of Cowichan Bay for an outfall alignment. This alignment was inspected at low tide on September 18/91 and was found to be feasible for construction of a pipeline.

11. The pipeline should be designed to initially convey effluent from the existing lagoons and in the future he suited for conveying effluent from a new treatment plant at Site 2 or alternatively act as a forcemain to convey raw sewage to a Regional plant site in the Cherry to Hatch Point area. The optimum pipeline size is 900 mm (36 in.) which provides for service to 100,000 people.

12. An initial stage discharge in Cowichan Bay just seaward of the Cowichan Estuary Plan houndary is estimated to cost $5,839,000.

13. Extending the pipeline to the emhayment line at Satellite Channel will increase the project cost to an estimated $8,933,000.

14. Dilution modelling at the possihle discharge locations showed slightly hetter effluent integration characteristics at Satellite Channel compared with Cowichan Bay. Fecal coliform ohjectives for recreational water use (200 MPN/100 mL) can he achieved at both locations without effluent disinfection. The shellfish fecal coliform ohjective (14 MPN/100 mL) is slightly exceeded at hoth locations without effluent disinfection. Effluent disinfection would reduce coliform levels to easily comply with the shellfish ohjectives.

4.2 Conclusions and Recommendations

The preliminary oceanographic studies and outfall dilution modelling indicate that either of the investigated discharge locations appear to offer suitahle characteristics for effluent integration into the receiving waters. A pipeline alignment along the Wescan causeway and south shore of Cowichan Bay is technically feasihle.

The following recommendations are made:

1. The Joint Utilities Board should select a treatment plant site for its long term needs (50 to 100 years). A site that also serves the southern portion of the Regional District should be considered.

2. If the Board accepts the concept of an expanded treatment and disposal role, then treatment plant site selection should be undertaken following additional oceanographic studies which determine the optimum discharge location (well flushed marine waters) that can best serve the long term needs of the area as a whole. Additionally, overall sewerage planning will be needed to conceptually develop the optimum layout of sewage conveyance facilities.

3. To provide the necessary concept level of planning, the Board should define with the Regional District a service area and then a Liquid Waste Management Plan should be undertaken for the service area. Treatment plant site selection should await the outcome of the Liquid Waste Management Plan process.

DUNCAN NORTH COWICHAN JOINT UTILITIES BOARD
COWICHAN BAY
OCEANOGRAPHIC AND EFFLUENT DiSPOSAL STUDIES

REFERENCES

(1) Dayton & Knight Ltd., Report to Duncan North Cowichan Joint Utilities Board on **Review of Sewage Treatment and Disposal Options**, February, 1989.

(2) Dayton & Knight Ltd., Duncan North Cowichan Joint Utilities Board, **Pre-Design Study for Trunk Sewer Routing and Treatment Plant Siting**, October, 1991.

(3) Province of British Columbia, **Pollution Controi Objectives for Municipal Type Waste Discharges**, September, 1975.

(4) E. Warnock, Director, Vancouver Island Region, letter to Mr. J. MacKay, District of North Cowichan, June 17, 1991.

(5) Institute of Ocean Sciences, letter received from Dario Succhi dated February 20, 1992 enclosing temperature, salinity and density data in Satellite Channel near Cowichan Bay.

DUNCAN NORTH COWICHAN JOINT UTILITIES BOARD
COWICHAN BAY
OCEANOGRAPHIC AND EFFLUENT DISPOSAL STUDIES

APPENDIX 1

A PHYSICAL OCEANOGRAPHIC STUDY REPORT
AXYS ENVIRONMENTAL CONSULTING LTD.
OCTOBER, 1991

and

LETTER OF JANUARY 9, 1992

AXYS | Axys Environmental Consulting Ltd

POST OFFICE BOX 2219, 2045 MILLS ROAD, SIDNEY, BRITISH COLUMBIA, CANADA V8L 3S8
TEL (604) 656-0881
FAX (604) 656-4511

9 January 1992 SKW.477

Brian Walker
Dayton & Knight Ltd.
626 Clyde Avenue
P.O. Box 91247
VANCOUVER, B.C.
V7V 3N9

Dear Brian:

This letter is a response to your fax of October 29, 1991 relating to the physical oceanographic study of Cowichan Bay. Accompanying this letter are some sketches of our interpretation of surface tidal current streams in the Cowichan Bay area compiled from our study, the "Narayanan, 1981" study, and the CHS Current Atlas, 1987. I believe these will help in understanding the surface circulation pattems in the Cowichan Bay area.

1. If a discharge is located at the middle of the bay off the marina, flood currents will direct effluent to the head of the bay.

2. If a discharge is extended to the mouth of the bay on the south side on a flood tide, the effluent will be directed mostly into the bay, but partially into Sansum Narrows. On an ebb tide, the fate of effluent will depend on the type of tidal current which is prevailing out of Saanich Inlet. During times in which the tidal currents from Saanich are flowing northward into Satellite Channel, it appears the fate of effluent would either be into a gyre, south of Musgrave Rock, which rotates counterclockwise, or toward Boatswain Bank. During times in which the tidal currents from Saanich Inlet are flowing eastward into satellite Channel, the fate of effluent would be toward Boatswain Bank and then either into Saanich Inlet or Satellite Channel.

3. For Cowichan Bay it is still unclear what the total net flow of water would be. For surface water it is out of the bay on the south side, since there is a constant input of freshwater at the head of the bay as a result of an eddy that circulates clockwise south of Separation Point during an ebb tide. These inputs must be mass balanced by (1) an inflow below the freshwater layer (i.e., estuarine circulation), and (2) a flow out on the south side of the head of the bay to mass balance the flow in at the middle. From our CTD casts this estuarine and eddy

circulation appears to be prevalent from the surface down to 10-20 meters depth.

Below 20 meters the circulation appears to be primarily tidal, flowing into the bay during flood tide and out of the bay during ebb tide. We cannot say what the net flow would be below 20 meters since current measurements have not been taken in this region.

4. With respect to mixing for a discharge of effluent at the mouth of the bay on the south side, certainly from the surface to about 20 meters depth there is a mixing occurring. Below 20 meters, currents velocities are probably lower and mixing would be poorer. With regard as to whether or not mixing is reasonably good or not, this is an engineering question which depends on the size of the outfall, rate and amount of discharge, number of diffusers, etc., and we would therefore refer you to your own people (e.g., John Boyle) to answer this question.

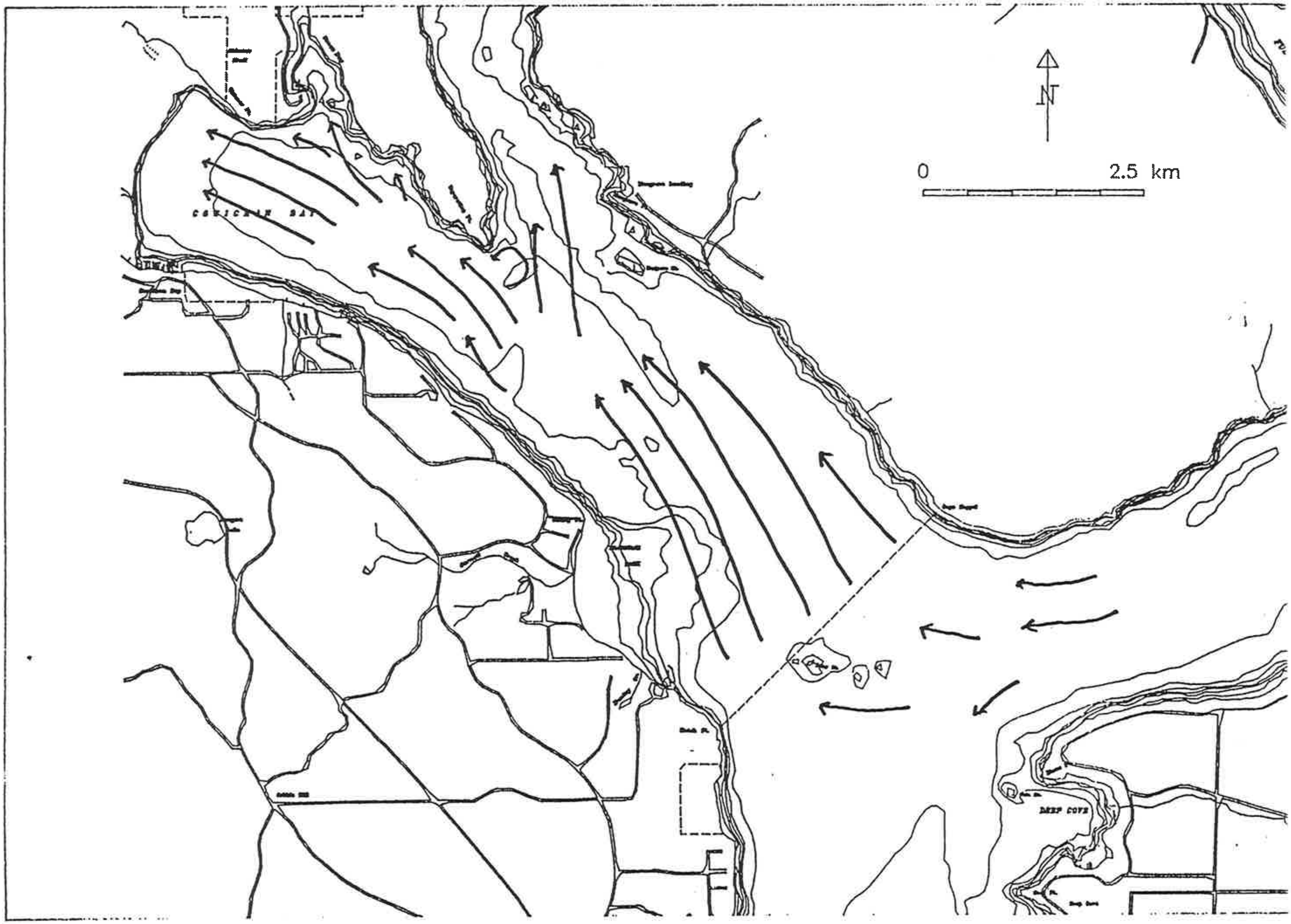
In conclusion, our study has determined surface (0-20 m) circulation patterns which exist in the Cowichan Bay area, but has not determined the deeper circulation patterns. To determine deeper water circulation, we would recommend the deployment of recording current meters for at least one month at your proposed site. For Cowichan Bay we would recommend a current meter mooring of three (3) current meters placed vertically at about 10, 30 and 40 meters depth. Data from the current meters would be analyzed to determine net flow at your proposed site. At some period during the period of current meter deployment, drogue studies which encompass both ebb and flood tides should be carried out with drogue sails positioned at the current meter depths. The drogue study would determine the fate of effluent discharged from your proposed site.

If you have any further questions, please call us.

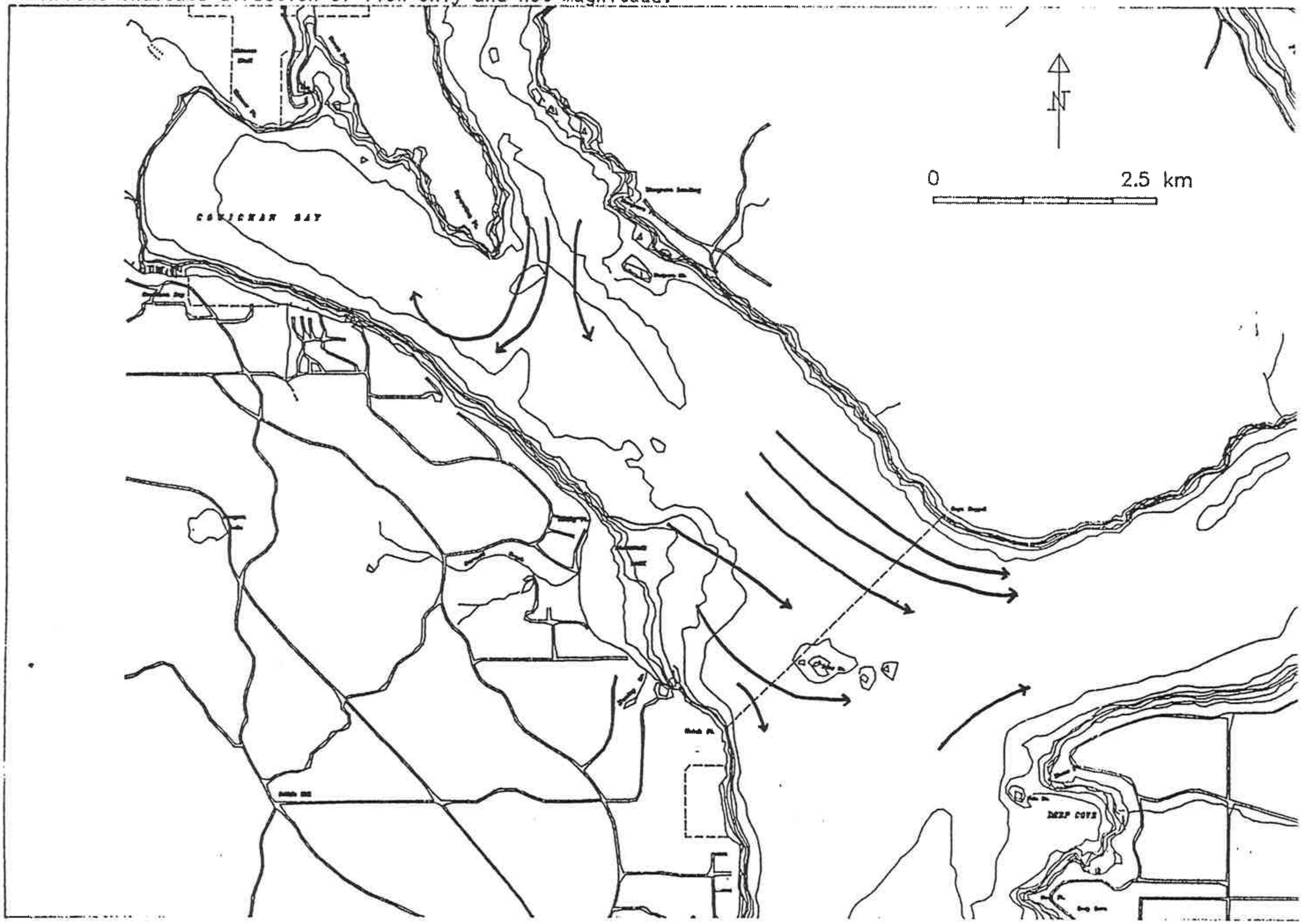
Sincerely,
AXYS ENVIRONMENTAL CONSULTING LTD.

Randolph K. Kashino, B.Sc., R.P.Bio.

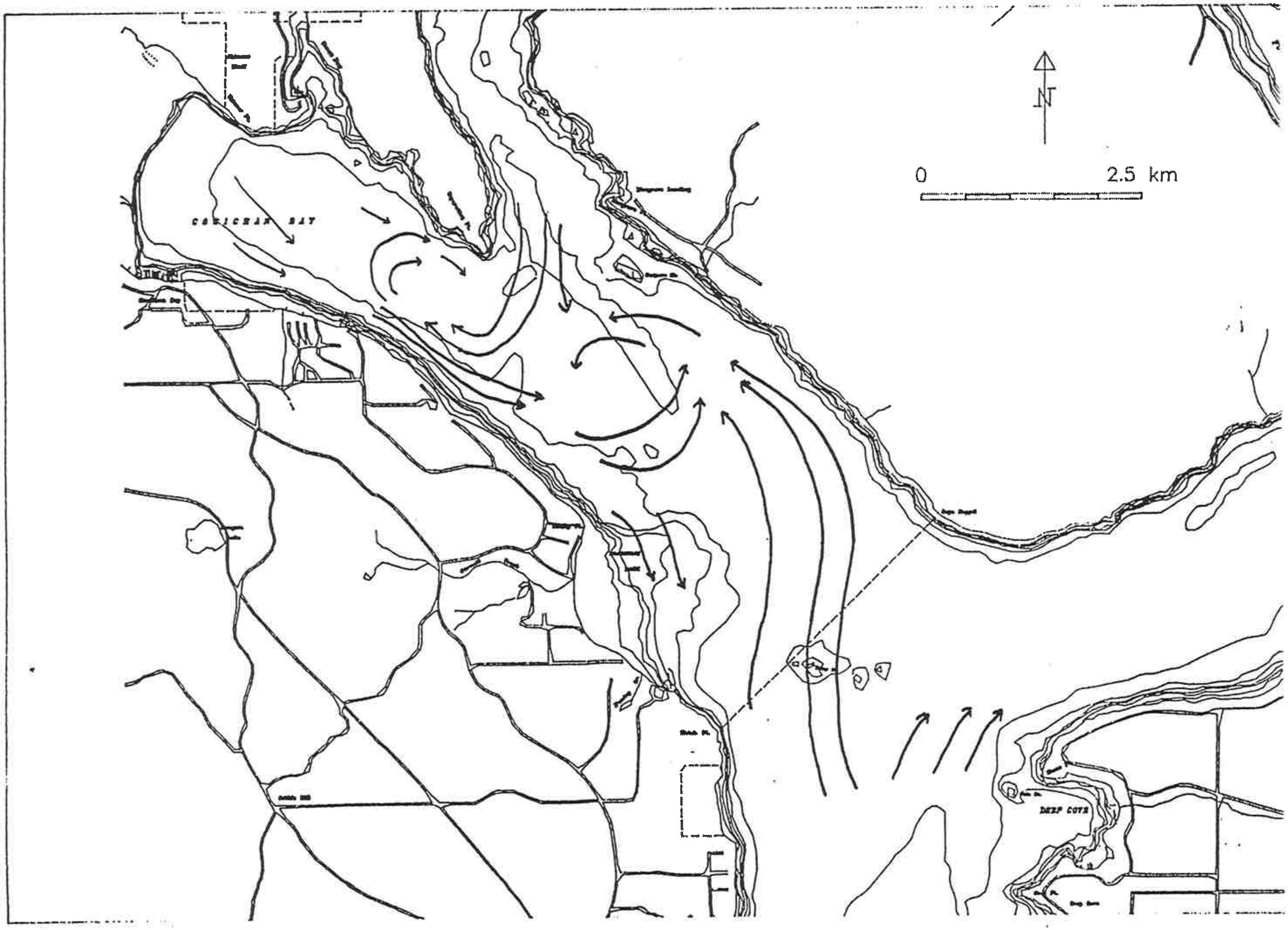
Interpretation of tidal streams during flood tide.
Arrows indicate directions of flow only and not magnitude.



Interpretation of tidal streams during ebb tide during times in which the ebb current from Saanich Inlet flows east into Satellite Channel.
Arrows indicate direction of flow only and not magnitude.

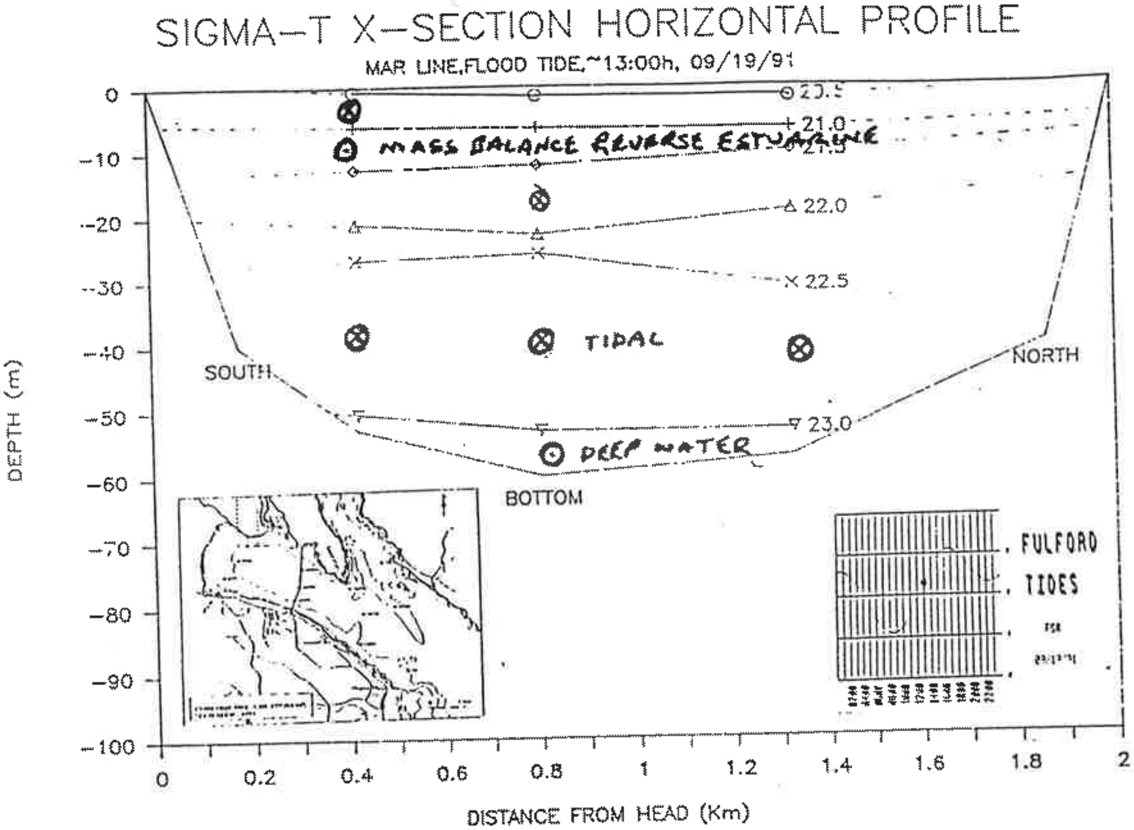


Interpretation of tidal streams during ebb tide during times in which the ebb currents from Saanich Inlet flow north into Satellite Channel.
Arrows indicate direction of flow only and not magnitude.



Interpretation of net flows at Marina cross section.
Magnitude is not indicated.

FIGURE 23.



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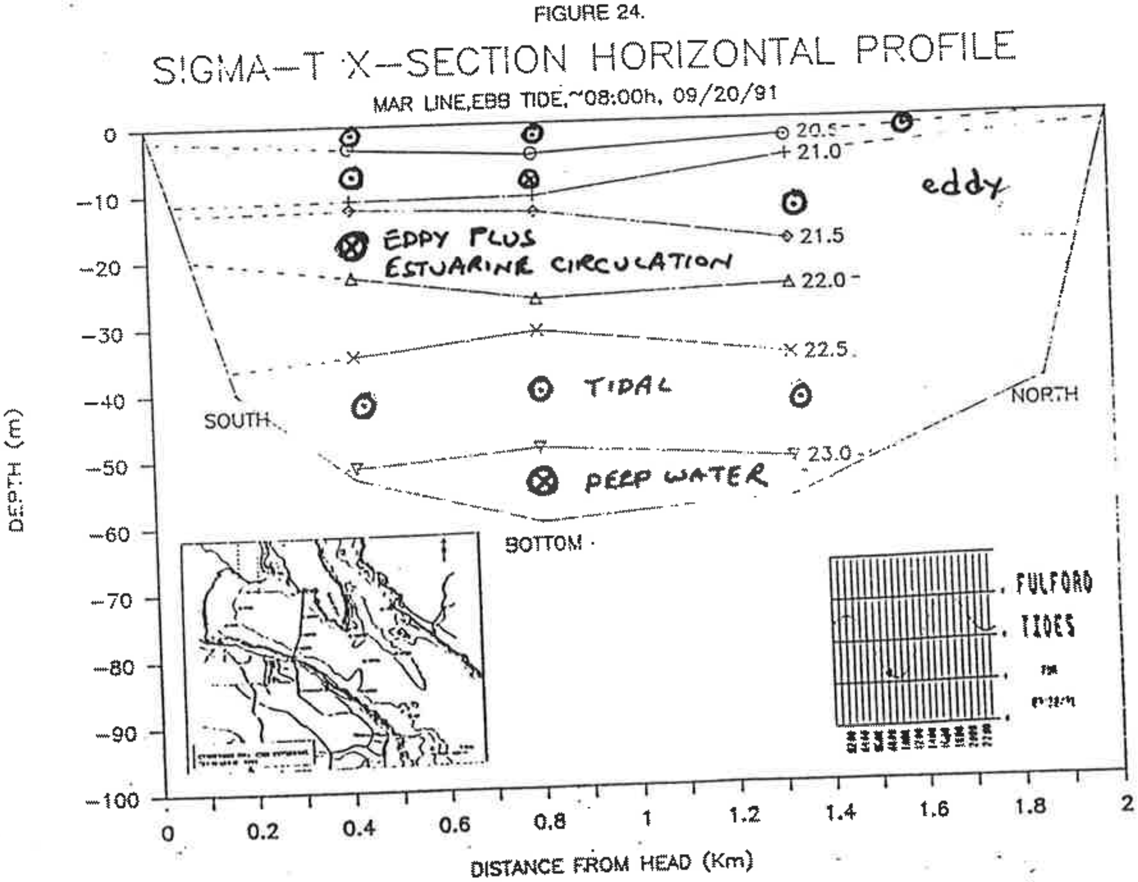
○ NO NET FLOW

FIGURE 24.



SKW-477

A PHYSICAL OCEANOGRAPHIC STUDY OF COWICHAN BAY, VANCOUVER ISLAND, BRITISH COLUMBIA.

Prepared For:

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Prepared By

Randolph K. Kashino, B.Sc., R.P.Bio.

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P.O. Box 2219, 2045 Mills Road
Sidney, British Columbia
Canada V8L 3S8

October 1991

TABLE OF CONTENTS

1.0 INTRODUCTION

From September 18 to 20,1991 Axys Environmental Consulting Ltd. (formerly Seakem Oceanography Ltd.) carried out three daily drogue (drifter buoy) studies in Cowichan Bay, B.C. for Dayton and Knight Ltd. The purpose of the study is to provide background oceanographic information for the location of a proposed marine outfall for sewerage water discharge for the Duncan-North Cowichan Joint Utilities Board.

Cowichan Bay is located north of Saanich Inlet at the confluence of Sansum Narrows and Satellite Channel (see Figure 1). The circulation of these three bodies of water along with the Cowichan and Koksilah Rivers and prevailing winds determine the circulation of Cowichan Bay.

Previous oceanographic studies which have been done in the area have been primarily concerned with circulation in the Satellite Channel-Saanich Inlet systems. These include Canadian Hydrographic Service (1966), Herlinveaux (1968), Coastal Zone Oceanography (1980), Byers (1980), and Narayanan (1981). The study by Narayanan (1981) was part of the Hatch Point Marine Environmental Assessment for Chevron Canada Ltd. which was submitted to the Federal Environmental Protection Service, the Habitat Protection Division of the Department of Fisheries and Oceans, and the Assessment Branch of the B.C. Ministry of Environment. The Narayanan (1981) study overlaps the Cowichan Bay study area and it will be referred to in this report. Much of the work that was done for the Hatch Point Marine Environmental Assessment is relevant to the Cowichan Bay area, however, the primary concern was directed toward the effects of possible oil spills. A separate biological oceanography study by Woods and Shaw (1981) was also carried out for the Hatch Point Marine Environmental Assessment. This author was part of that study which was an intensive study of the Boatswain Bank area which is considered to be the most environmentally sensitive area near Hatch Point. The Woods and Shaw (1981) report would be very relevant if an outfall is located near Cherry Point.

A review of environmental information for the Cowichan Bay area can also be found in a report by Bell and Kallman (1976), "The Cowichan-Chemainus River Estuaries, Status of Environmental Knowledge to 1975". This report includes information on geology, climatology, hydrology, water quality, oceanography, marine biology, fisheries, wildlife, land and water use, pollution and the effects of development in the area. However, the Bell and Kallman (1976) report concentrated primarily on the oceanography of the Stuart Channel area and has very little on Cowichan Bay. Inasmuchas there have been these previous studies in the area there is very little information on the actual circulation patterns within Cowichan Bay itself. This study attempts to further define the circulation of Cowichan Bay.

2.0 SURFACE AND DEEP CURRENTS

To study water circulation patterns in Cowichan Bay a Lagrangian method by use of current following drogues (drifting buoys) was used. This is in contrast to Eularian methods which use moored current meters.

2.1 Drogue Studies

For this study Window Shade type drogues were deployed in the study area near proposed outfall discharge locations. Two types of drogues were deployed to study shallow water and deep water circulation. Shallow water drogues had 2 m by 2 m sails which were positioned at the surface, and deep water drogues had 3 m by 2 m sails which were positioned at 10 m depth (see Appendix II for typical window shade drogue configuration). For each day of the study, 5 shallow and 5 deep drogues were deployed at initial positions which were at even distances from and perpendicular to the south shore of Cowichan Bay. Drogues were then positioned at approximately hourly intervals by use of horizontal sextant angles. When drogues drifted out of the study area they were recovered and redeployed at points along the initial alignment.

2.1.1 Results

Drogue tracks plots for each day of this study were separated into shallow and deep drogues and then morning and afternoon tracks. These are shown in Figures 3 to 14. Time of drogue positions plotted are Pacific Daylight Time. The accompanying tide graph is also in Pacific Daylight Time. Morning drogue tracks are ebb tidal currents turning to flood. Afternoon drogue tracks are mainly flood tidal currents, but some flood currents turning to ebb were measured. Resulting current velocities were calculated from drogue movements and can be found in Appendix I.

Current velocity statistics derived from drogue movements for each day can be found in Table 3. Average currents for this study did not exceed 35 cm/s (0.7 knots). The maximum surface current measured was on September 19, 1991 at 130.9 cm/s (2.5 knots). The maximum 10 m current measured was on September 18, 1991 at 81.0 cm/s (1.6 knots).

Figures 3, 4, 5 and 6 are drogues tracks for September 18, 1991 for which the major study area was the mouth of Cowichan Bay near Cherry Point. Figures 3 and 5 are surface and 10 m drogue tracks, respectively, which correspond to currents from the end of an ebb tide to the beginning of flood tide. Figures 4 and 6 are surface and 10 m drogue tracks, respectively, for a flood tide to the beginning of an ebb tide. Figure 3 demonstrates that a complex circulation pattern exists at the mouth of Cowichan Bay. The general pattern seems to indicate two eddies, one about 1 km south of Separation Point which rotates clockwise, and another about 1.5 km north of Cherry Point which rotates counter-clockwise. Figure 4 shows that during a flood tide there is a persistence of a clockwise eddy at the centre of the mouth of Cowichan Bay about 1.5 km south-south east of Separation Point. Figures 5 and 6, which show the 10 m deep drogue tracks for the same period as the surface drogues, indicate a 3 eddy system. One eddy south of Separation Point correlates with the surface eddy but rotates counter-clockwise. Another eddy about 1.5 km northeast of Cherry Point also correlates with the surface eddy in the area and also rotates clockwise. There appears also to be a smaller counter-clockwise eddy just northeast of Cherry Point about 1 km which is probably a flood tide back-eddy caused by Boatswain Bank.

Figures 7, 8, 9 and 10 are drogues tracks for September 19, 1991 for which the major study area was the centre of Cowichan Bay off the marina on the south shore. Figures 7 and 9 are surface and 10 m drogue tracks, respectively, which correspond to currents of an ebb tide to the turning of flood tide, and Figures 8 and 10 are, respectively, surface and 10 m drogue tracks for a flood tide to the beginning of an ebb tide. Figure 7 indicates that during an ebb tide there is an eddy centred about 1.5 km south west of Separation Point which rotates clockwise and appears to shift position and reverse as the flood tide begins. Figure 8 demonstrates a normal flood tide current regime as full flood tide current sets up. This indicates that within Cowichan Bay, from about the Marina, a less complex, more typical circulation pattern for an estuarine bay exists. Figure 9 indicates that at 10 m depth there is an eddy during an ebb south of Separation Point which follows the surface current eddy. On the south side of Cowichan Bay near the marina, 10 m deep water moves in toward the head of the bay. This is a movement typical of estuarine circulation patterns. As the flood tide becomes dominant, 10 m water at the mouth of the bay begins to flow into Sansum Narrows as indicated by the drogue positioned at 1218 and 1329. Figure 10 indicates that 10 m deep flood tide waters appear to originate along the southern half of Cowichan Bay and spread out toward the northwest and into the head of the bay.

Figures 11, 12, 13 and 14 are drogues tracks for September 20, 1991 for which the major study area was again the centre of Cowichan Bay off the marina on the south shore. Figures 11 and 13 are, respectively, surface and 10 m drogue tracks which correspond to currents of an ebb tide to the turning of flood tide, and Figures 13 and 14 are, respectively, surface and 10 m drogue tracks for a flood tide. Figure 11 again shows that during an ebb tide there is a clockwise eddy at the mouth of Cowichan Bay south west of Separation Point. Also demonstrated is a 1/2 km wide outflow counter current which hugs the south shore of Cowichan Bay. Figure 12 again shows that as the flood current sets up, the currents within the bay become typical. Figure 13 shows ebb tide current patterns which reflect typical estuarine circulation for the 10 m deep water and flow into the bay as the surface water flows out. This inward flow seems particularly strong on the south side of Cowichan Bay. Figure 14 shows that as the tide continues to flood the 10 m deep water first reverses its flow out of the bay as if to reverse estuarine circulation because surface fresh water is flowing back into the bay and then with the onset of full flood tide currents the 10 m deep water follows the surface flow.

Figures 15, 16 and 17 are some relevant surface drogue track results of the Hatch Point study done by Narayanan (1980). Figure 15 shows surface ebb currents from Sansum Narrows and show the same eddy south of Separation Point at the mouth of Cowichan Bay.

Figure 16 shows flood currents in Satellite Channel from Hatch Point Figure 17 shows "ebb" currents in Satellite Channel from Hatch Point. Figure 17 is enlightening because it shows that water ebbs from Saanich Inlet north into Satellite Channel and is forced along its eastern side. If Figure 15 is superimposed on Figure 17 to give a composite picture of ebb currents a complex system of eddy circulation must exist off the Cherry Point area and the Narayanan (1980) results are in agreement with this study.

2.2 Weather Measurements

During this study wind measurements were made using a hand held anemometer. Also during the study, for comparison the marine weather broadcasts were monitored to obtain recorded winds at Victoria International Airport which is the nearest permanent weather station that records winds. There is a climatological station in Cowichan Bay but winds are not recorded.

2.2.1 Results

Weather observations during each days drogue study are shown in Table 1. During the period of this study winds were light and variable not exceeding 8 knots and therefore had little effect on the ocean circulation occurring during the period of this study.

However as a general rule wind will cause surface currents at about 3% of the wind velocity, Thomson (1981). A 30 knot wind can therefore drive surfaces currents downwind at speeds exceeding 1 knot (51.4 cm/s) and a 15 knot wind will drive currents downwind at 1/2 knot (25.7 cm/s). In the Strait of Georgia area, according to the CHS British Columbia Coast (South Portion) Sailing Directions, "winds in excess of 34 knots occur on the average 3 or 4 times per month during the period October-March" and "in exposed areas sustained wind speeds of about 50 knots have been recorded on the rare occasions with peak gusts estimated at about 70 knots." These "gales accompany the more intense storms of winter, blowing southeast as the system approaches and veering to the west or northwest after its passage. Figure 18 shows the Wind Rose of Percentage Frequency and Mean Wind Speed by Direction for Victoria International Airport and indicates that winds in the area are primarily from the west or southeast. Since surface currents measured in Cowichan Bay from the drogue movements averaged less than 1 knot it can be expected that prevailing strong winds will strongly affect surface water circulation in Cowichan Bay. For example, if strong southeasterly winds prevail, then the surface water flow during an ebb tide will be stalled and a flood tide enhanced. If strong westerly winds prevail, then the surface water flow during an ebb will be enhanced and a flood tide stalled an even reversed the result of which may increase the estuarine circulation flows in Cowichan Bay. Climatological measurements of temperature and precipitation are available for Cowichan Bay and 1951-1980 average statistics for these are shown in Appendix III and are from the CHS Sailing Directions (1984).

2.2.2 River Discharges

Hydrological measurements for the Cowichan River have been taken and Figure 19 shows a typical Hydrograph from Bell and Kallman (1976). More stream flow information is available from the Water Survey of Canada. The discharges of the Cowichan River and the Koksilah River which flow into Cowichan Bay as stated by Bell and Kallman (1976) "exhibit the unique characteristics of Vancouver Island and coastal river systems. That is to say, the maximum flows occur during the winter months as the result of rainfall, instead of during the snow melt generated spring freshet of May through July, which is typical of rivers draining interior mainland basins."

The discharges of the Cowichan and Koksilah Rivers affect the circulation of Cowichan Bay as they are an integral part of estuarine circulation. The period of our study was at a low discharge period, therefore the estuarine circulation effect was at it lowest for the year. As winter approaches and rainfall increases the river discharges and therefore will increase estuarine circulation currents. River discharges for the Cowichan River in the winter could be as much as 160 times the summer discharges, as determined from values given by Bell and Kallman (1976). More typical values of winter discharge however are 15-20 times summer discharge, as determined from values given by Bell and Kallman (1976). Since estuarine circulations currents are an important part of currents in Cowichan Bay, winter patterns could be significantly different from the results of this study which was done at a period of low river discharge.

3.0 WATER STRUCTURE

3.1 Methods

During this study the water structure of Cowichan Bay was studied using a Seabird model SBE-19 CTD Profiler which records Conductivity,Temperature and Depth from which profiles of Salinity, Temperature and Water Density (as Sigma-t) are calculated. Sigma-t is simply defined as: (Density in g/cm ^ 3 minus 1) X 1000. Profiles were done at various locations to determine spatial variation in water structure and also at a common locations for different times to obtain temporal variation in water structure. By examination of temporal and spatial variation of water structure circulation patterns may be implied.

3.2 Results

Figure 2 shows the location of CTD stations occupied during this study and Table 2 is a summary of CTD casts which were done over the study period. Figures 25 to 50 are vertical profiles of Temperature, Salinity and Sigma-t of each cast done for each period with an accompanying tide graph which shows the phase of the tide at the time of the cast.

The vertical profiles show that there are four layers of water in Cowichan Bay. The first layer extends from the surface to about 5 m depth and varies in depth approximately plus or minus 3 m. The second layer extends from approximately 5 m depth to 20 m depth plus or minus 10 m. The third layer extends from approximately 20 m depth to near the bottom. The fourth layer is from the bottom to about 5 m above the bottom. Between each layer there are thermoclines and haloclines which result in pycnoclines that vary in thickness of from 1 to 10 m. Figures 51, 52 and 53 contrast vertical profiles at different tide phases for stations "COW1" and "MARM". These figures show that there is a strong stratification of layers during ebb tide and that on the flood stratifications become weaker. These figures also show that during ebb tides the second layer of water from ~5 to 20 m depth stratifies into two layers from ~5 m to ~10 m and from ~10 m to ~20-~30 m.

Figures 20, 21 and 22 are horizontal profiles of Sigma-t, Salinity and Temperature, respectively, through a longitudinal section of Cowichan Bay from the head to the Satellite Channel-Sansum Narrows confluence. These horizontal profiles show that, generally, salinity increases,temperature decreases and therefore sigma-t increases from the head of Cowichan Bay to Satellite Channel. This is typical for an estuary, however a detailed examination of the horizontal profiles show variations from a typical nature at depths between ~10 m and ~30 m.

Figures 23 and 24 are horizontal profiles of Sigma-t through a cross section of Cowichan Bay at our "MAR"(marina) line. These horizontal profile cross sections represent water structure during flood and ebb tidal phases respectively. These cross sections show that during an ebb tide the 21.0 sigma-t isopleth deepens on the south side of Cowichan Bay and shallows on the north side. The 21.5 sigma-t isopleth deepens on the north and remains at the same level on the south during and ebb tide. The 22.5 sigma-t isopleth slopes remain constant but deepens approximately 5 meters during an ebb tide. The 23.0 sigma-t isopleth shallows at the centre of the bay during an ebb tide.

The 21.0 sigma-t isopleth represents changes in the surface layer, the 21.5 sigma-t isopleth represents changes in the second stratification layer, the 22.5 sigma-t isopleth represents changes in the third stratification layer, and the 23.0 sigma-t isopleth represents changes in the bottom layer. These results indicate that during an ebb tide surface waters above the 21.0 sigma-t isopleth are flowing out primarily on the south side of Cowichan Bay and that below this indicated by the 21.5 sigma-t isopleth, ~10-20 m deep water is flowing into the bay on the south side. The shallowing of the 21.0 sigma-t isopleth and deepening of the 21.5 sigma-t isopleth on the north side is the signal of ~10-20 m deep water flowing out of Cowichan Bay as a result of the Separation Point eddy. The deepening of the 22.5 sigma-t isopleth during an ebb tide indicates that deep water flow in Cowichan Bay is primarily tidal, flowing into the bay during a flood and out of the bay during an ebb. The 23.0 sigma-t isopleth is a layer of deeper water intruding from Satellite Channel originating ultimately from Haro Strait.

The shallowing of the 23.0 sigma-t isopleth during an ebb tide may indicate that this bottom water is a mass balance response (like estuarine circulation) to the water above flowing out and therefore flows into the bay. Conversely during a flood tide the water flowing into the bay above the 23.0 sigma-t isopleth causes the bottom water to flow out of the bay.

4.0 CONCLUSIONS

The water circulation of Cowichan Bay is complex because of the influence of several oceanographic and topographic features unique to its location. An oceanographic phenomena which dominates the inner area of Cowichan Bay is "Estuarine Circulation". The outflow of freshwater from the Cowichan River at the head of Cowichan Bay on the surface must be replaced to conserve mass by an inflow of deeper saltier water. The freshwater outflow appears also to be under the influence of the Coriolis Effect and therefore tends to flow out on the south side of the bay. This estuarine circulation is however greatly modified by the more dominant oceanographic phenomena of "Tides" and the resulting tidal currents. The effect of tides on estuarine circulation in Cowichan Bay results in the distribution of the surface freshwater plume being changed at different phases of the tide. Results of this study indicate that during an ebb tide an estuarine circulation pattern is evident within Cowichan Bay and even enhanced by outflow tidal currents. On a flood tide this estuarine circulation appears to be stalled and then reversed with surface currents flowing into the bay and deeper (10 m) currents flowing out of the bay. This deeper outward flow is probably a combined effect due to two things:

1) the reversed freshwater flow at the surface causes a reversed estuarine circulation pattern;

2) the surface tidal flow in at the surface of the bay causes a backing up and thickening of the freshwater layer at the head of the bay.

The increased hydrostatic pressure at the head of the bay causes the deeper saltier water to be displaced, and therefore to flow out of the bay at the bottom. However, as flood currents increase the deeper (10 m) water again reverses direction to flood with surface waters.

The unique topography and geography of Cowichan Bay contributes to the complexity of circulation in the area. Two geographic features which effect Cowichan Bay circulation are: firstly, that it is a bay, the mouth of which joins the tidal channel of Sansum Narrows; and, secondly, Cowichan Bay is geographically positioned near the mouth of the Saanich Inlet Fjord. Both Sansum Narrows and Saanich Inlet affect the circulation of Cowichan Bay.

Two topographic features which affect the circulation of Cowichan Bay are Separation Point on the north side of the mouth of Cowichan Bay and Boatswain Bank on the south side of the mouth of Cowichan Bay. NOTE: Separation Point back-eddy on ebb/Boatswain Bank eddy on flood.

As a result, during ebb tide water flowing out of Sansum Narrows and out of Saanich Inlet into Satellite Channel causes a clockwise eddy in Cowichan Bay at its mouth southwest of Separation Point. A second eddy appears to exist north east of Cherry Point and rotates counter-clockwise. The outflow of fresher water from the head of Cowichan Bay hugs the south shore at its mouth. Along the south side of outer Cowichan Bay and at its head, estuarine circulation prevails and deeper ~10-20 m water flows in on the south side. On the north side the Separation Point eddy prevails and the deeper ~10-20 m water flows out.

During a flood tide the Separation Point clockwise eddy shifts east and may break up into smaller eddies. A small counter-clockwise eddy appears near Cherry Point and is probably a back eddy as a result of Boatswain Bank. Flood waters flow in on the south side of outer Cowichan Bay and spread toward the northwest. Deeper ~10-20 m waters during a flood appear at first to reverse in response to a reversal of surface waters but then, as flood currents increase, the deeper water floods also.

The water structure changes of deeper ~20 m to 50 m water indicate that flows are typically tidal in nature flooding into and ebbing out of Cowichan Bay. The bottom water ~50 m to bottom is an intrusion of water from Satellite Channel which originates from Haro Strait and appears to respond in a mass balance manner, similar to estuarine circulation, and flows into Cowichan Bay when the water above is ebbing out, and flows out of Cowichan Bay when the water above is flooding in.

Since this study was done during a period of low river discharge into Cowichan Bay estuarine circulation currents were probably at there weakest. Winter estuarine circulation currents will be stronger and could significantly modify current pattems observed during this study. A winter study could determine these patterns.

Deep water, 30 m to bottom, flow has been implied from water structure measurements and are probably dominated by tidal components. Long term eularian measurements by current meters could determine deep water current strengths and net flow.

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FIGURES AND TABLES

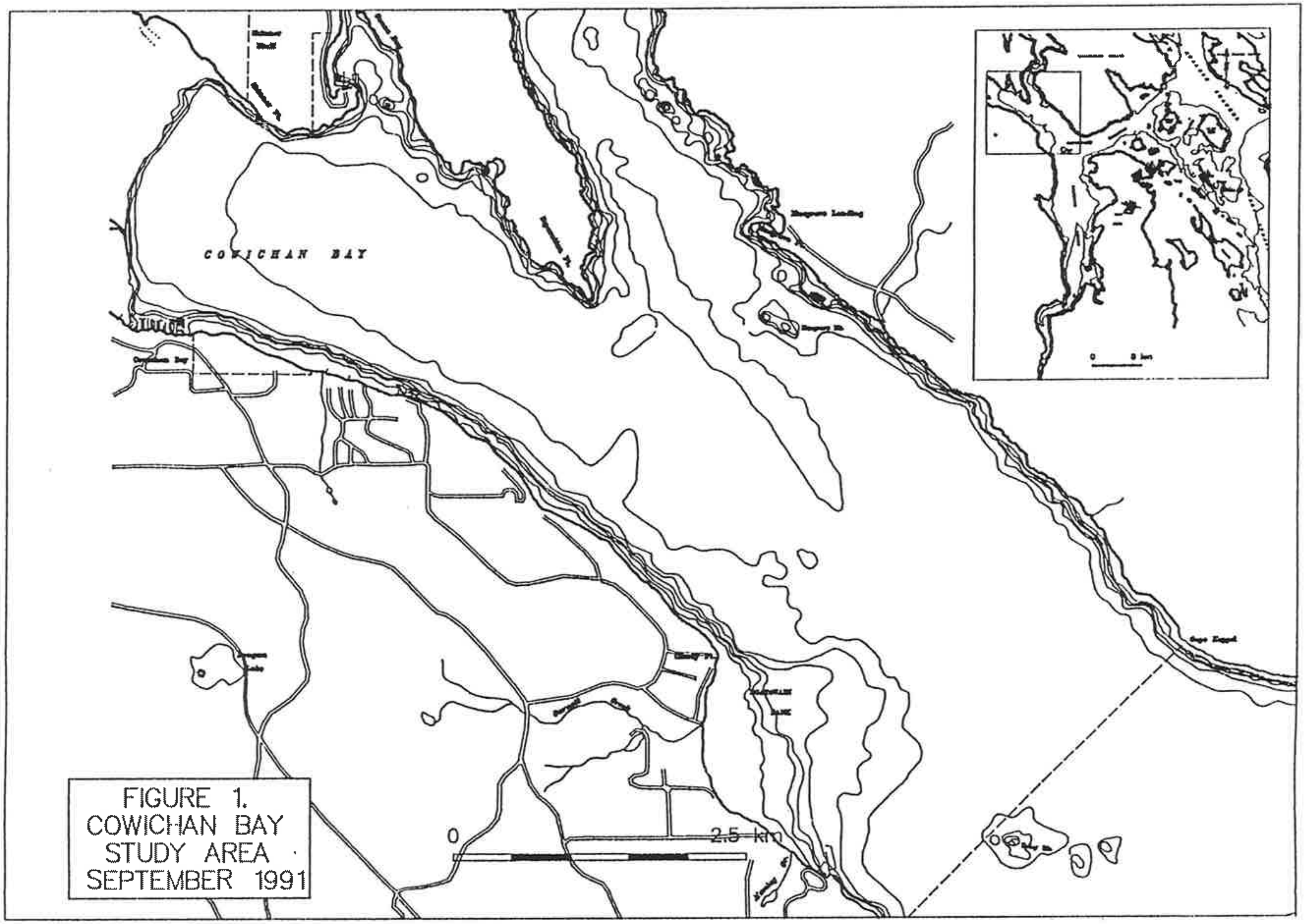


FIGURE 1.
COWICHAN BAY
STUDY AREA
SEPTEMBER 1991

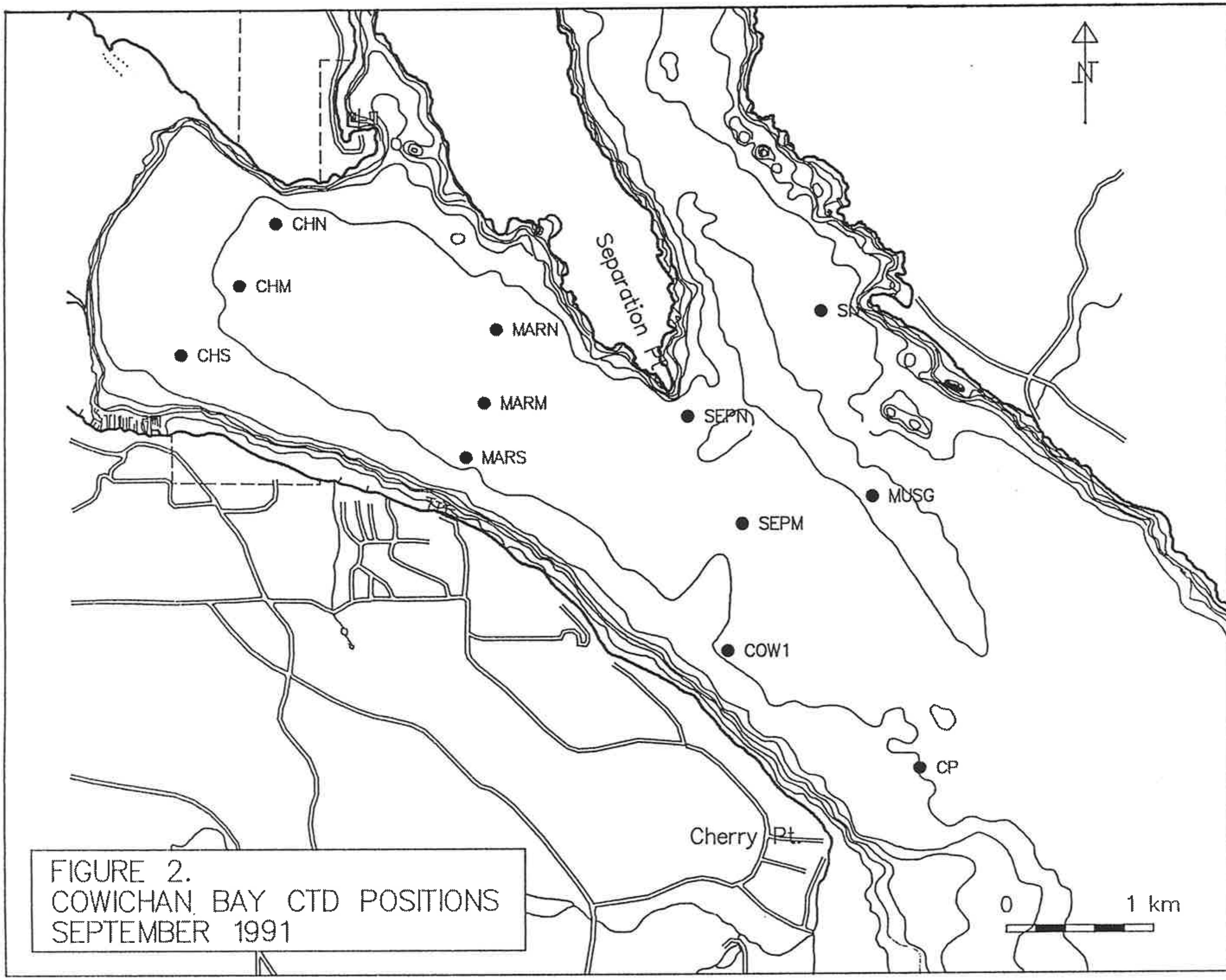


FIGURE 2.
COWICHAN BAY CTD POSITIONS
SEPTEMBER 1991

TABLE 1: COWICHAN BAY DROGUE STUDY WEATHER OBSERVATIONS

DATE / TIME	SPEED (knots)	DIRECTION	REMARKS	
SEPT. 18/91				
0759	6	NW	water calm	
0800	4	W	Victoria Airport	
0915	7.5	NW		
1001	0	-	water calm	
1241	0	-	water rippled	
1320	0	-		
1320	4	NW	Victoria Airport	
1424	5	SW		
SEPT. 19/91				
0817	0	-	water rippled	
0833	6	NW		
1059	6	SE	water rippled	
1302	7	SE		
1402	8	SE		
1643	6	SE		
SEPT. 20/91				
0650	0	-	water calm, high clouds with some fog banks	
0805	0	-		
1045	8	SE		
1415	6	SE		
1457	8	SE	Victoria Airport	
1730	6	SE		

TABLE 2: COWICHAN BAY CTD CASTS SEPTEMBER 1991			
DATE / TIME	CTD CASTS	REMARKS	
SEPT. 18/91			
950	COW1A	Cherry Point, Cast 1	
1003	SEPM1	Separation Point Middle, Cast 1	
1015	SEPN1	Separation Point North, Cast 1	
1020	MUSG1	Musgrave Rock, Cast 1	
1027	MARM1	Marina Middle, Cast 1	
1036	CHM1	Cowichan Head Middle, Cast 1	
1230	CP1	Satellite Channel, Cast 1	
1600	COW1B	Cherry Point, Cast 2	
SEPT. 19/91			
912	SEPN2	Separation Point North, Cast 2	
924	SEPM2	Separation Point Middle, Cast 2	
930	COW1C	Cherry Point, Cast 3	
1011	MARM2	Marina Middle, Cast 2	
1240	MARS1	Marina South, Cast 1	
1249	MARM3	Marina Middle, Cast 3	
1257	MARN1	Marina North, Cast 1	
SEPT. 20/91			
805	MARM4	Marina Middle, Cast 4	
813	MARS2	Marina South, Cast 2	
820	MARN2	Marina North, Cast 2	
1045	CHM2	Cowichan Head Middle, Cast 2	
1137	SN1	Sansum Narrows, Cast 1	
1227	SEPN3	Separation Point North, Cast 3	
1233	SEPM3	Separation Point Middle, Cast 3	
1241	COW1D	Cherry Point, Cast 4	
1320	CHN1	Cowichan Head North, Cast 1	
1330	CHS1	Cowichan Head South, Cast 1	
1457	MARM5	Marina Middle, Cast 5	

TABLE 3. DROGUE CURRENT VELOCITY STATISTICS

	Sept. 18		Sept. 19		Sept. 20	
Currents (cm/s)	Surface	10 m	Surface	10 m	Surface	10 m
Average	26.7	34.5	33.7	17.0	18.6	12.4
Maximum	79.7	81.0	130.9	48.0	44.8	46.8
Minimum	5.5	7.4	0.7	3.7	1.8	2.8
Standard Deviation	17.4	21.9	28.5	9.8	11.1	9.0

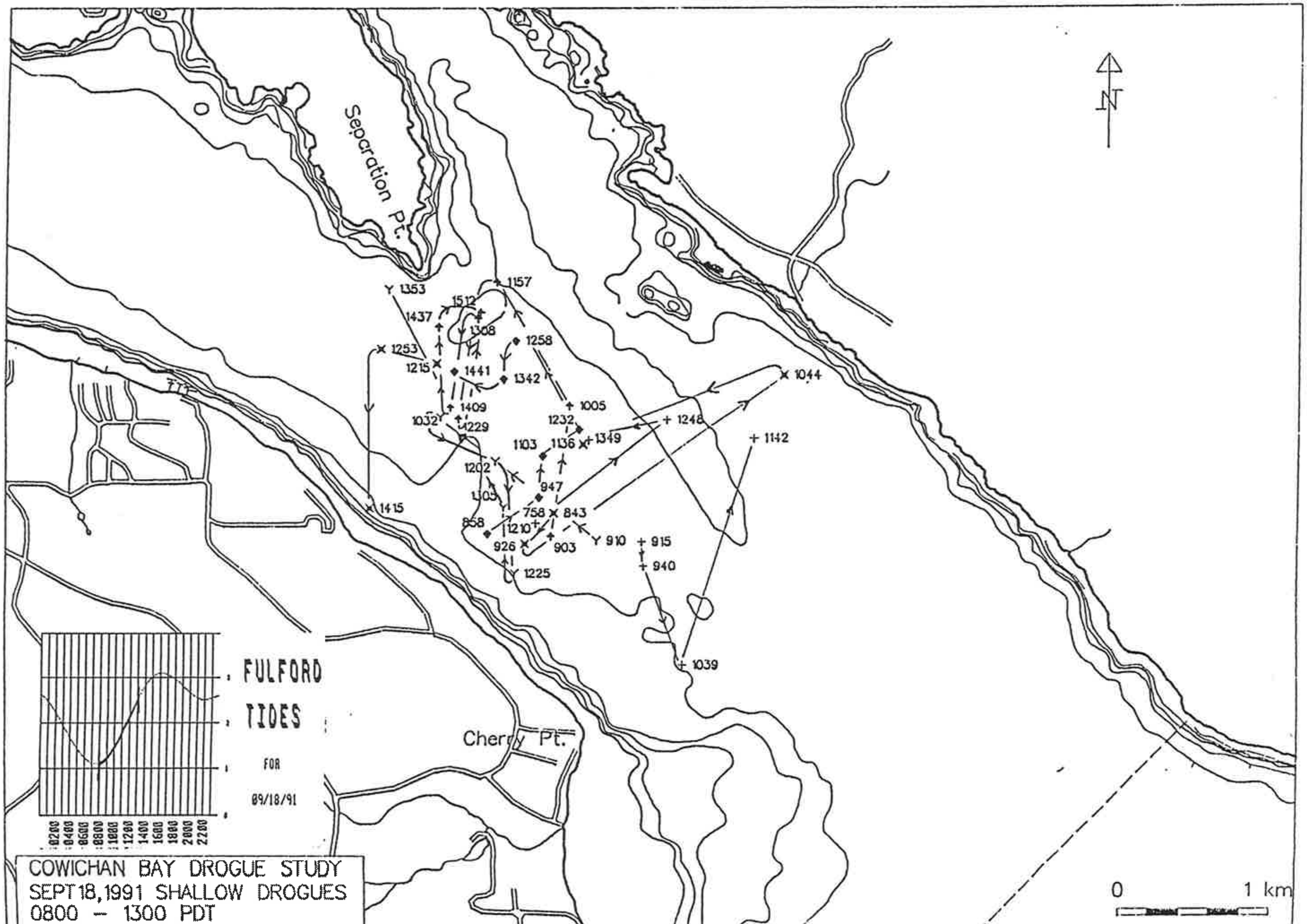

Separation Pt.
Cherry Pt.
N
0
1 km
FULFORD
TIDES
FOR
09/18/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
COWICHAN BAY DROGUE STUDY
SEPT 18, 1991 SHALLOW DROGUES
0800 – 1300 PDT

FIGURE 3.

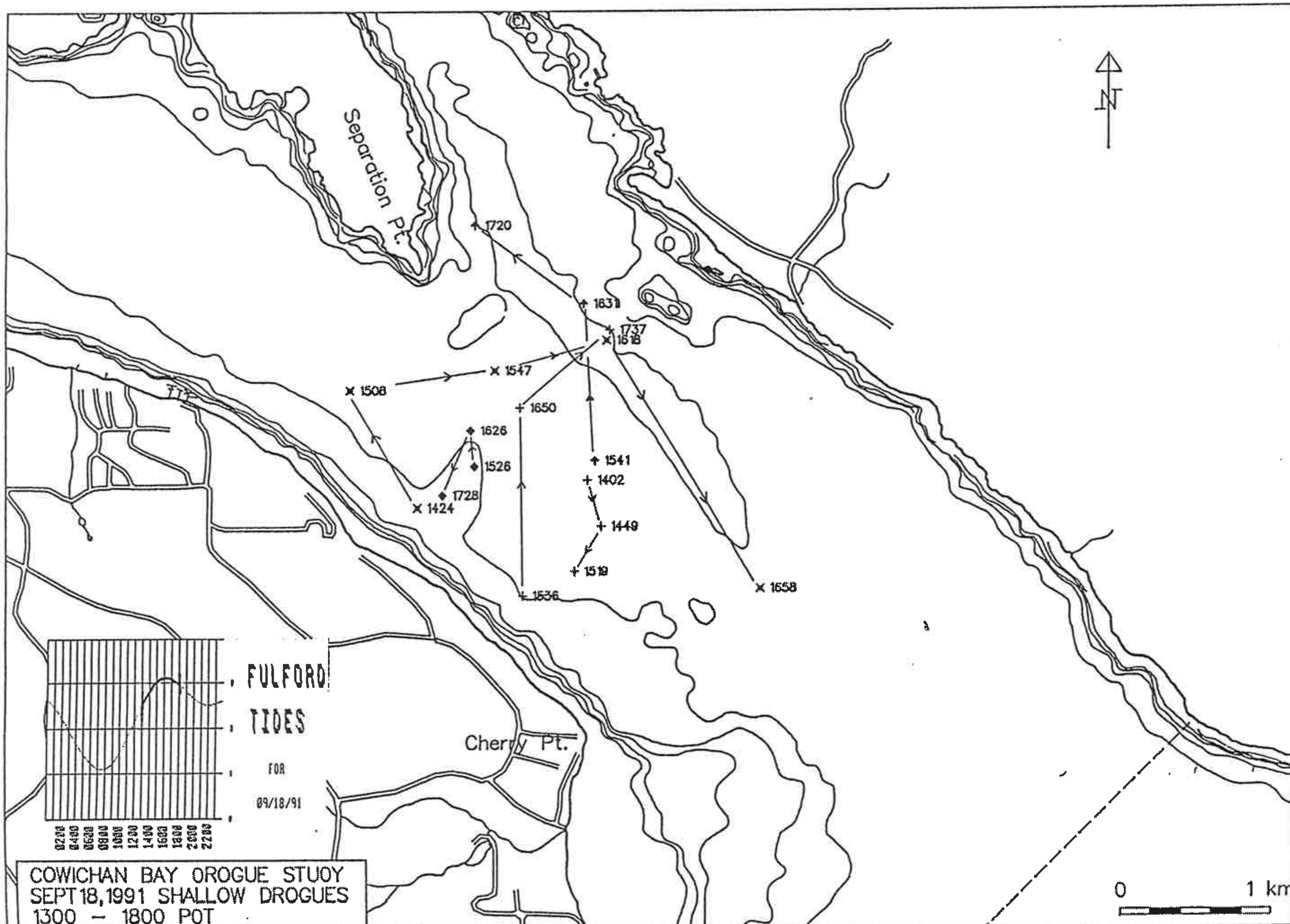
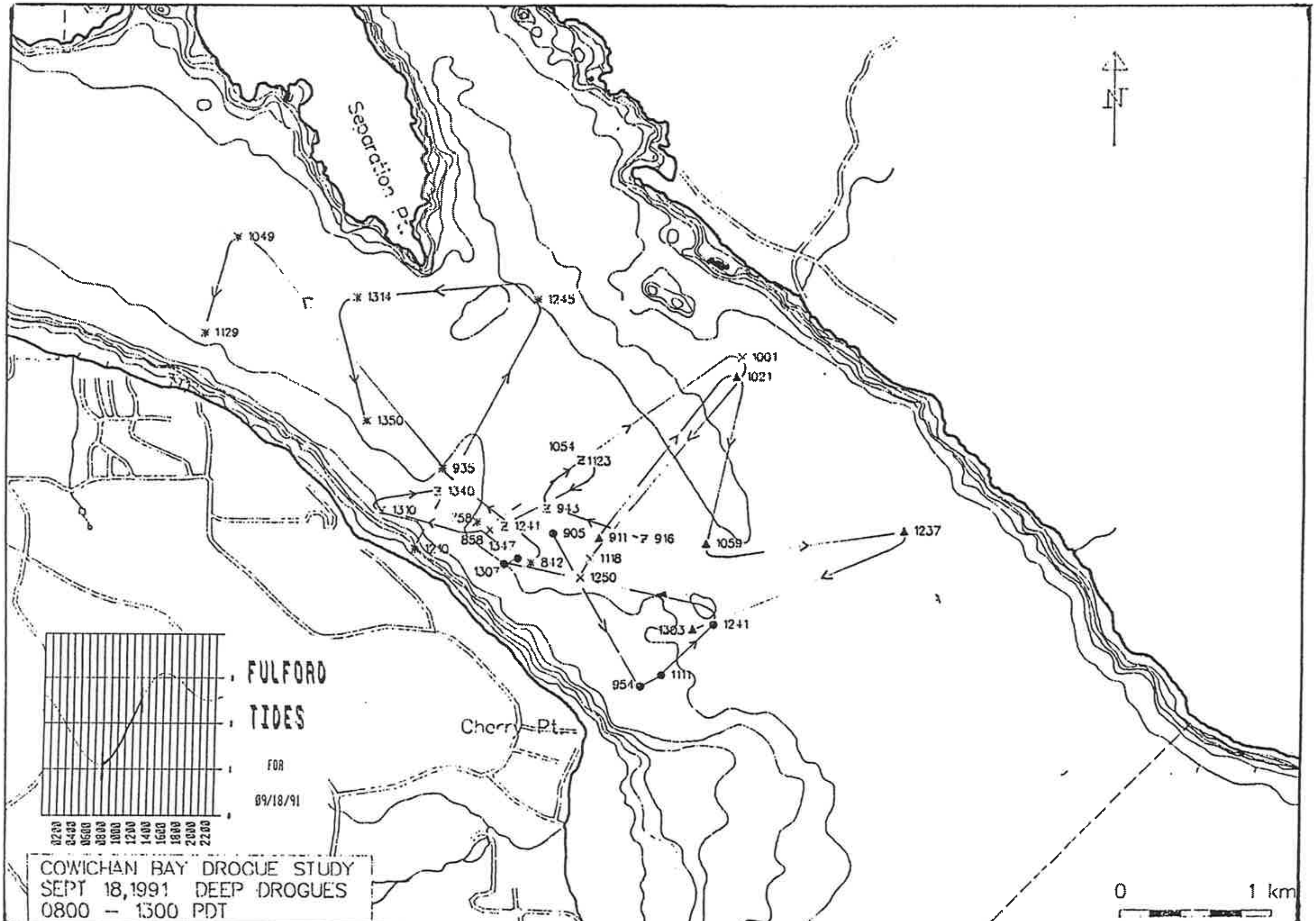

Separation Pt.
Cherry Pt.
N
1720
1631
1737
1618
1547
1508
1650
1626
1526
1728
1424
1541
1402
1449
1519
1536
1658
FULFORD
TIDES
FOR
09/18/91
0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200
0
1 km
COWICHAN BAY OROGUE STUOY
SEPT 18, 1991 SHALLOW DROGUES
1300 – 1800 POT

FIGURE 4.



N
Separation Pt.
Cherry Pt.
FULFORD
TIDES
FOR
09/18/91
0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200
COWICHAN BAY DROGUE STUDY
SEPT 18,1991 DEEP DROGUES
0800 – 1300 PDT
0
1 km

FIGURE 5.

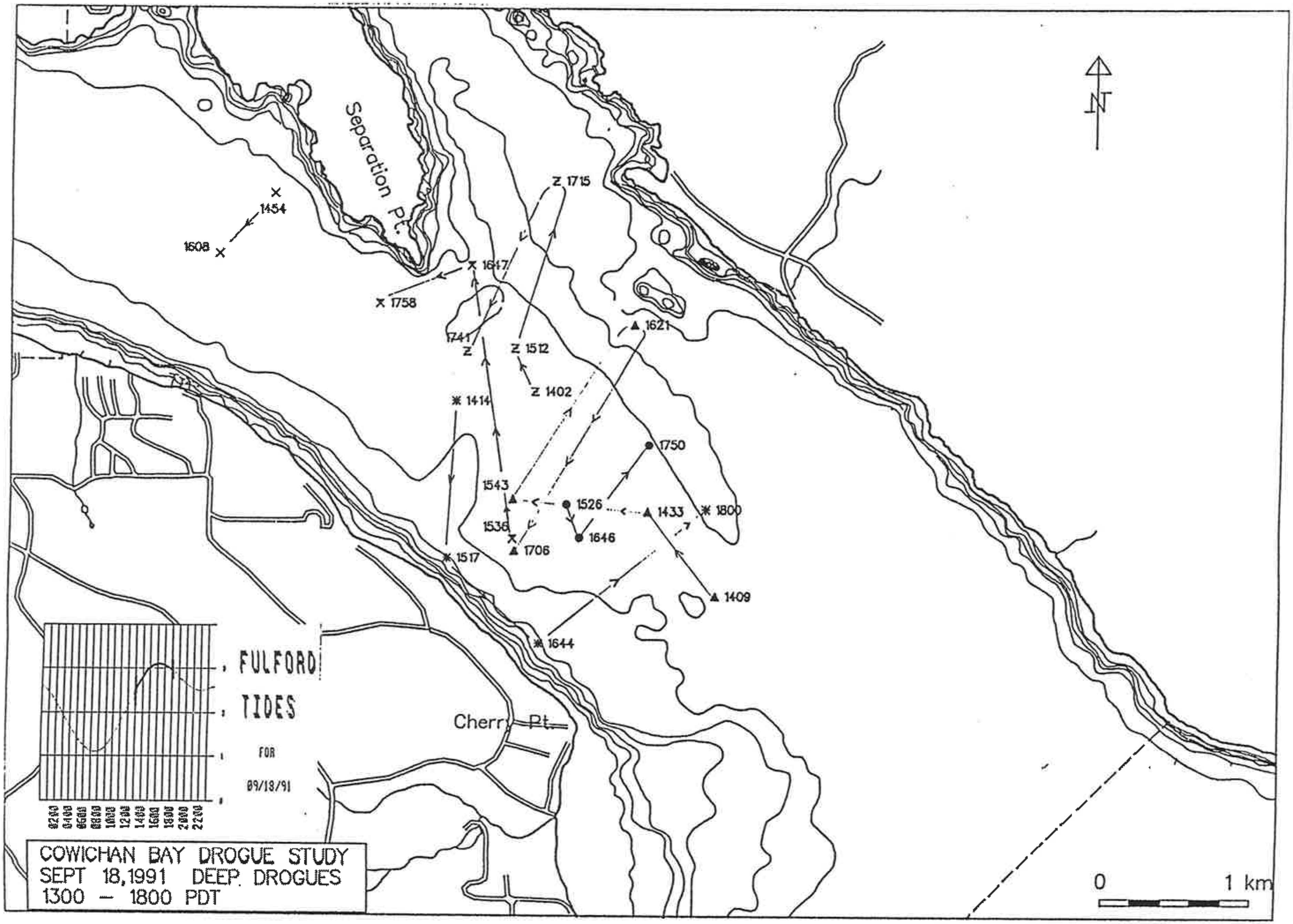

N
Separation Pt.
Cherry Pt.
1454
1608
1715
1647
1758
1741
1512
1621
1402
1414
1750
1543
1526
1433
1800
1536
1646
1706
1517
1409
1644
FULFORD
TIDES
FOR
09/18/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
COWICHAN BAY DROGUE STUDY
SEPT 18,1991 DEEP DROGUES
1300 — 1800 PDT
0
1 km

FIGURE 6.

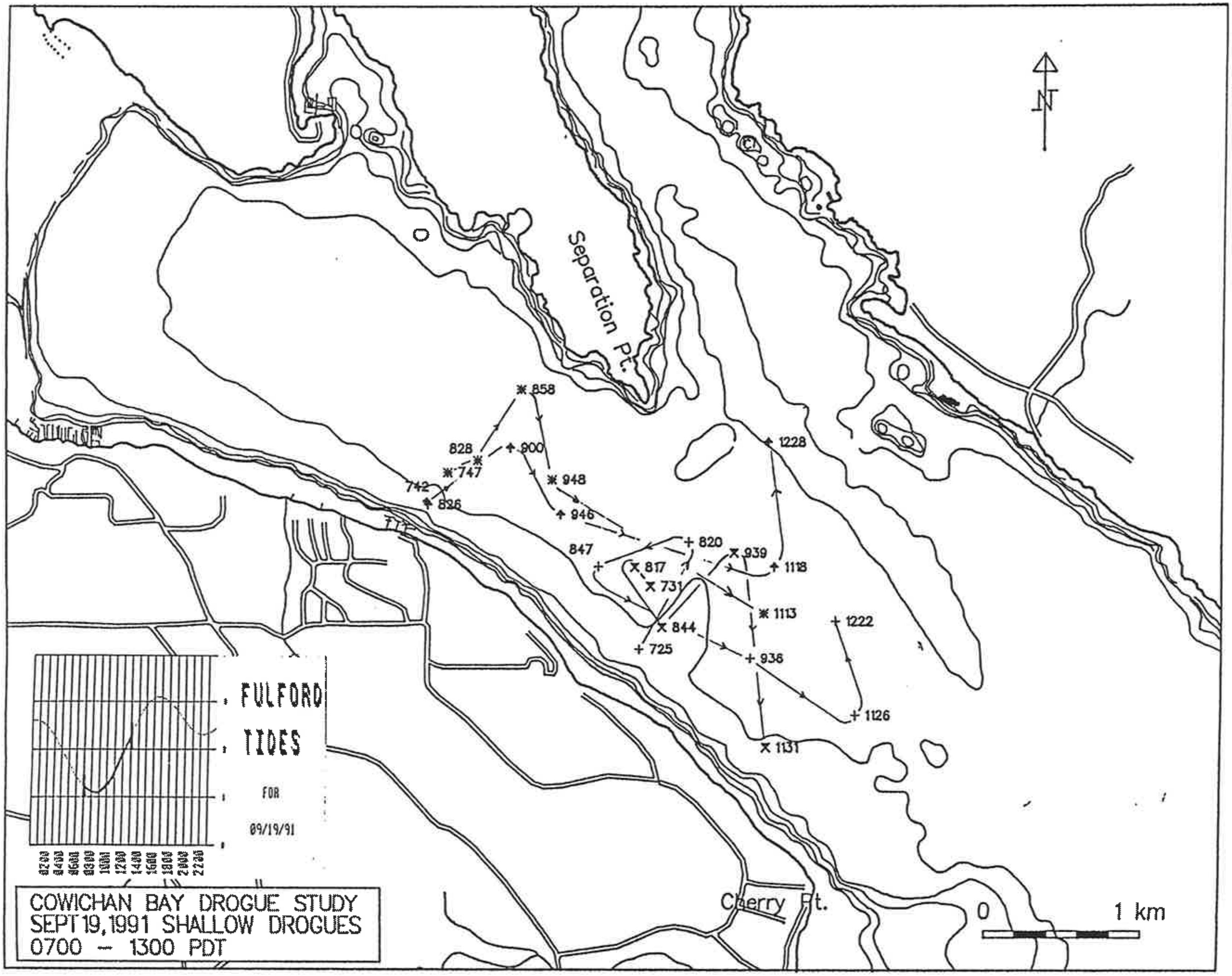

N
Separation Pt.
Cherry Pt.
858
828
900
747
948
742
826
946
820
847
939
817
1118
731
1113
1222
844
725
936
1126
1131
1228
0
1 km
FULFORD
TIDES
FOR
09/19/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
COWICHAN BAY DROGUE STUDY
SEPT 19, 1991 SHALLOW DROGUES
0700 – 1300 PDT

FIGURE 7.

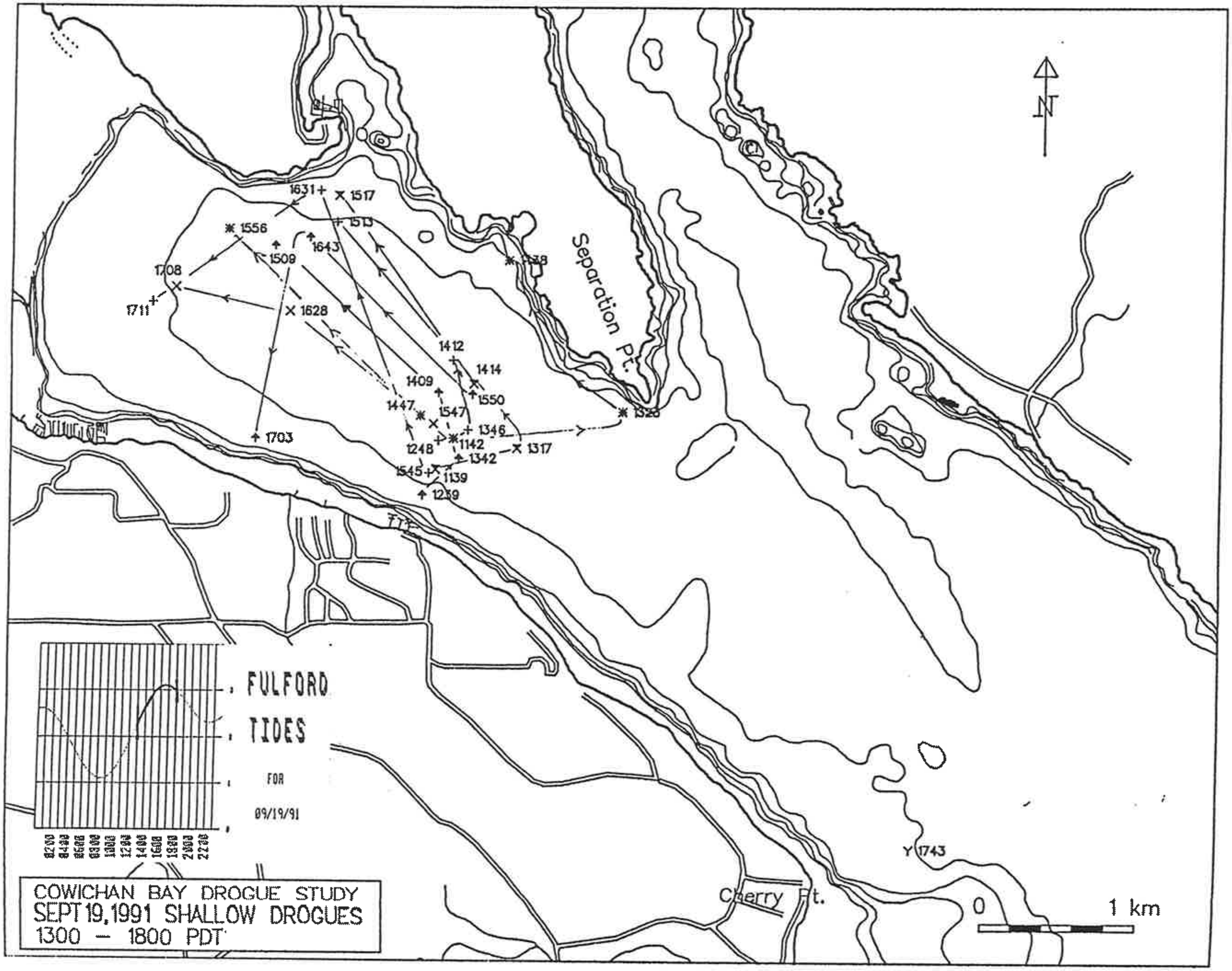

N
Separation Pt.
Cherry Pt.
0
1 km
1631
1517
1513
1556
1643
1509
1708
1711
1628
1412
1414
1409
1550
1447
1547
1346
1328
1248
1142
1317
1342
1545
1139
1239
1703
1743
FULFORD
TIDES
FOR
09/19/91
COWICHAN BAY DROGUE STUDY
SEPT 19, 1991 SHALLOW DROGUES
1300 — 1800 PDT

FIGURE 8.

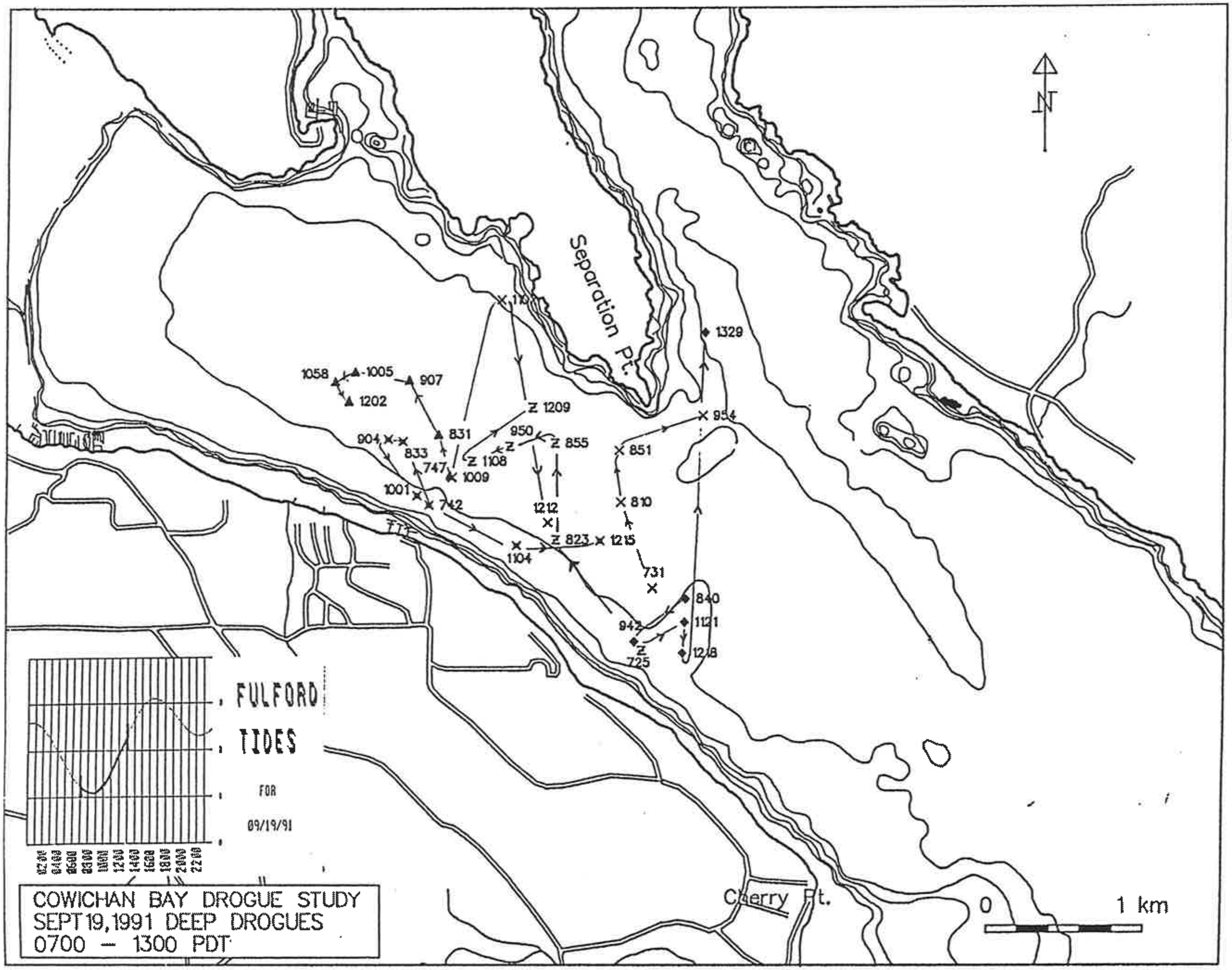

Separation Pt.
Cherry Pt.
N
0
1 km
1058
1005
907
1202
831
1209
950
855
1108
904
833
747
1009
1001
742
1212
851
810
954
1329
1104
823
1215
731
840
1121
1218
942
725
FULFORD
TIDES
FOR
09/19/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
COWICHAN BAY DROGUE STUDY
SEPT 19, 1991 DEEP DROGUES
0700 — 1300 PDT

FIGURE 9.

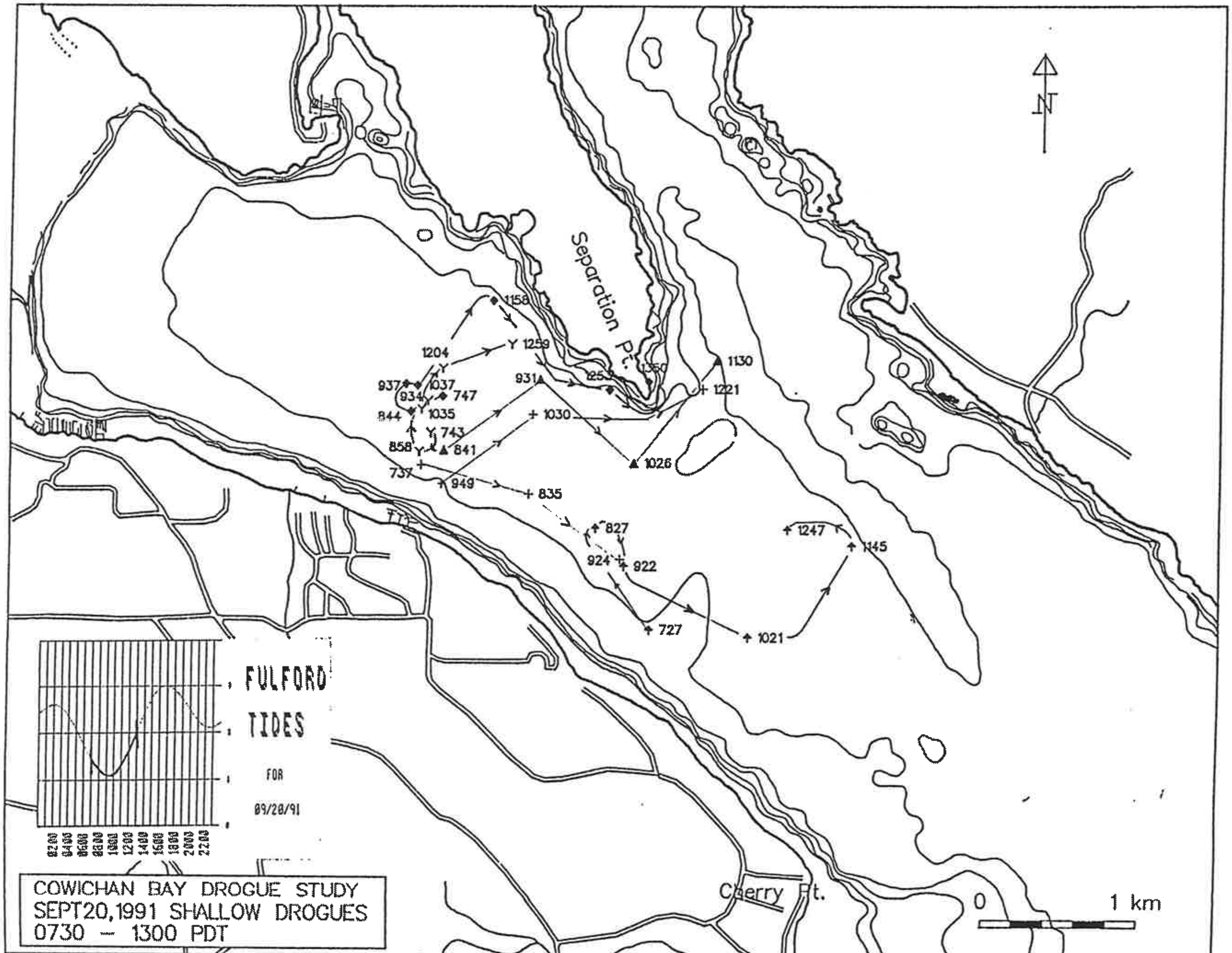

COWICHAN BAY DROGUE STUDY
SEPT20,1991 SHALLOW DROGUES
0730 - 1300 PDT
FULFORD
TIDES
FOR
09/20/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
Separation Pt.
Cherry Pt.
N
0
1 km
1158
1204
1259
937
1037
934
747
1035
844
743
858
841
737
949
835
931
1030
1253
1350
1130
1221
1026
827
924
922
727
1021
1247
1145

FIGURE 11.

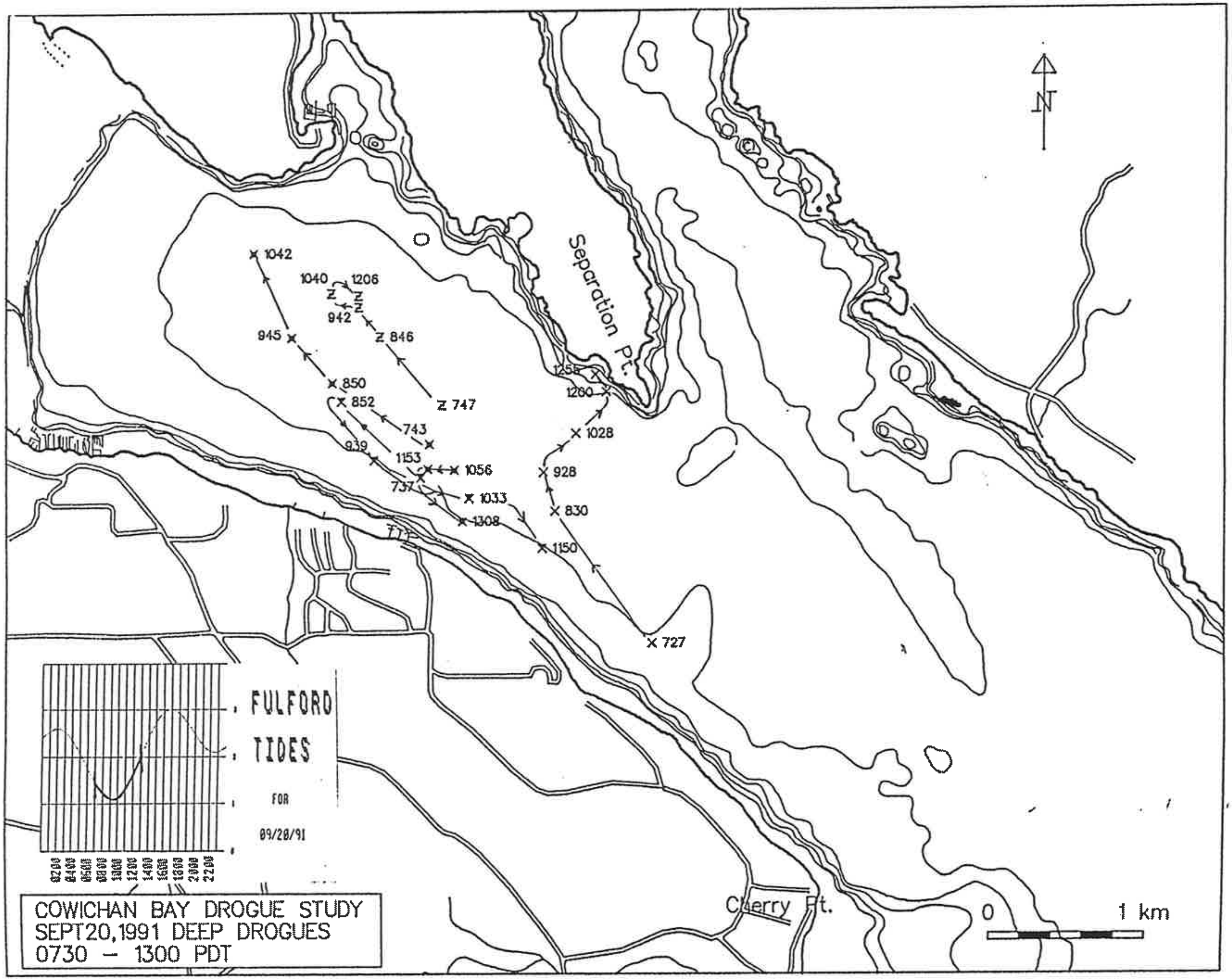

N
Separation Pt.
Cherry Pt.
0
1 km
1042
1040
1206
942
945
846
850
852
747
743
939
1153
1056
737
1033
1308
1150
1255
1200
1028
928
830
727
FULFORD
TIDES
FOR
09/20/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
COWICHAN BAY DROGUE STUDY
SEPT20,1991 DEEP DROGUES
0730 – 1300 PDT

FIGURE 13.

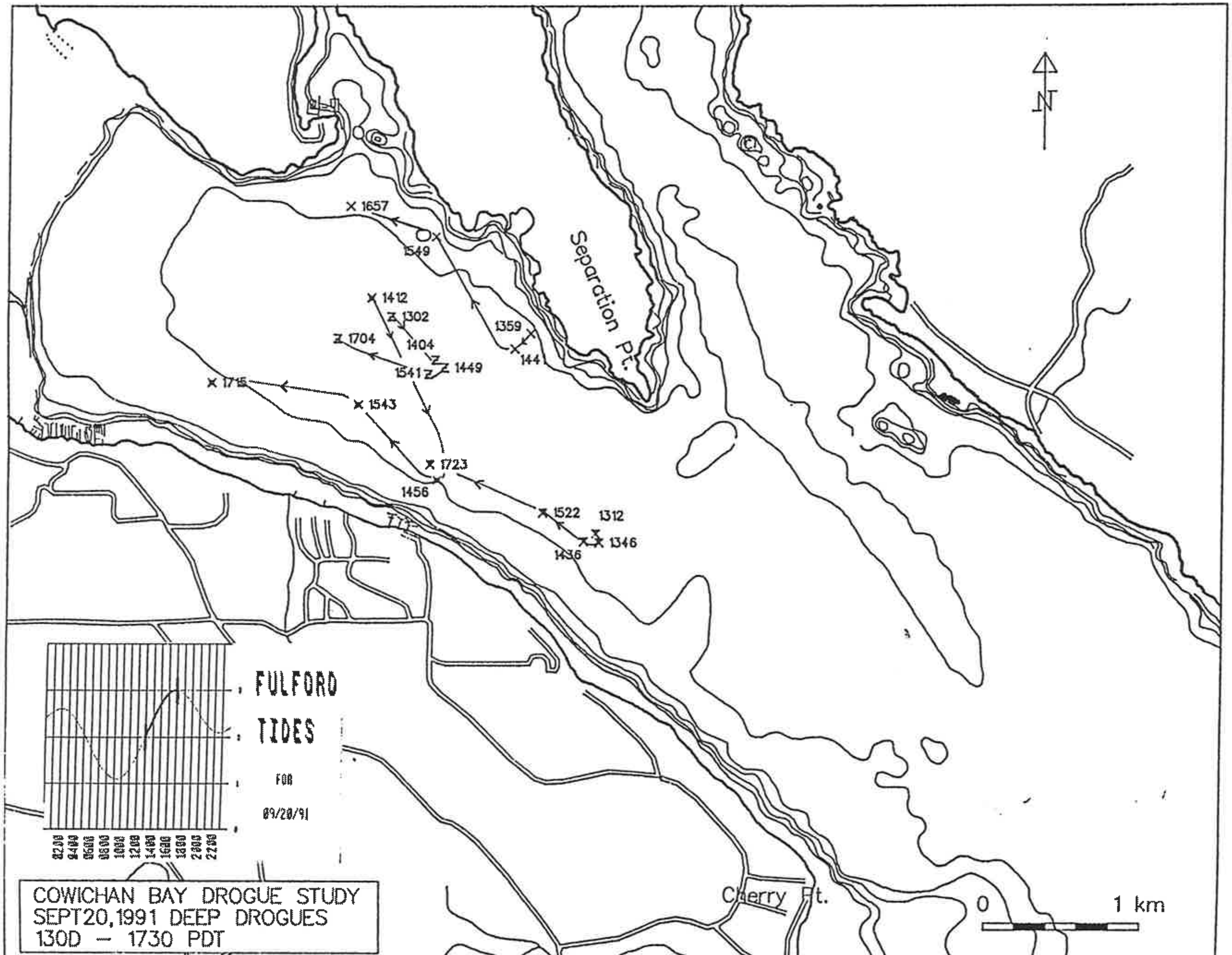

N
Separation Pt.
1657
1549
1412
1302
1704
1404
1449
1541
1359
144
1715
1543
1723
1456
1522
1312
1346
1436
FULFORD
TIDES
FOR
09/20/91
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
COWICHAN BAY DROGUE STUDY
SEPT20,1991 DEEP DROGUES
130D — 1730 PDT
Cherry Pt.
0
1 km

FIGURE 14.

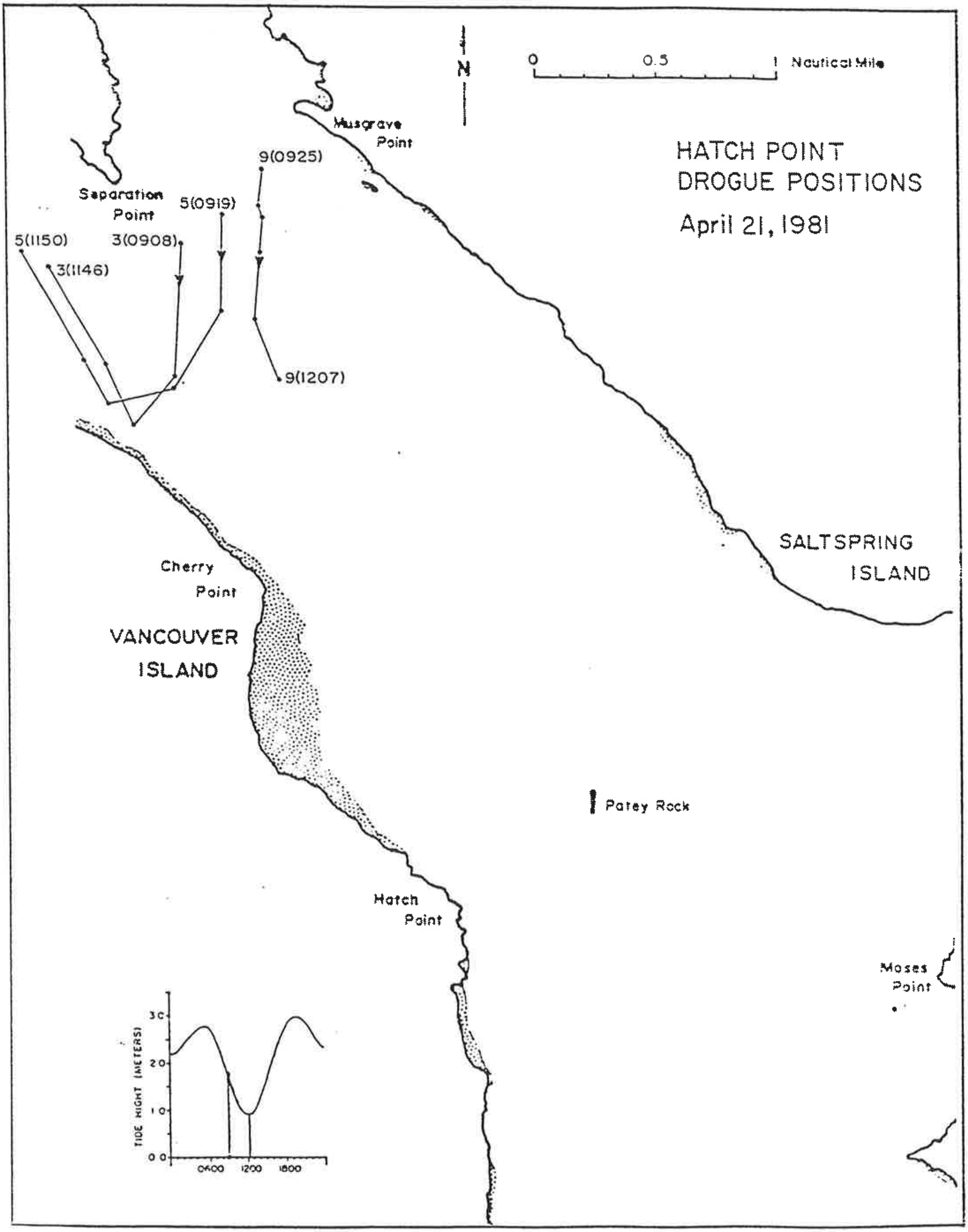


FIGURE 15. Cowichan Bay Ebb Tide Surface Drogue Tracks, April 21, 1981. From Narayanan, 1981. Physical Oceanography. Hatch Point Marine Environmental Assessment.

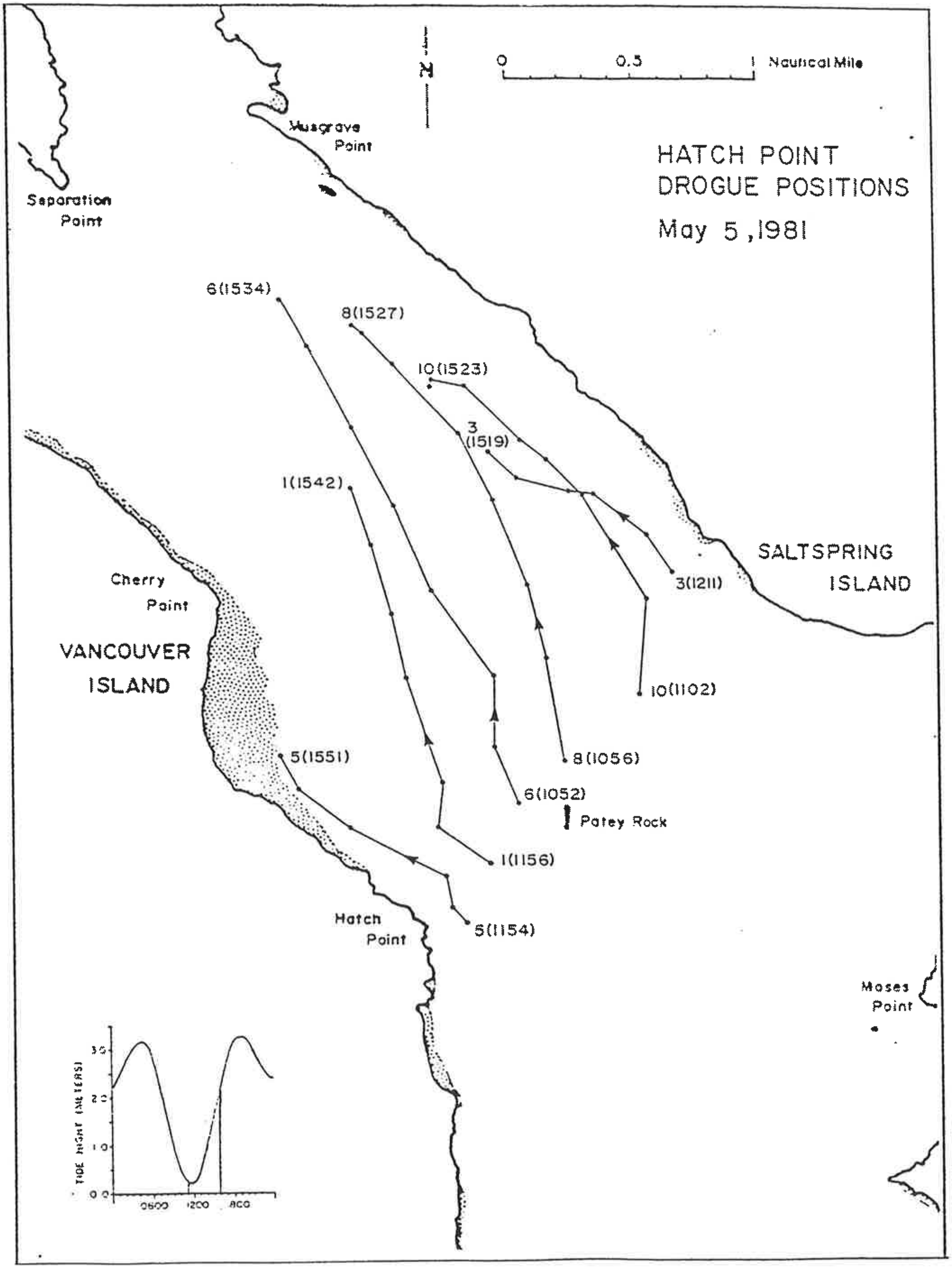


FIGURE 16. Satellite Channel Flood Tide Drogue Tracks, May 5, 1981. From Narayanan, 1981. Physical Oceanography. Hatch Point Marine Environmental Assessment.

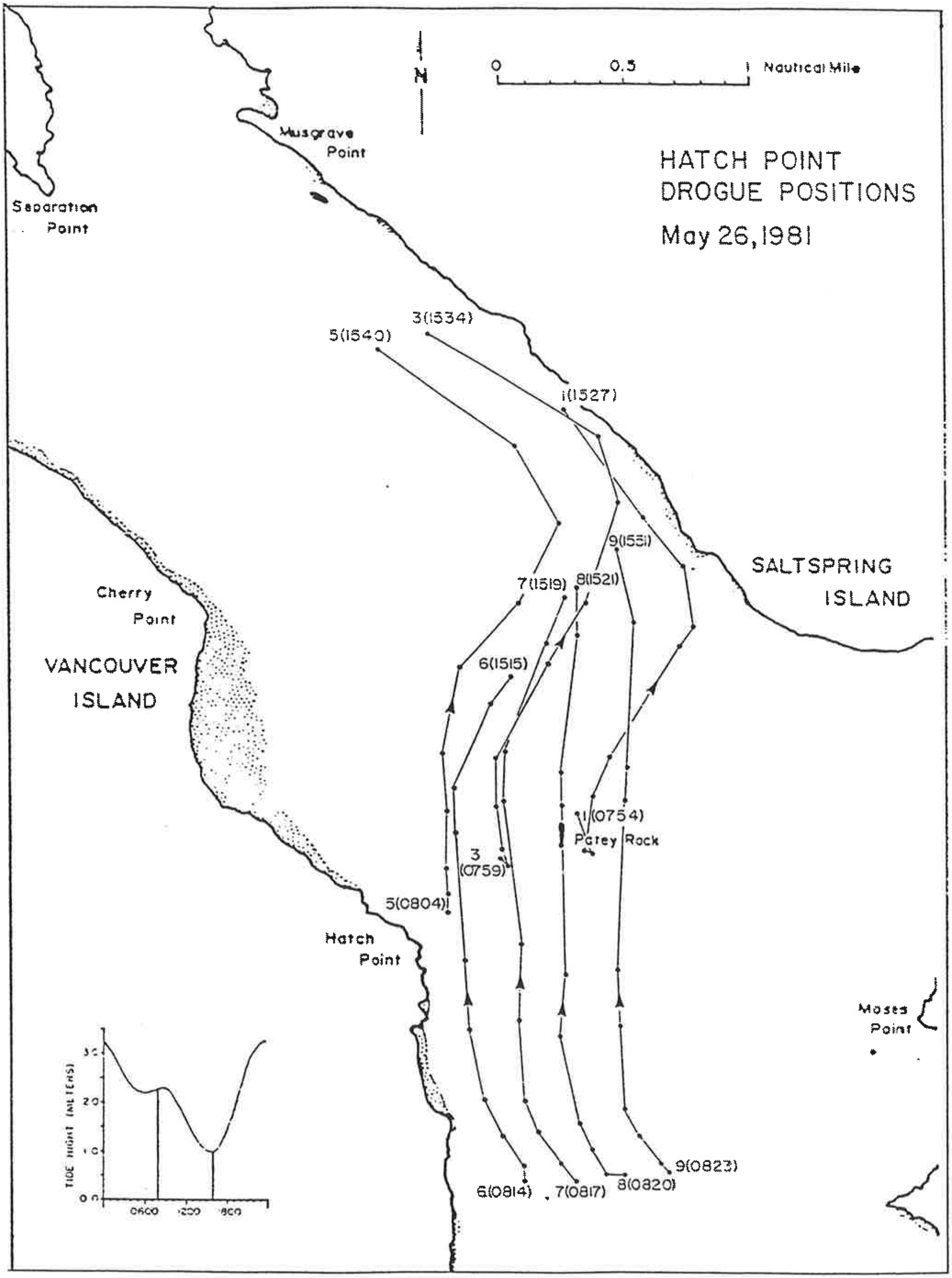


FIGURE 17. Satellite Channel Ebb Tide Drogue Tracks, May 26, 1981. From Narayanan, 1981. Physical Oceanography. Hatch Point Marine Environmental Assessment.

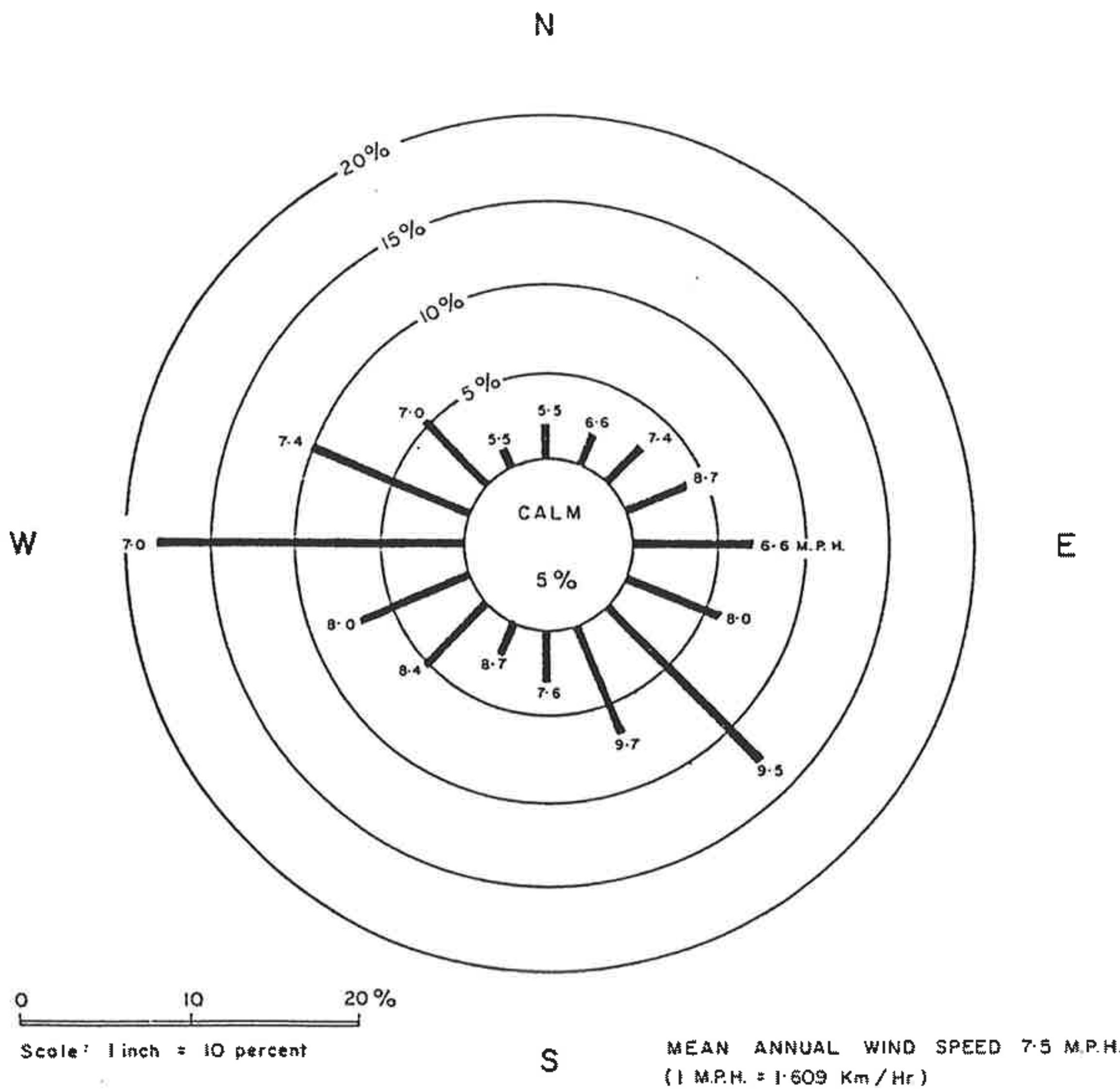


FIGURE 18. Victoria International Airport - Wind Rose. Percentage Frequency and Mean Wind Speed by Direction -1955 to 1972. (Atmospheric Environment Service) From Bell and Kallman, 1976. The Cowichan-Chemainus River Estuaries. Status of Environmental Knowledge to 1975.

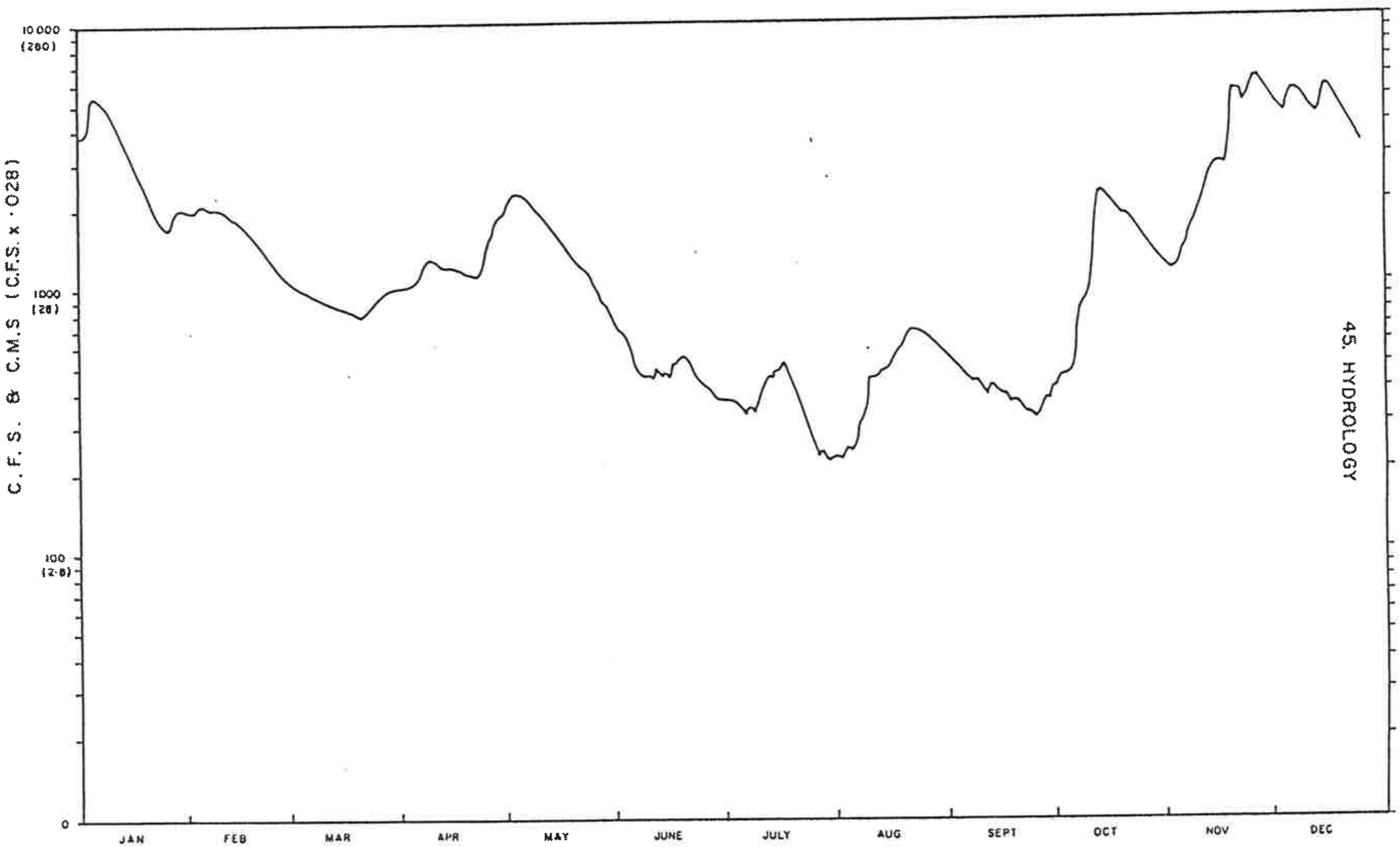


FIGURE 19. Cowichan River Discharge Hydrograph for 1962. From Bell and Kallman, 1976. The Cowichan-Chemainus River Estuaries. Status of Environmental Knowledge to 1975.

FIGURE 21.

TEMPERATURE HORIZONTAL PROFILE

COWICHAN BAY, SEPTEMBER 1991

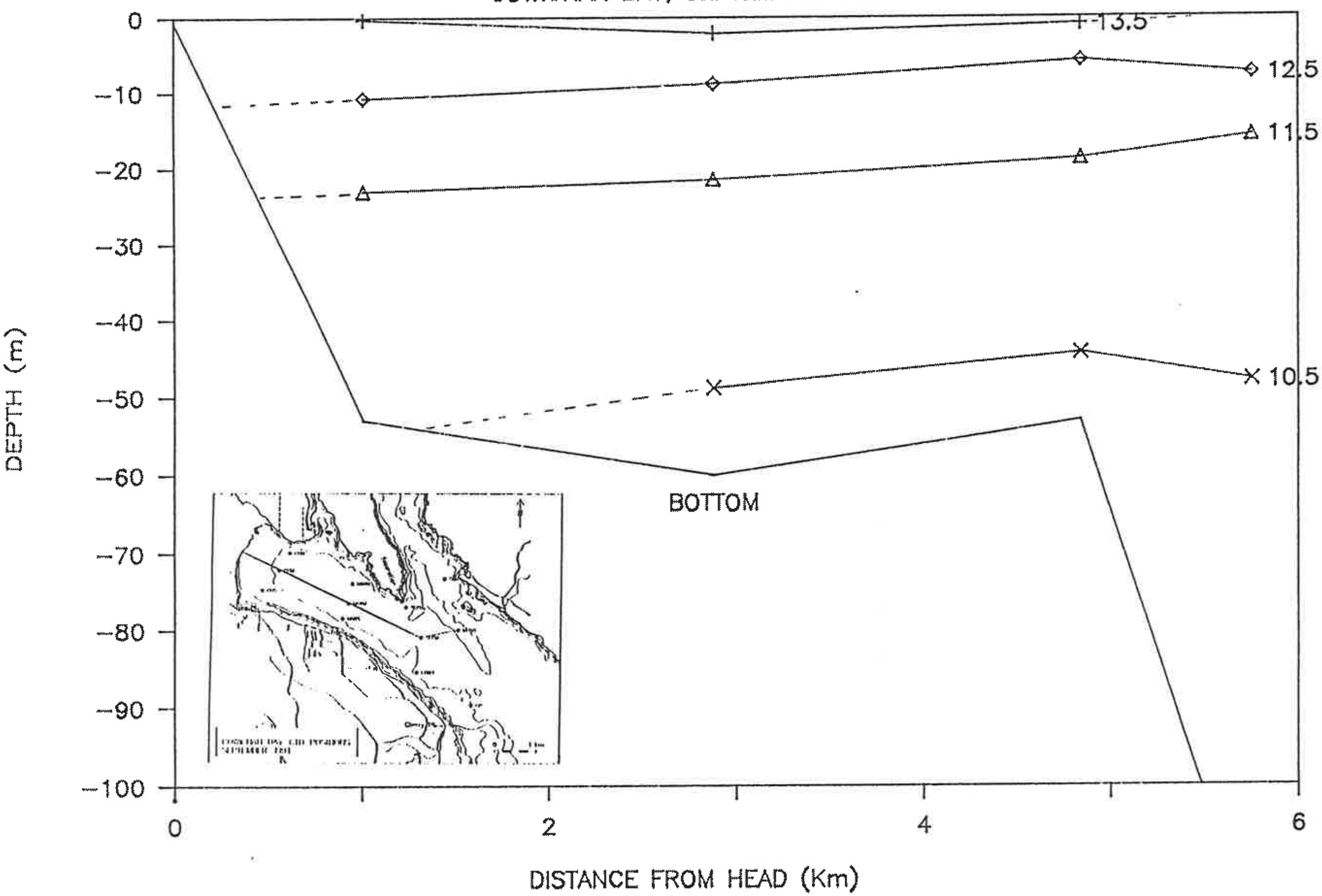


FIGURE 22.

SIGMA-T HORIZONTAL PROFILE

COWICHAN BAY, SEPTEMBER 1991

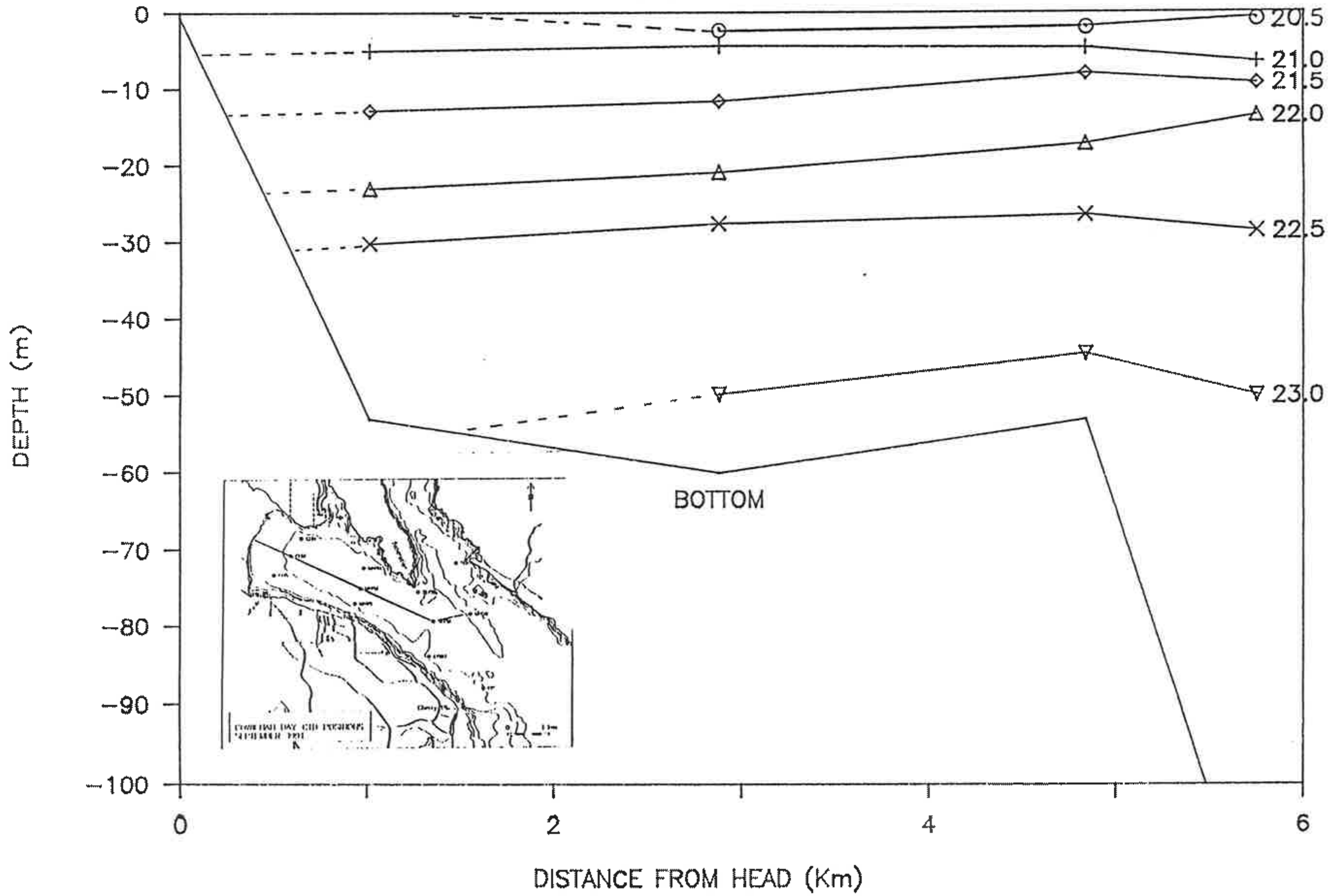


FIGURE 20.

SALINITY HORIZONTAL PROFILE

COWICHAN BAY, SEPTEMBER 1991

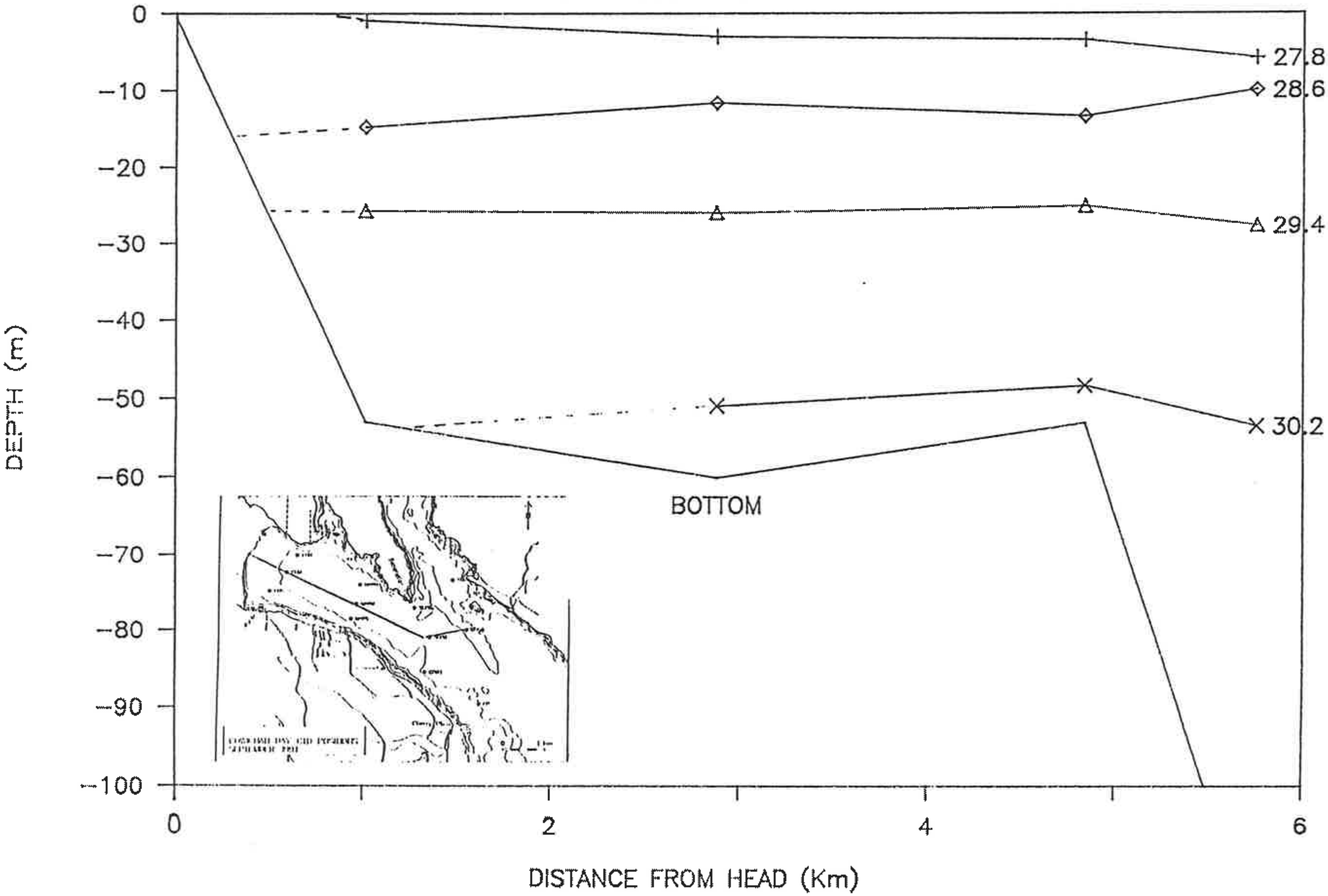


FIGURE 23.

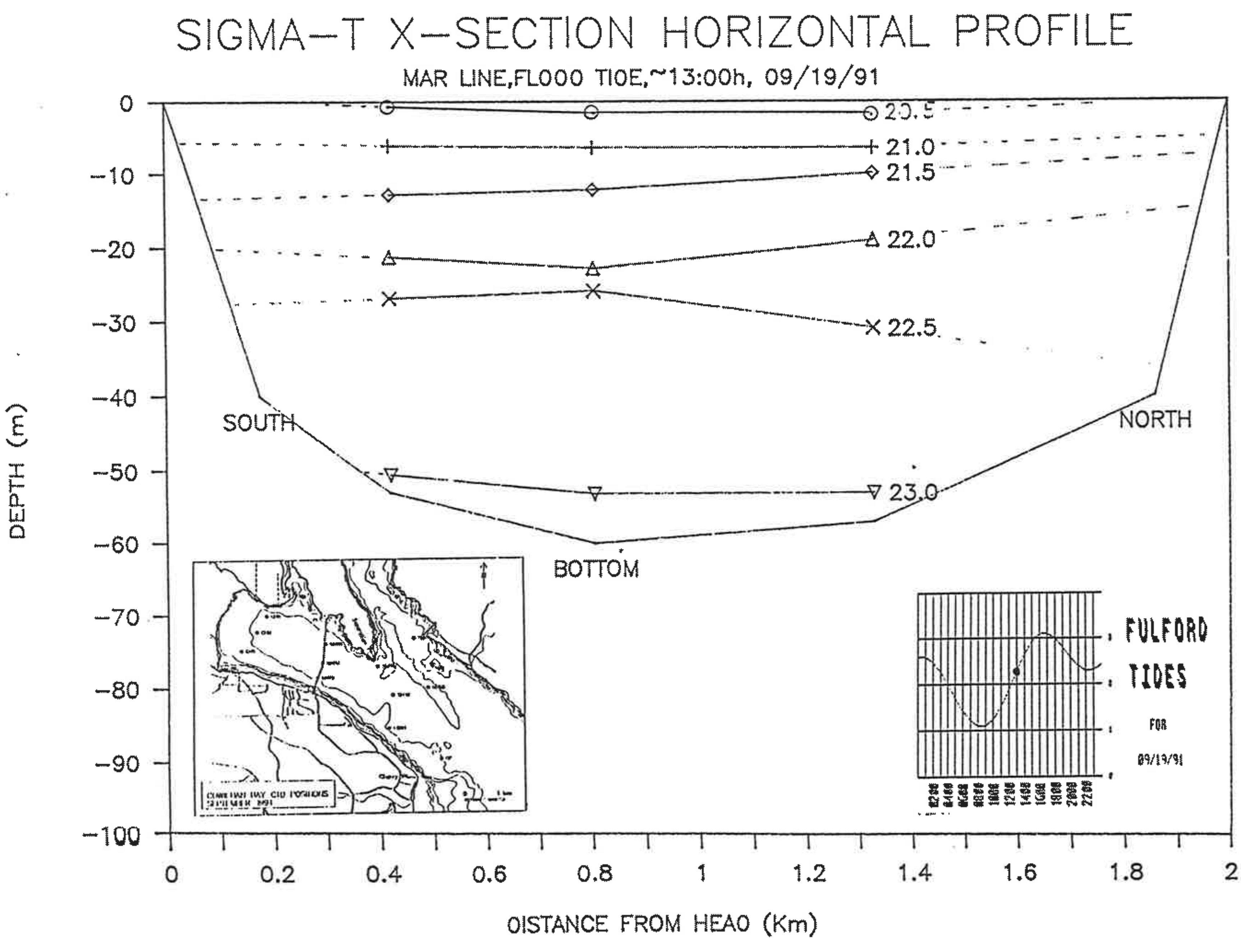
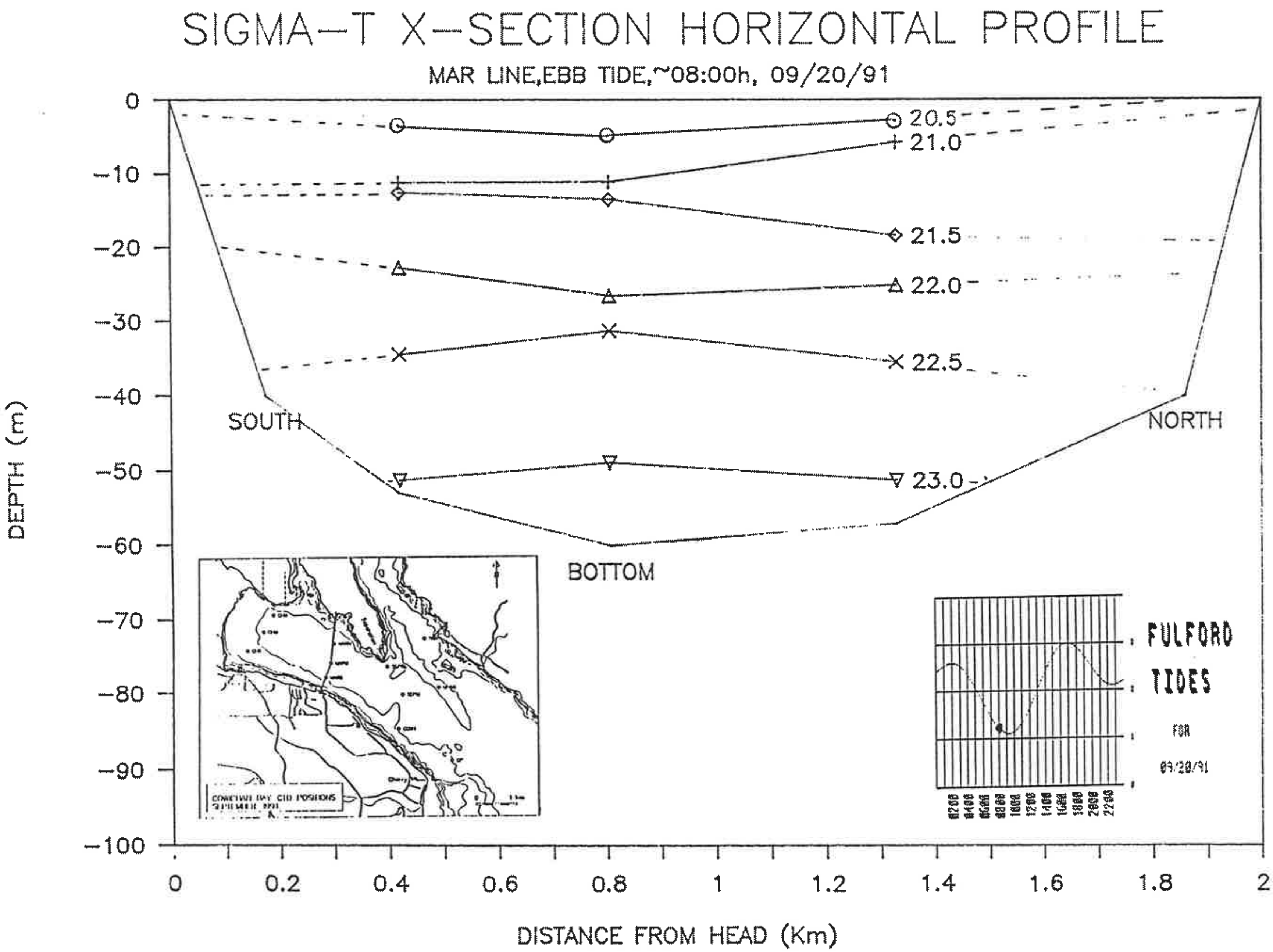

SIGMA-T X-SECTION HORIZONTAL PROFILE
MAR LINE,FLOOO TIOE,~13:00h, 09/19/91
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
DEPTH (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
OISTANCE FROM HEAO (Km)
21.0
21.5
22.0
22.5
23.0
SOUTH
NORTH
BOTTOM
FULFORD
TIDES
FOR
09/19/91

FIGURE 24.


SIGMA-T X-SECTION HORIZONTAL PROFILE
MAR LINE,EBB TIDE,~08:00h, 09/20/91
DEPTH (m)
DISTANCE FROM HEAD (Km)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
20.5
21.0
21.5
22.0
22.5
23.0
SOUTH
NORTH
BOTTOM
FULFORD
TIDES
FOR
09/20/91

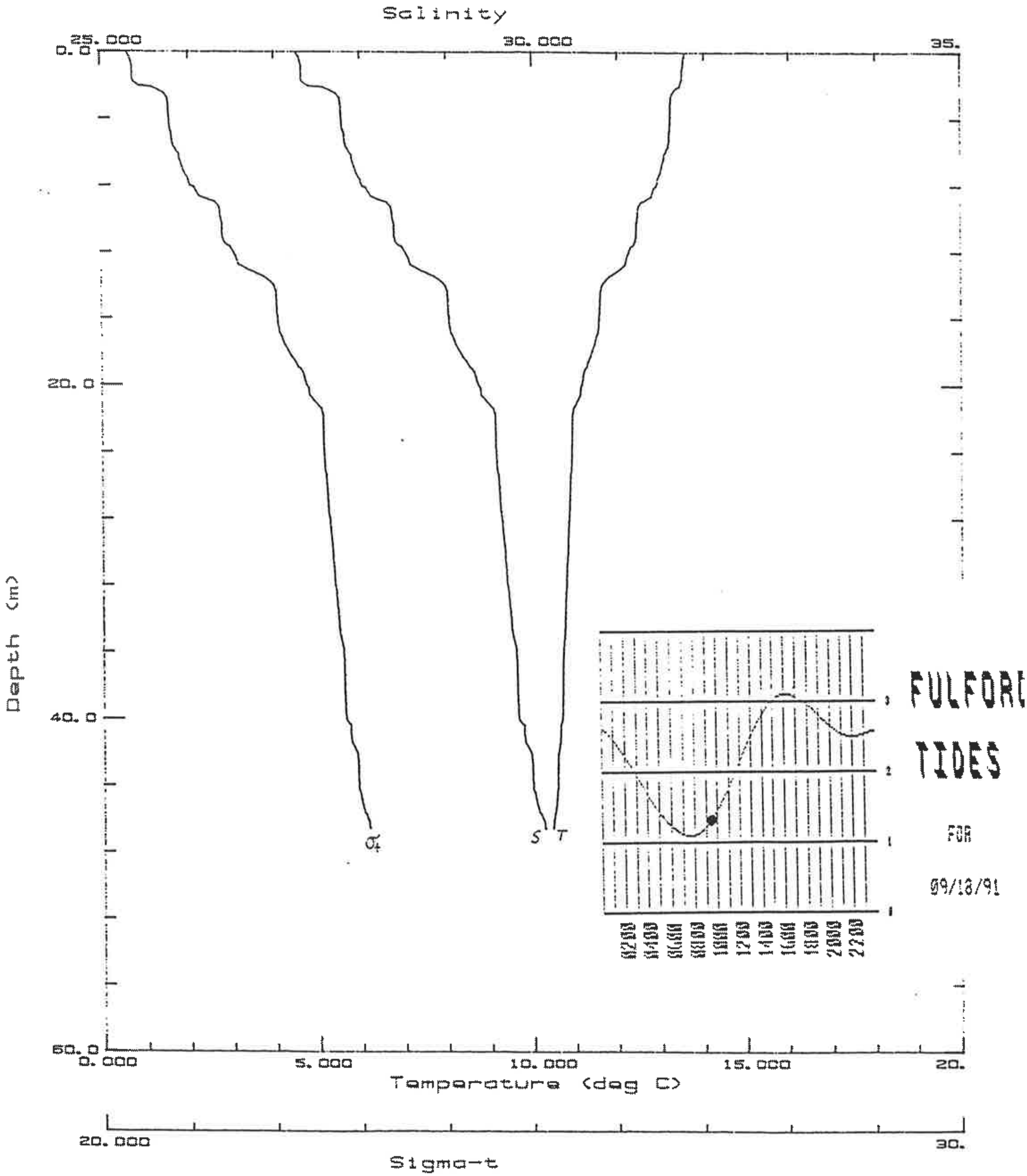


FIGURE 25.

DACOW1A. avg: CHERRY POINT. CAST 1

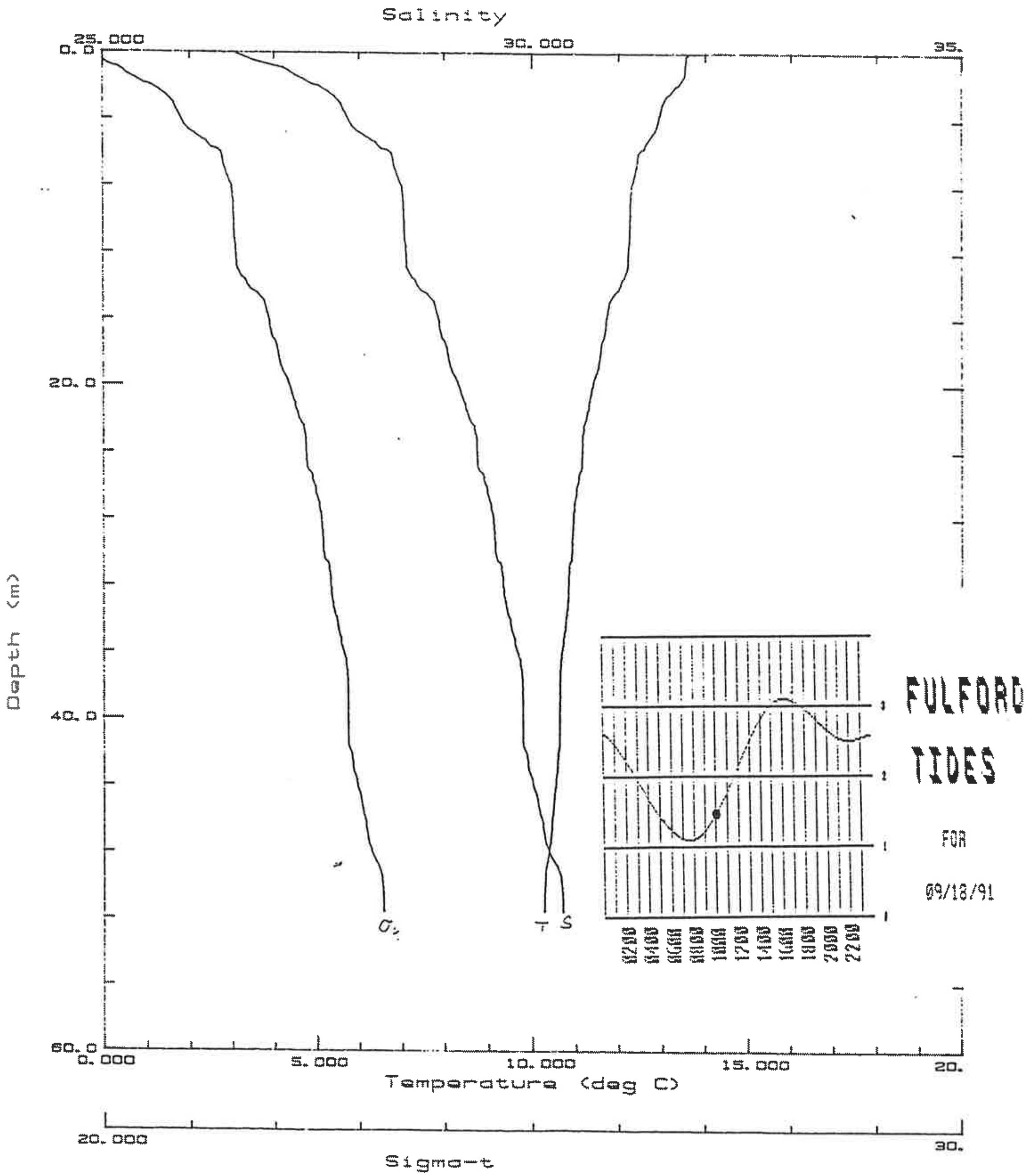


FIGURE 26.

DASEPM1.avg: SEPARATION PT. MIDDLE. CAST 1

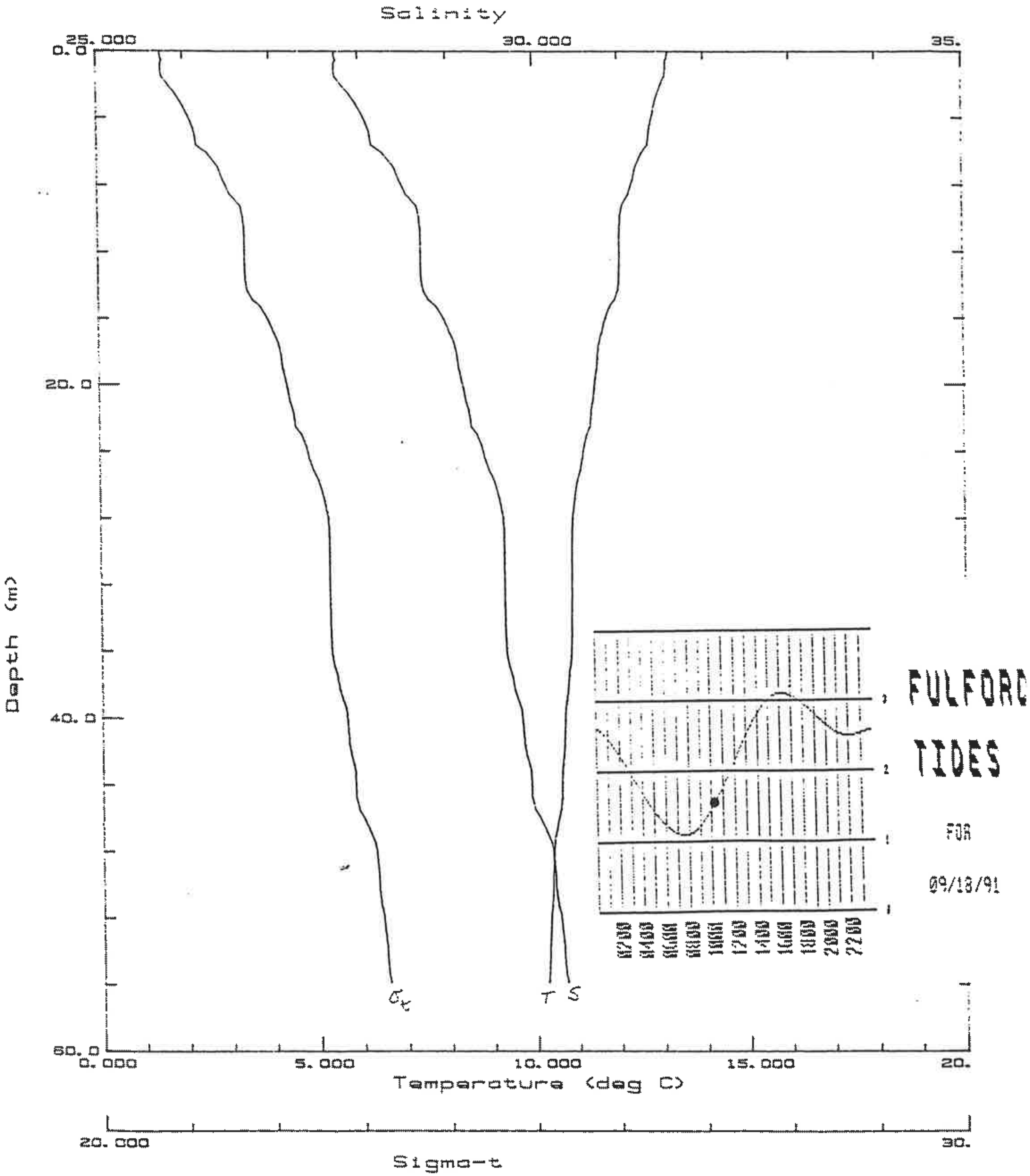


FIGURE 27.

DASEPN1.avg: SEPARATION PT. NORTH. CAST 1

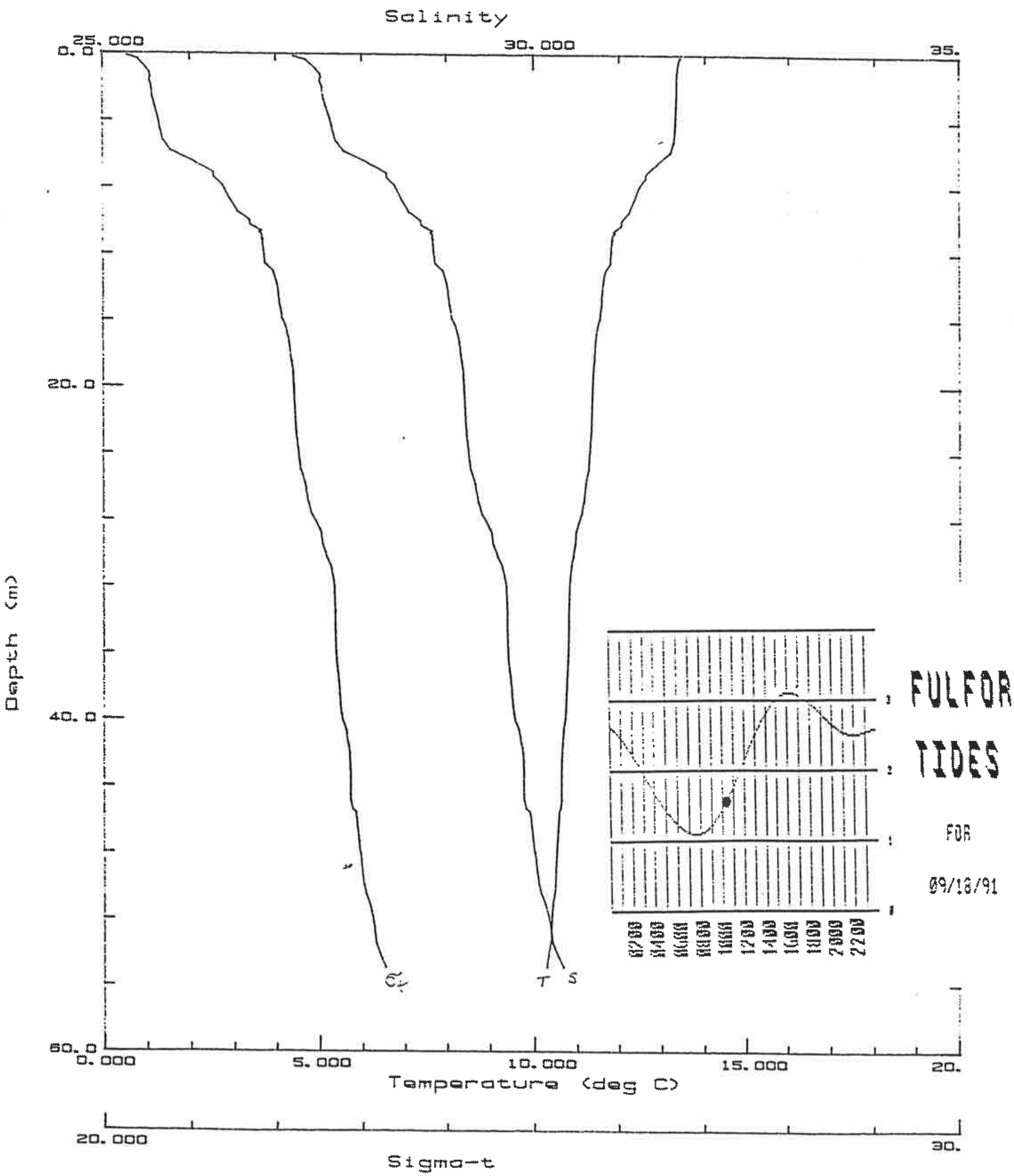


FIGURE 28.

DAMUSG1.avg: MUSGRAVE ROCK. CAST 1

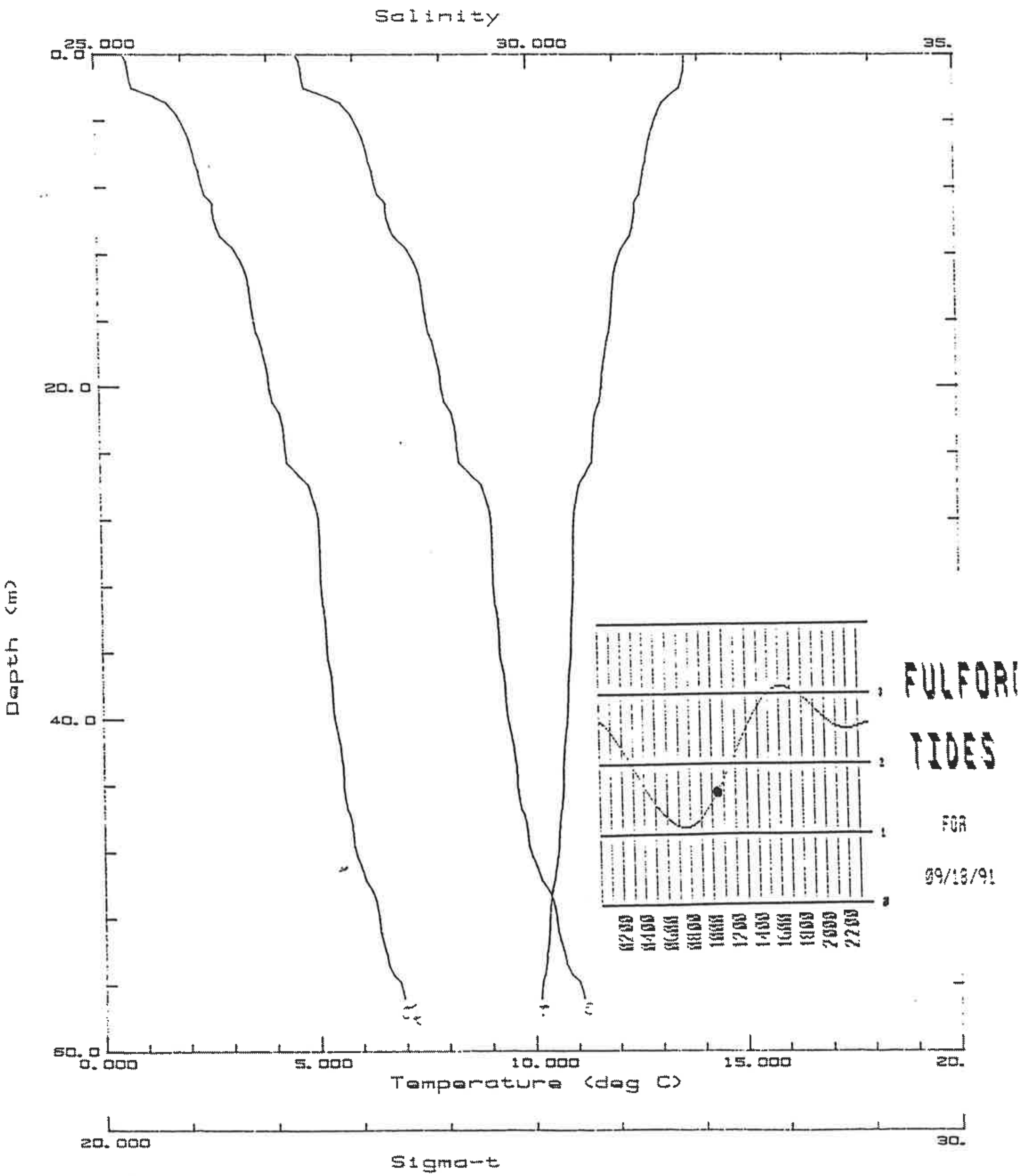


FIGURE 29.

DAMAR1.avg: MARINA MIDDLE. CAST 1

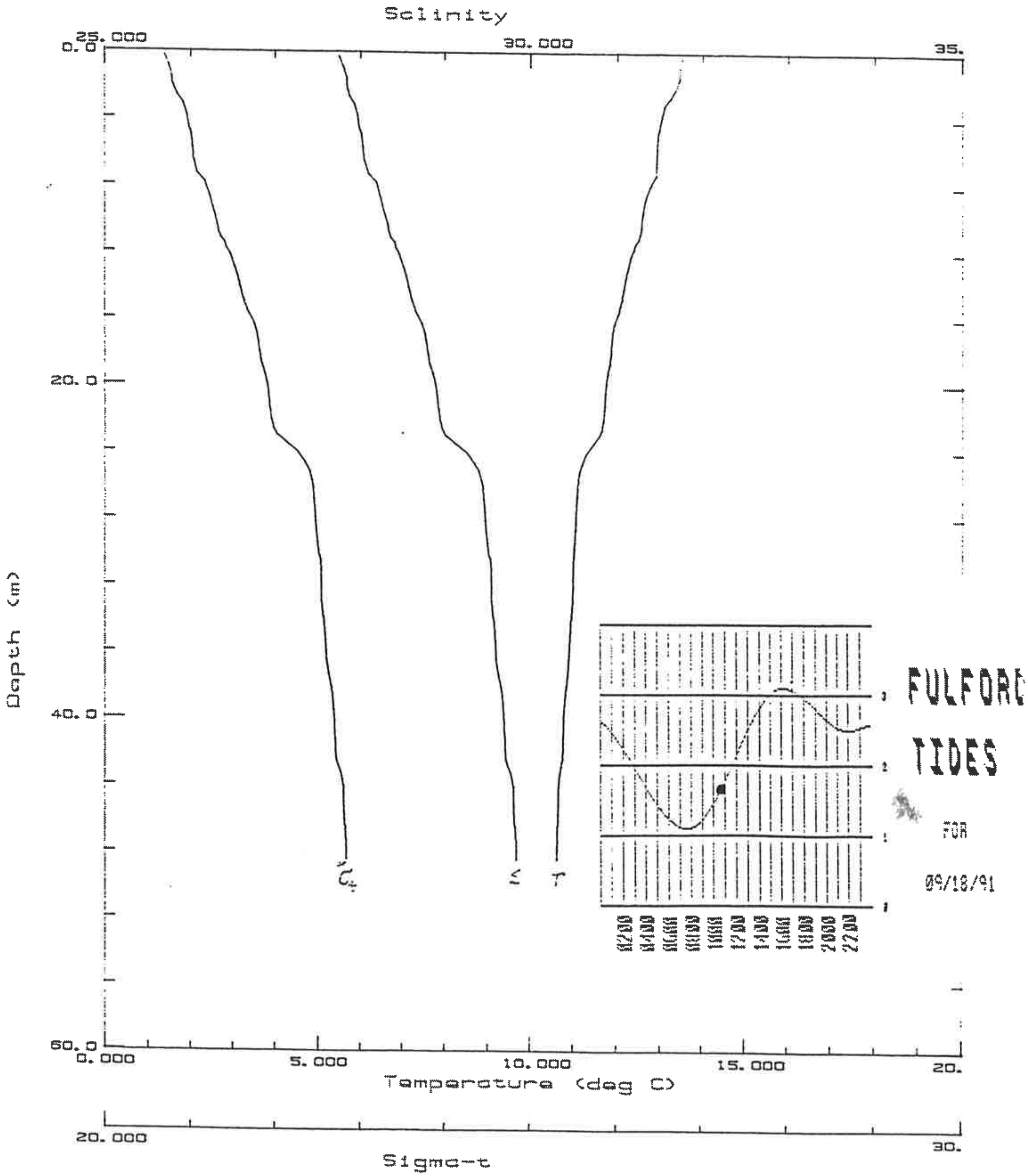


FIGURE 30.

DACHM1.avg: COWICHAN HEAD MIDDLE. CAST 1

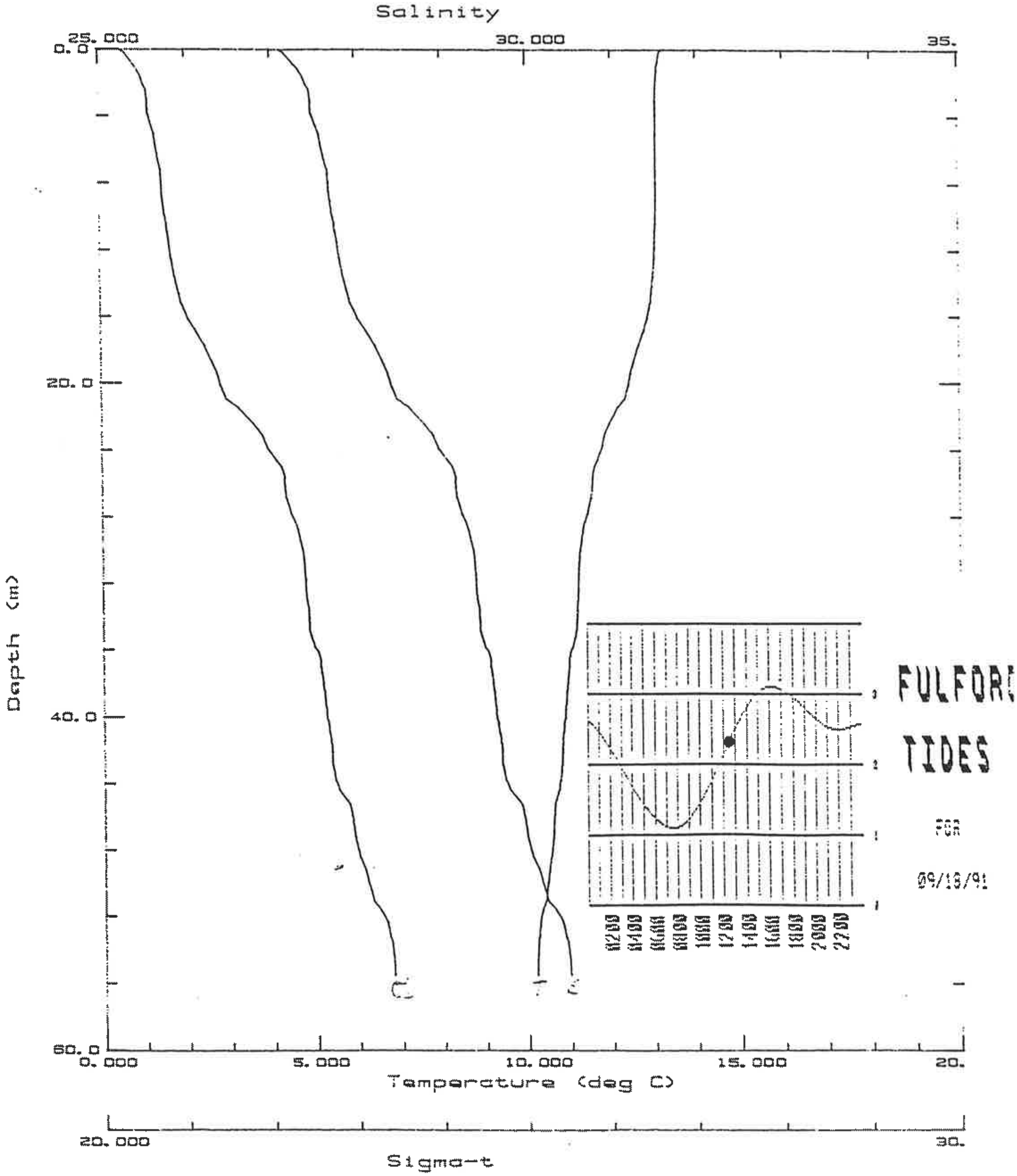


FIGURE 31.

DACP1.avg: SATELLITE CHANNEL. CAST 1

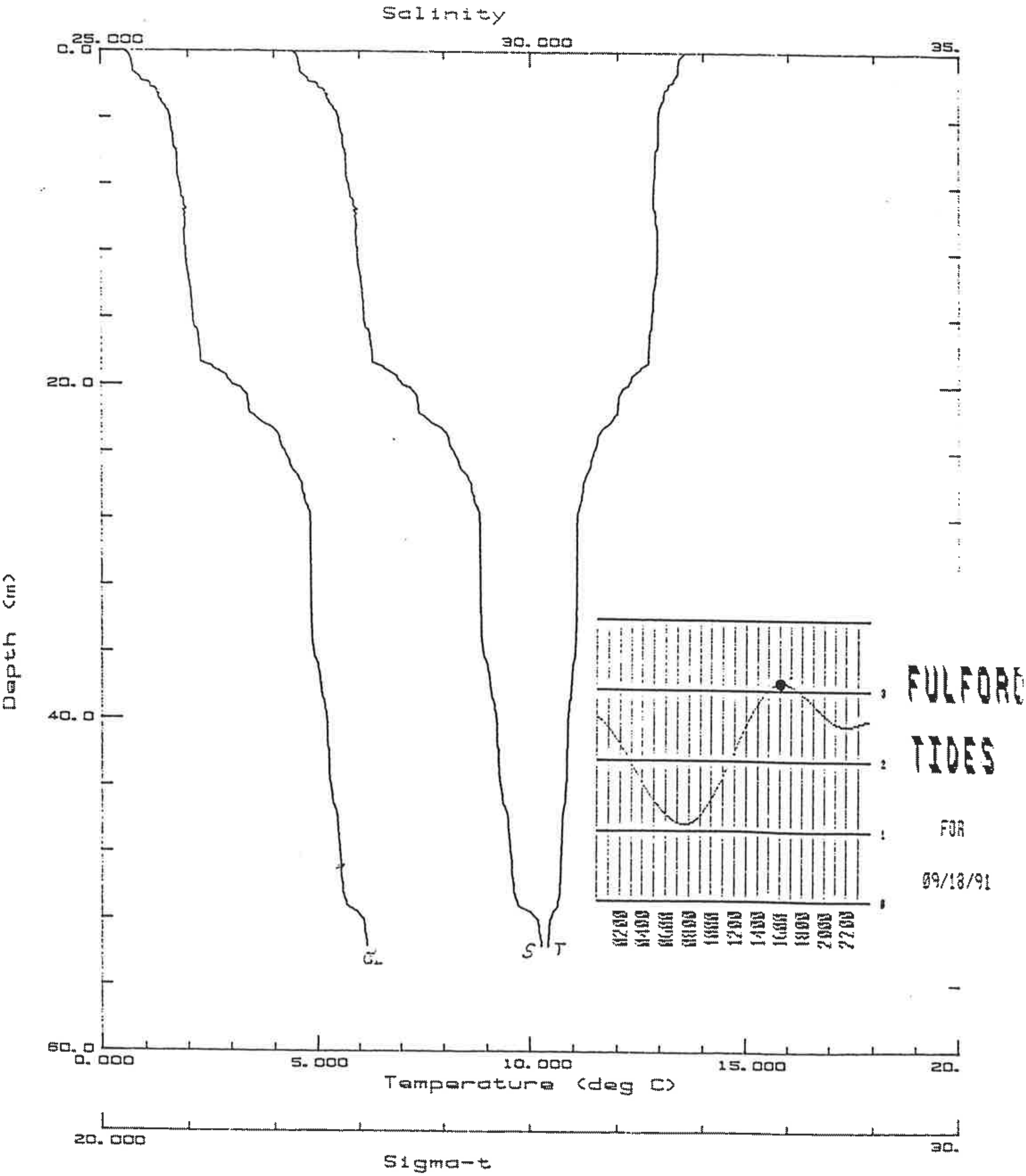


FIGURE 32.

DACOW18.avg: CHERRY POINT, CAST 2

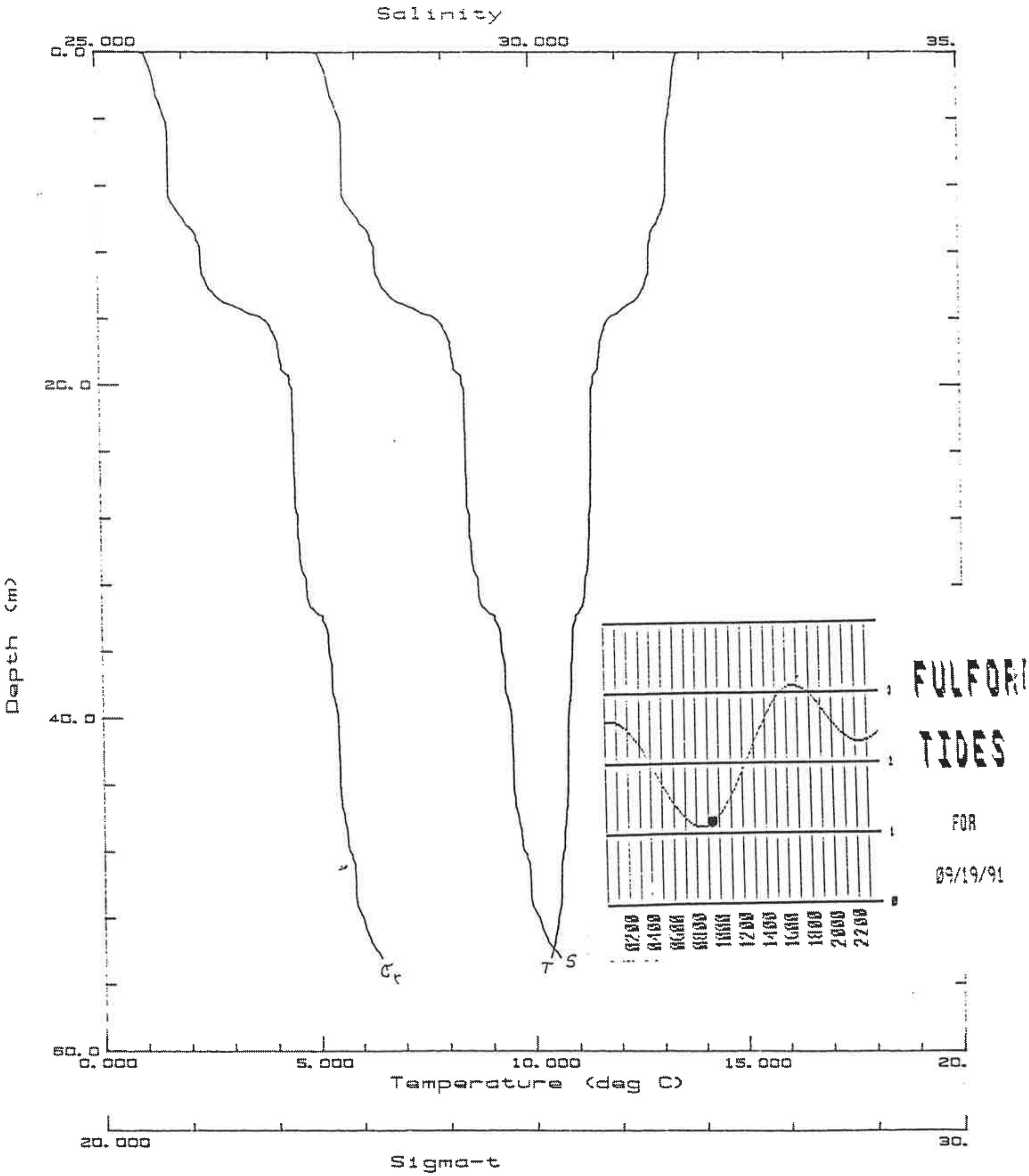


FIGURE 33.

DASEPN2.avg: SEPARATION PT. NORTH. CAST 2

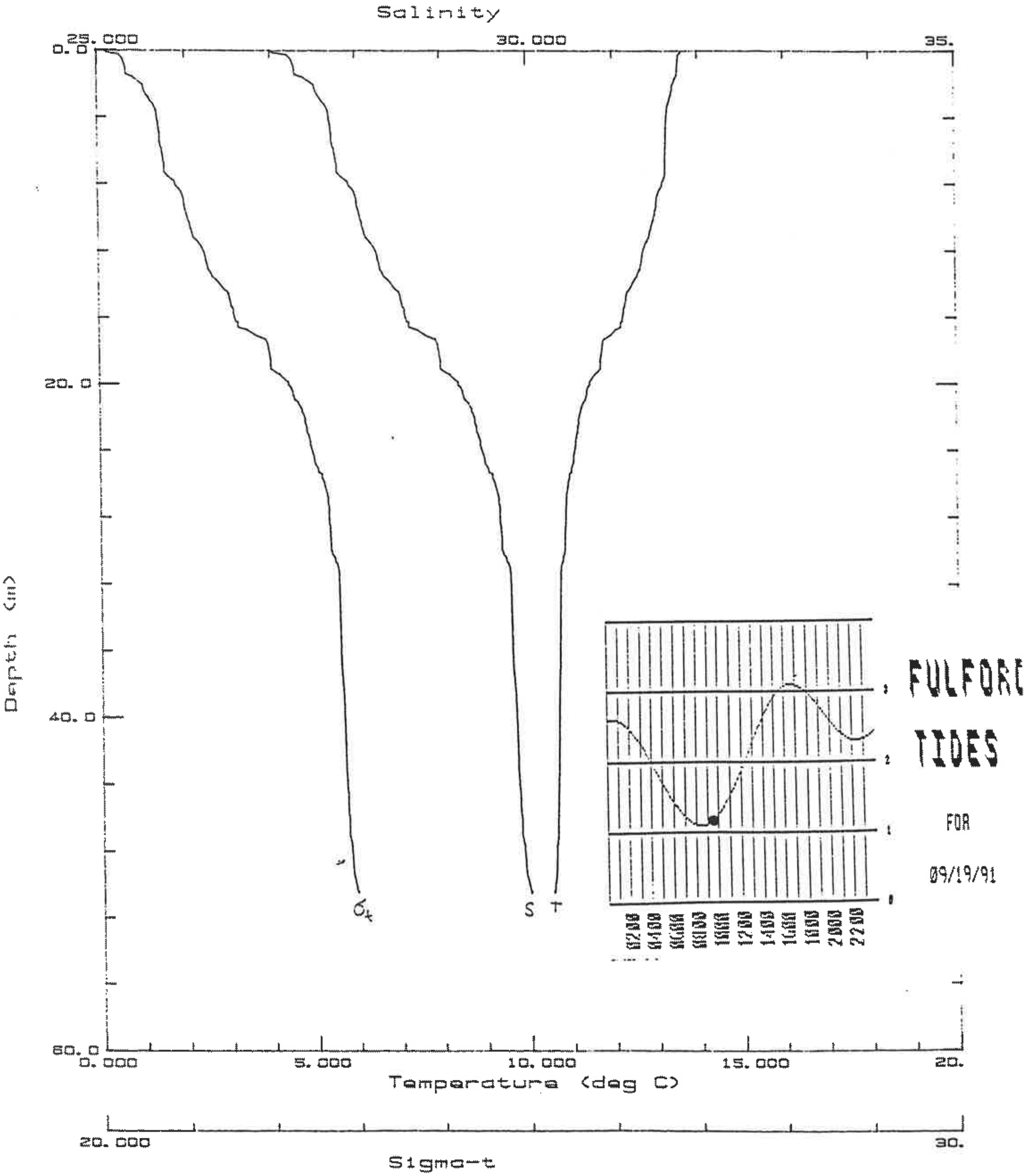


FIGURE 34.

DASEPM2.avg: SEPARATION PT. MIDDLE, CAST 2

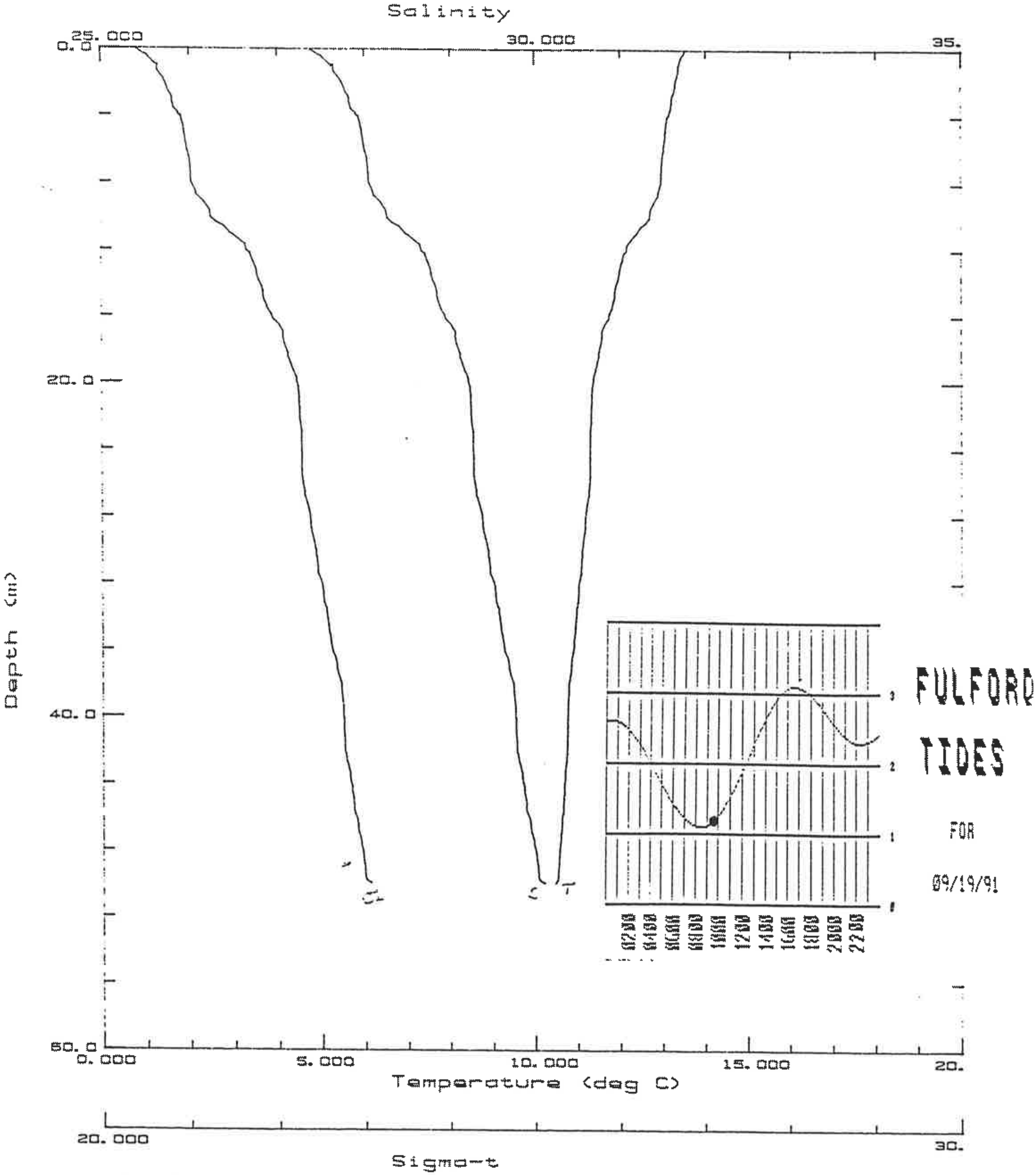


FIGURE 35.

JACOW1C.avg: CHERRY POINT, CAST 3

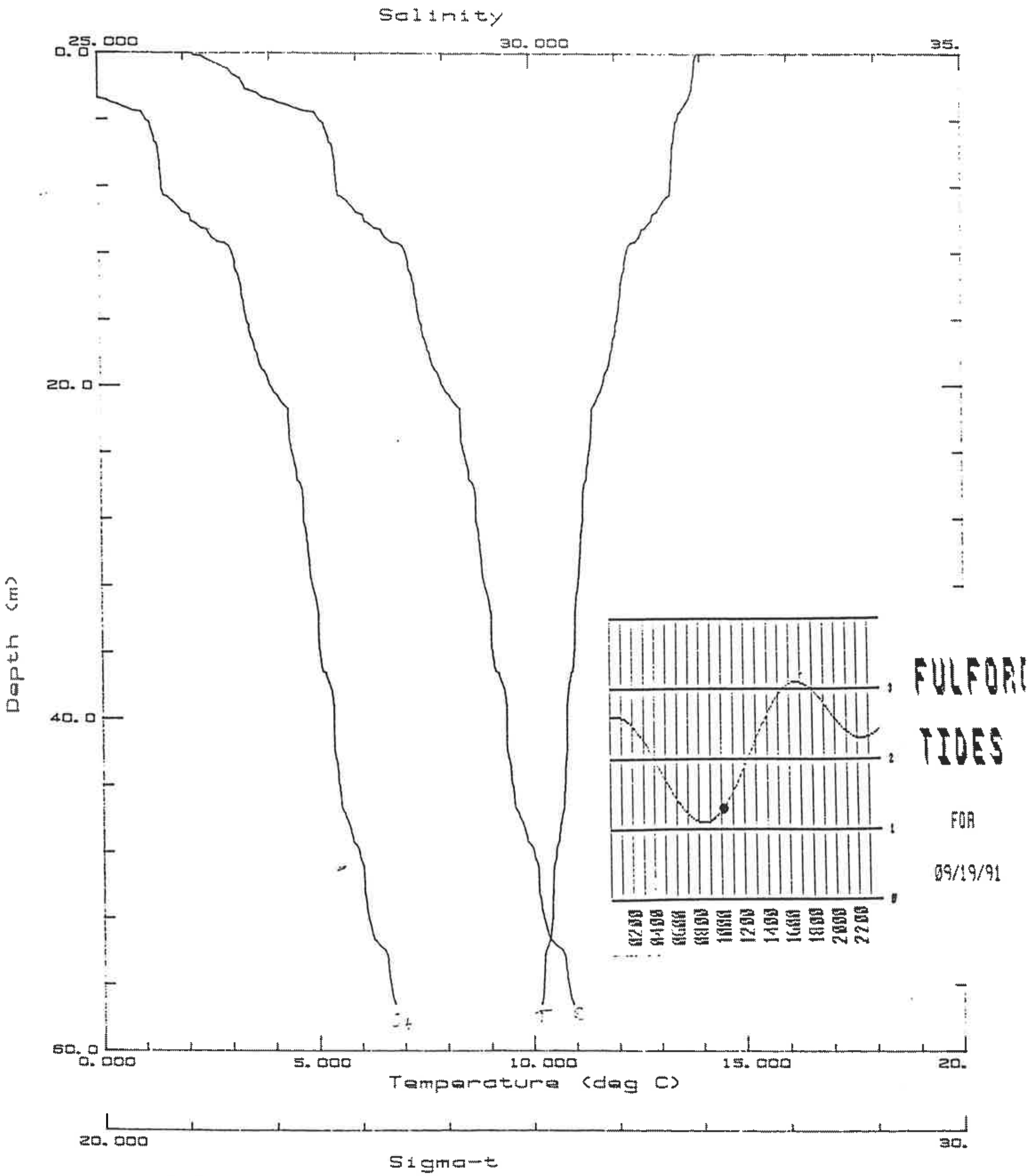


FIGURE 36.

DAMAR2.avg: MARINA MIDDLE. CAST 2

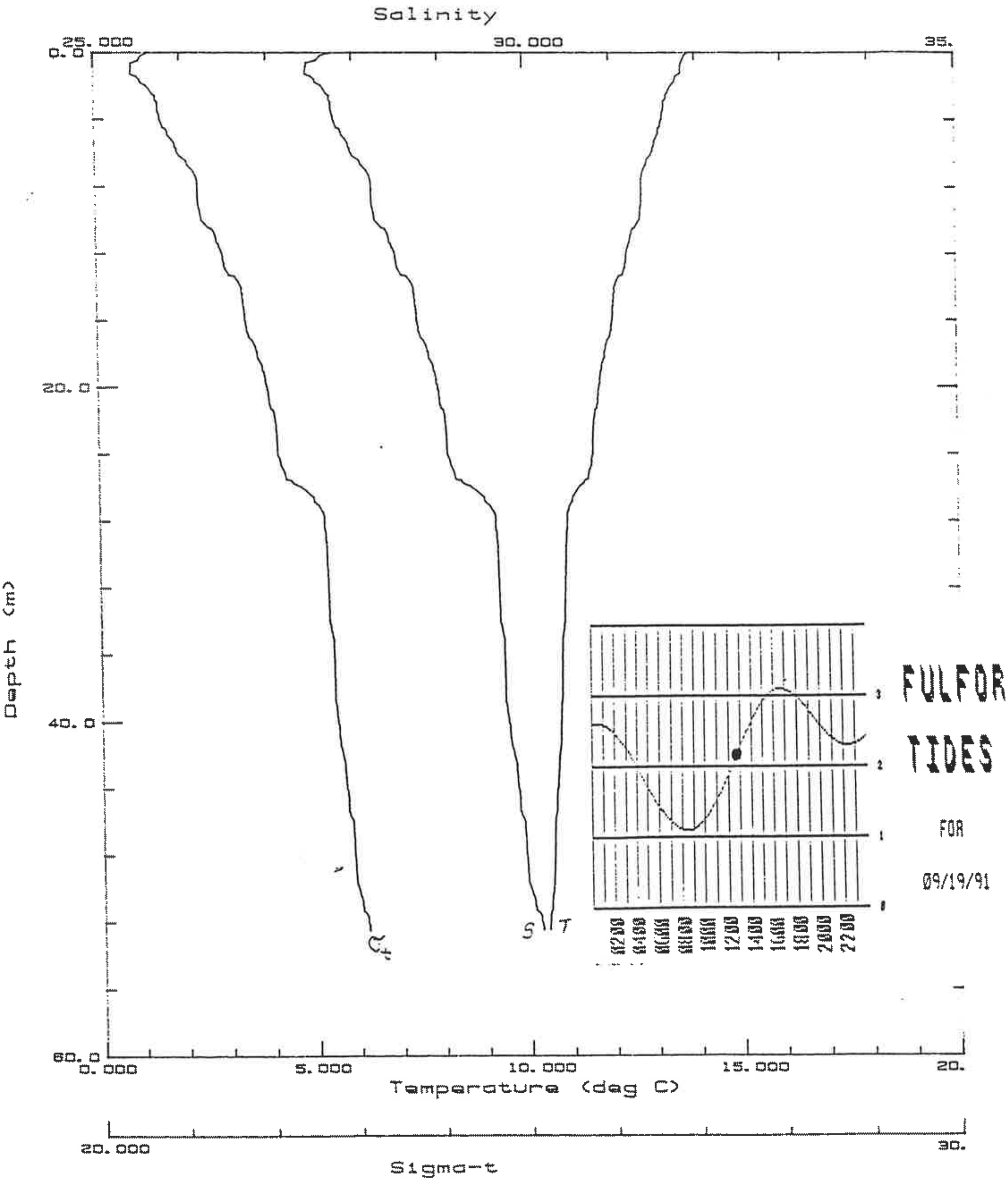


FIGURE 37.

damars1.avg: MARINA SOUTH. CAST 1

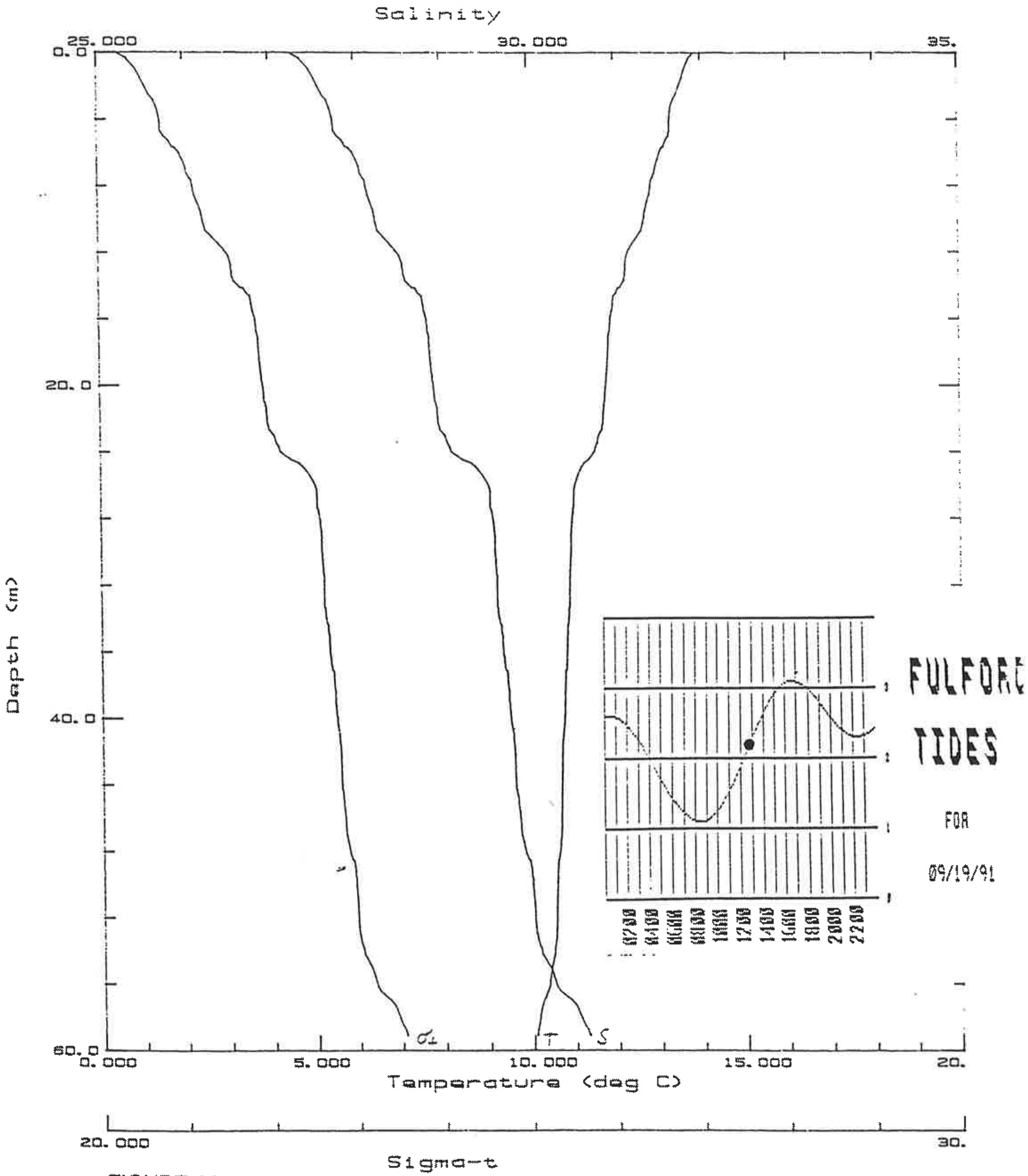


FIGURE 38.

DAMAR3.avg: MARINA MIDDLE. CAST 3

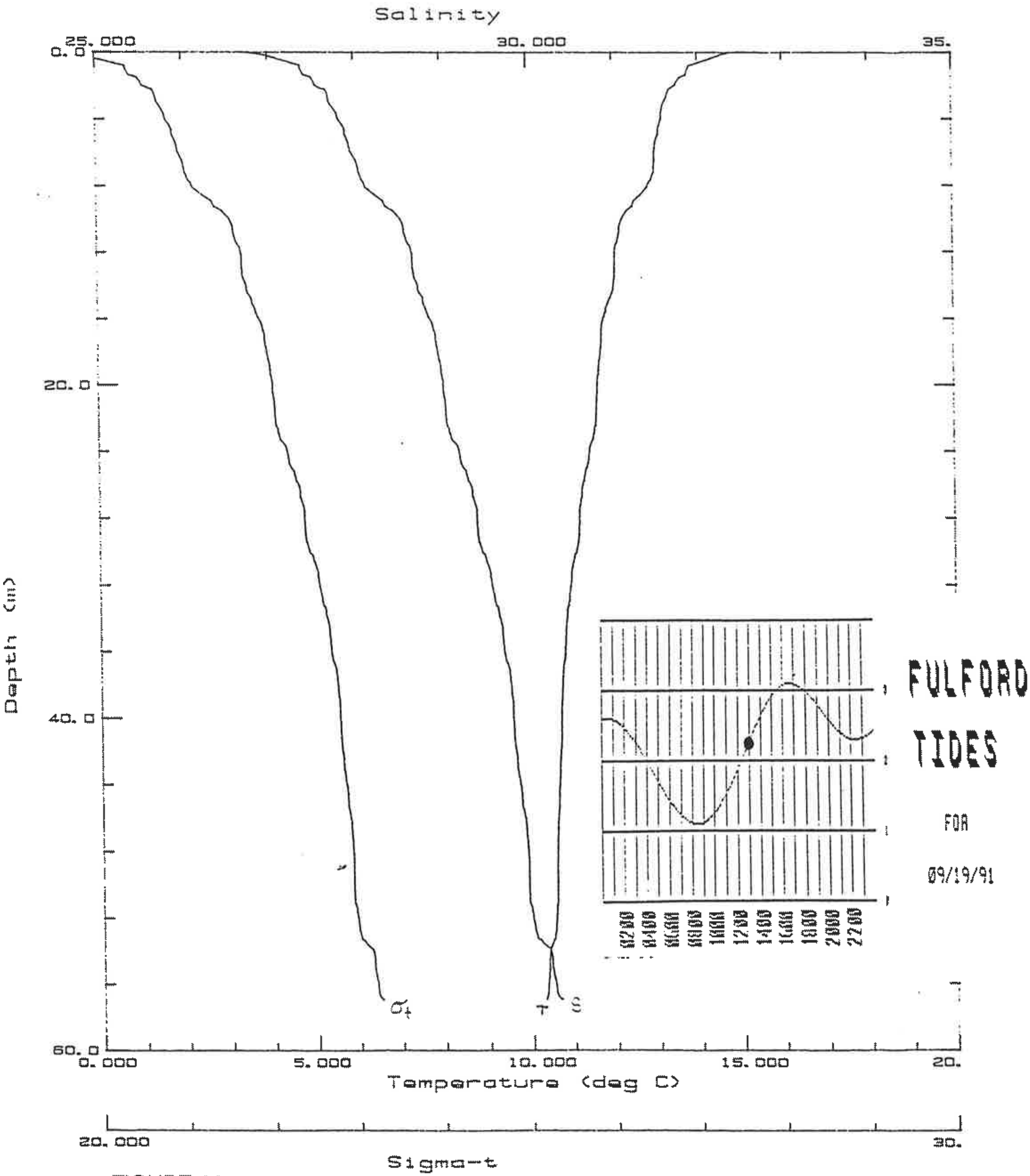


FIGURE 39.

DAMARN1.avg: MARINA NORTH. CAST 1

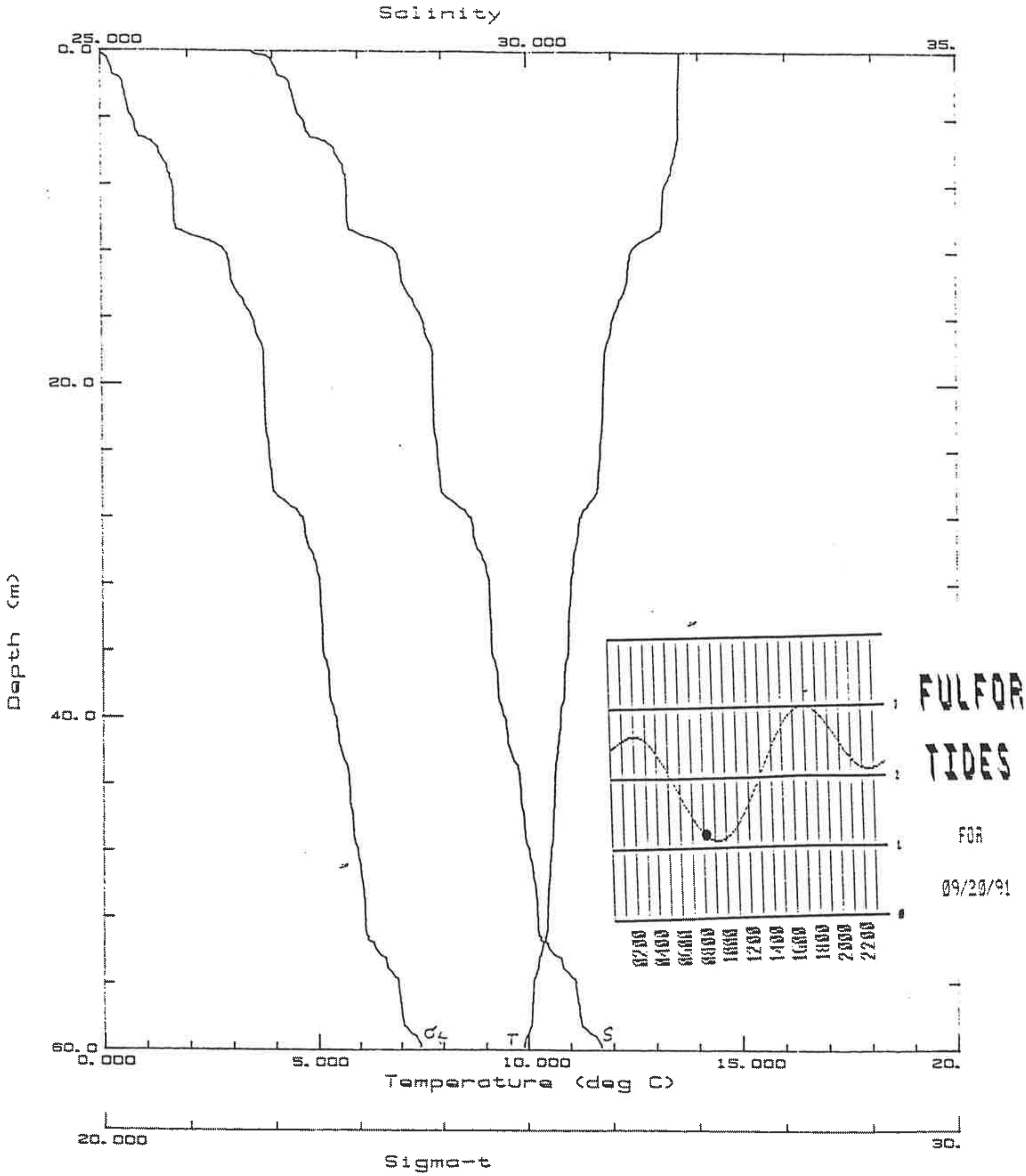


FIGURE 40.

DAMAR4.avg: MARINA MIDDLE. CAST 4

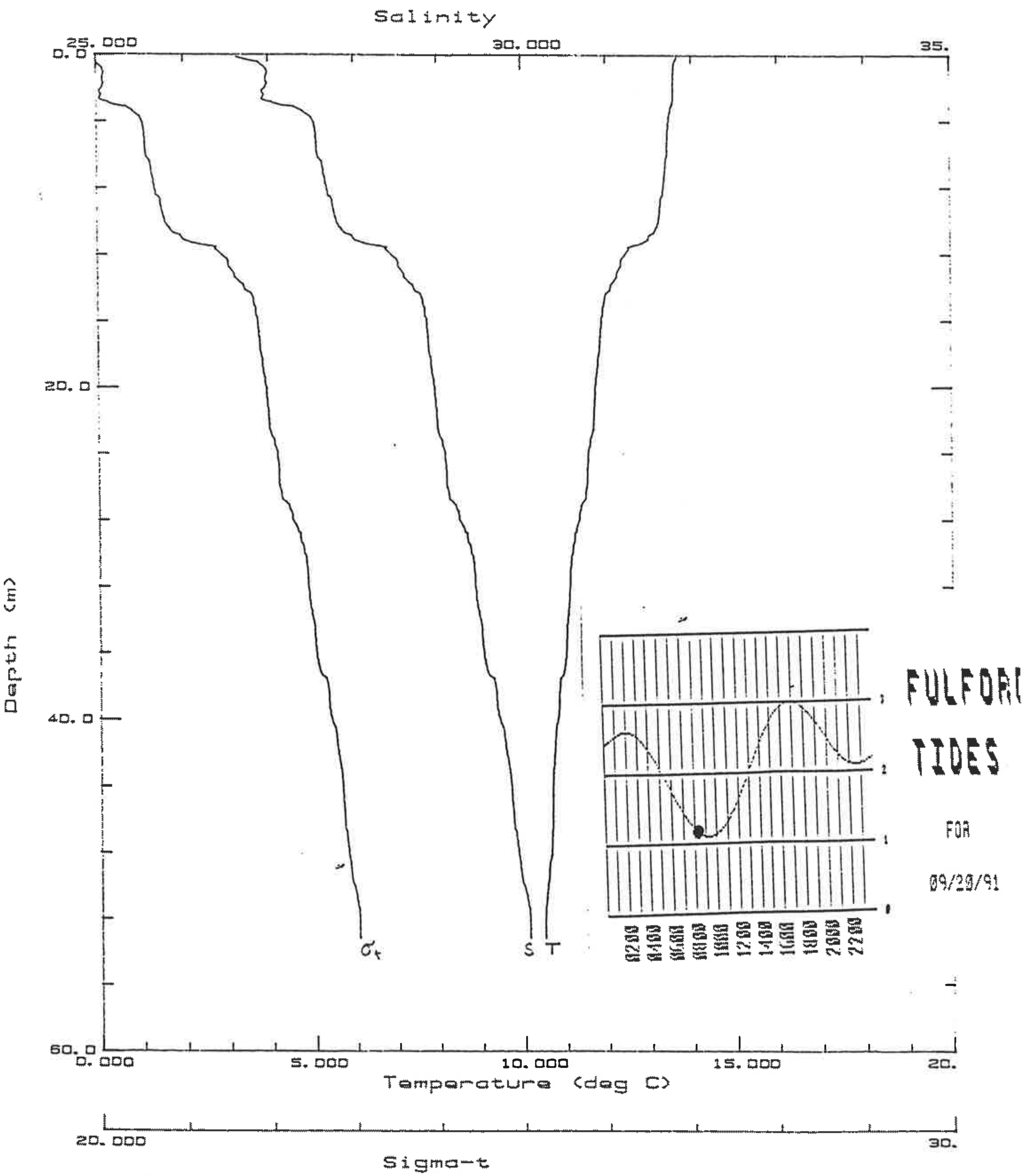


FIGURE 41.

DAMARS2.avg: MARINA SOUTH, CAST 2

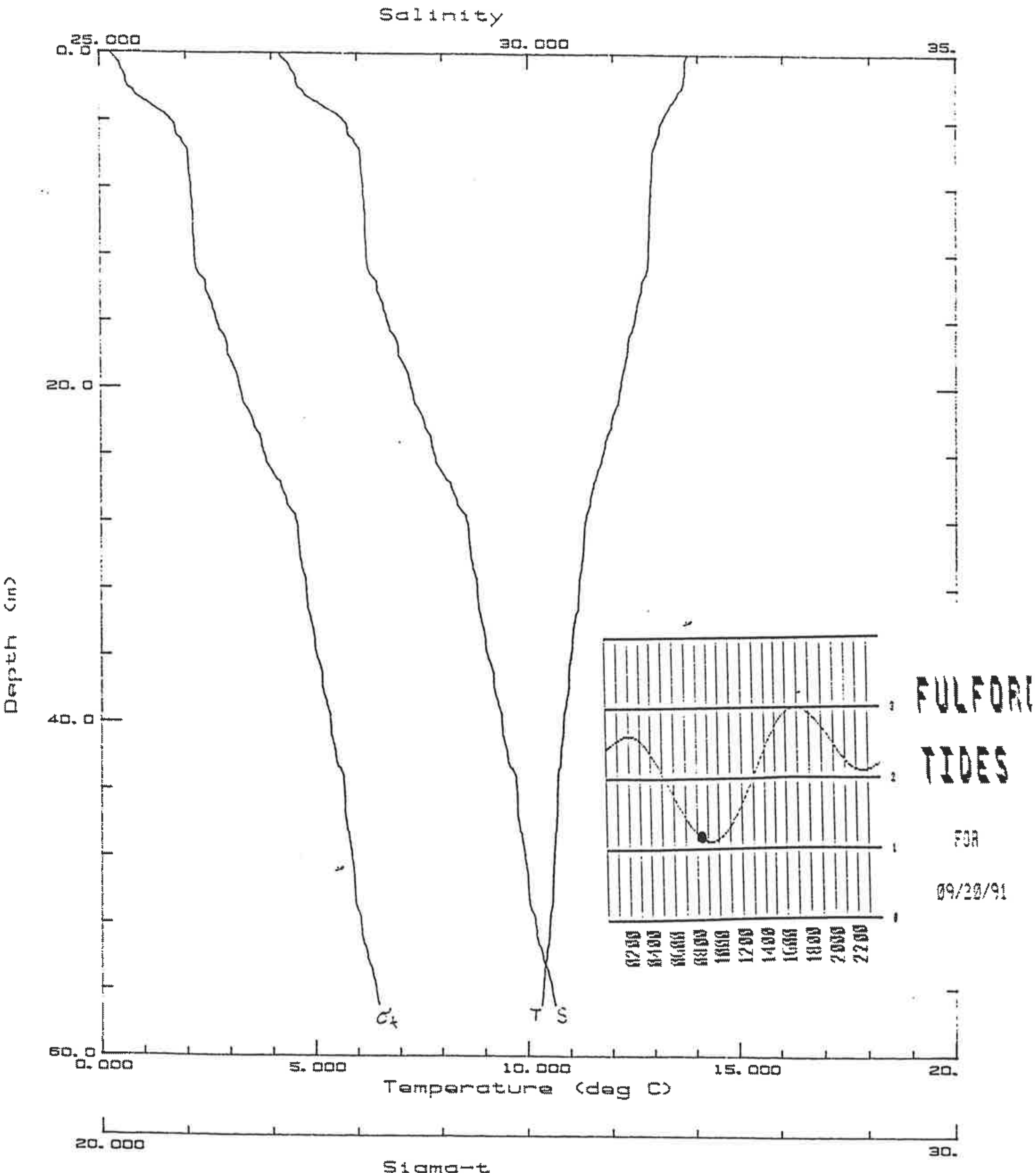


FIGURE 42.

DAMARN2.avg: MARINA NORTH. CAST 2

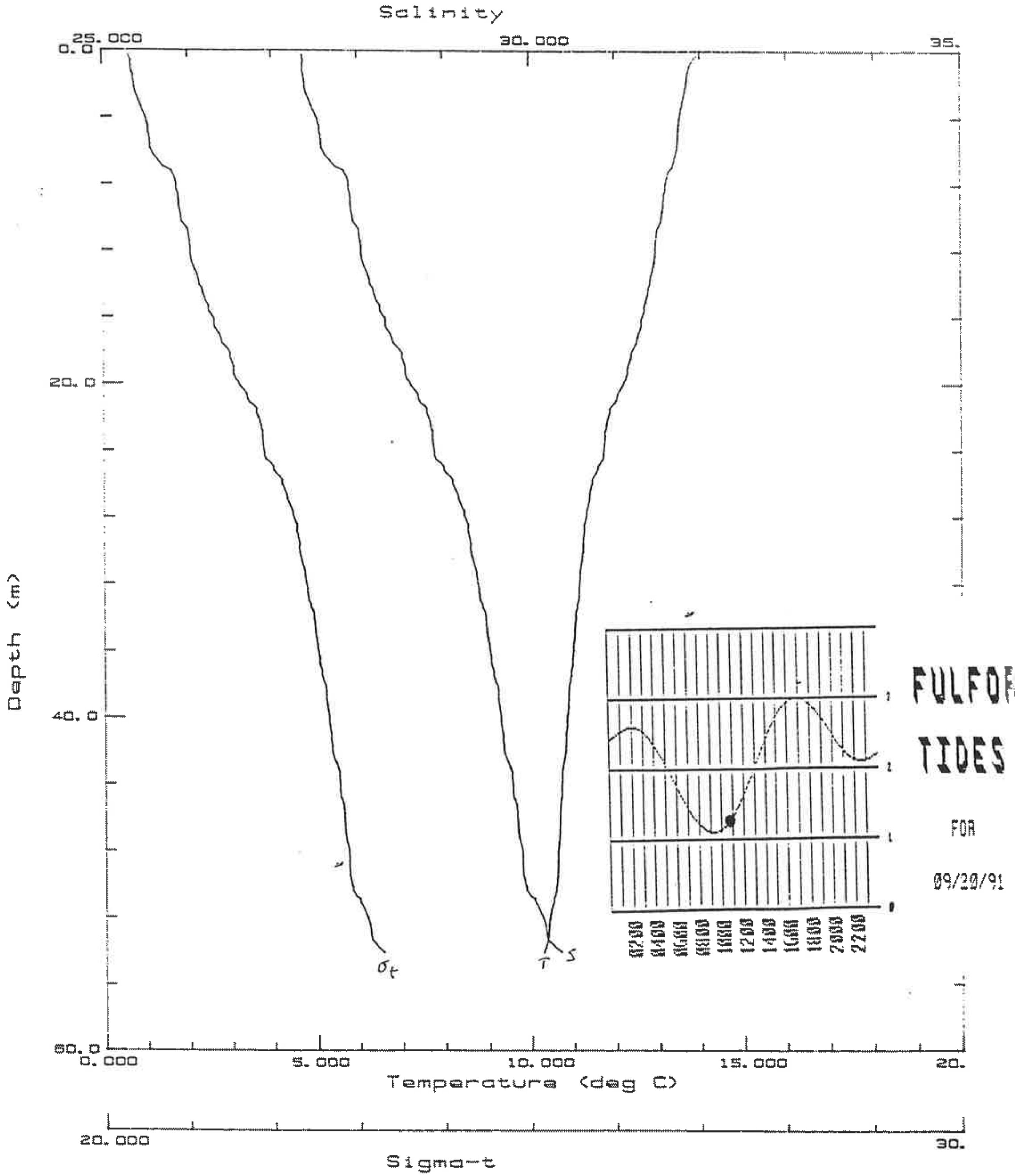


FIGURE 43.

DACHM2.avg: COWICHAN HEAD MIDDLE. CAST 2

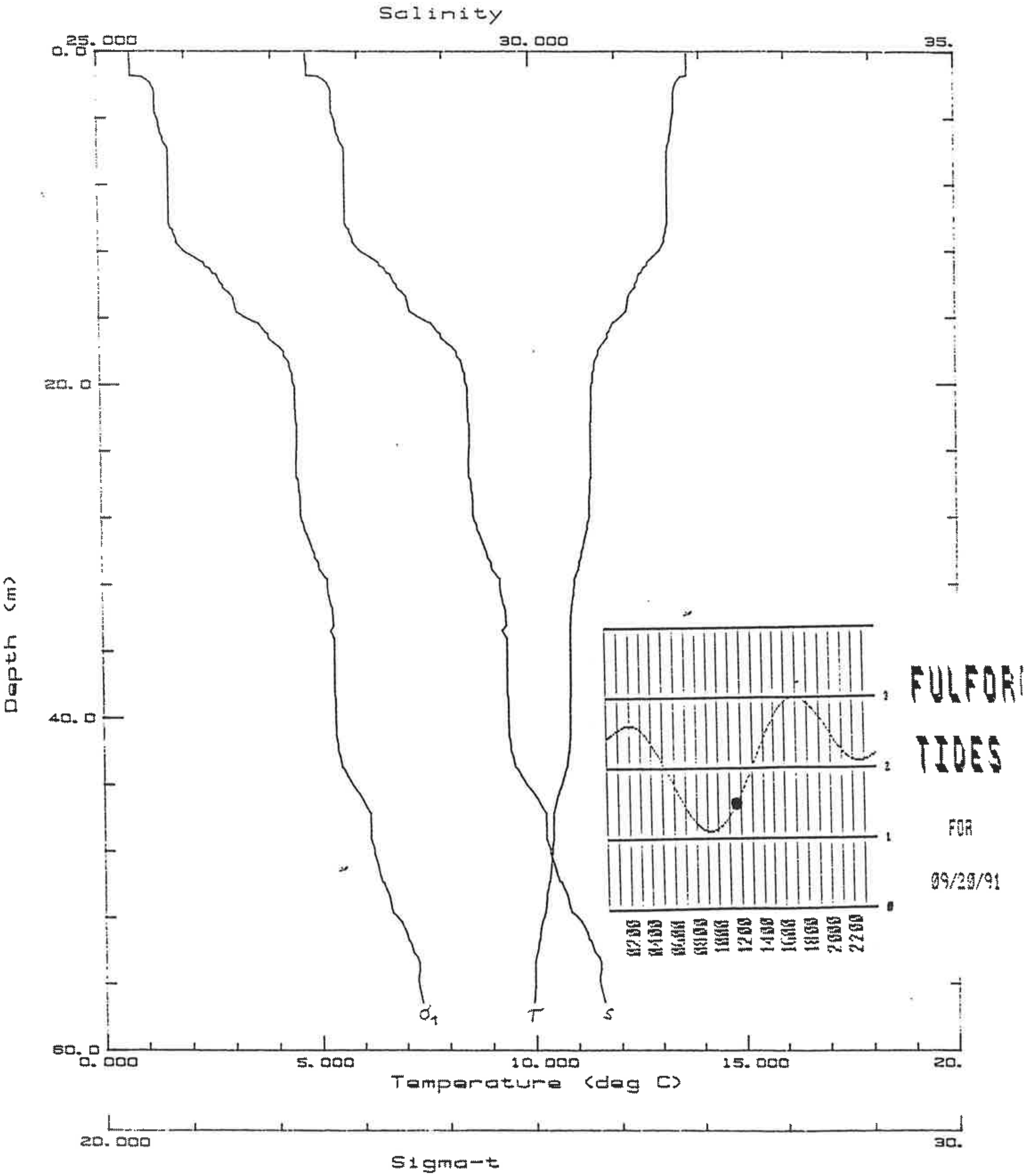


FIGURE 44.

DASN1.avg: SANSUM NARROWS, CAST 1

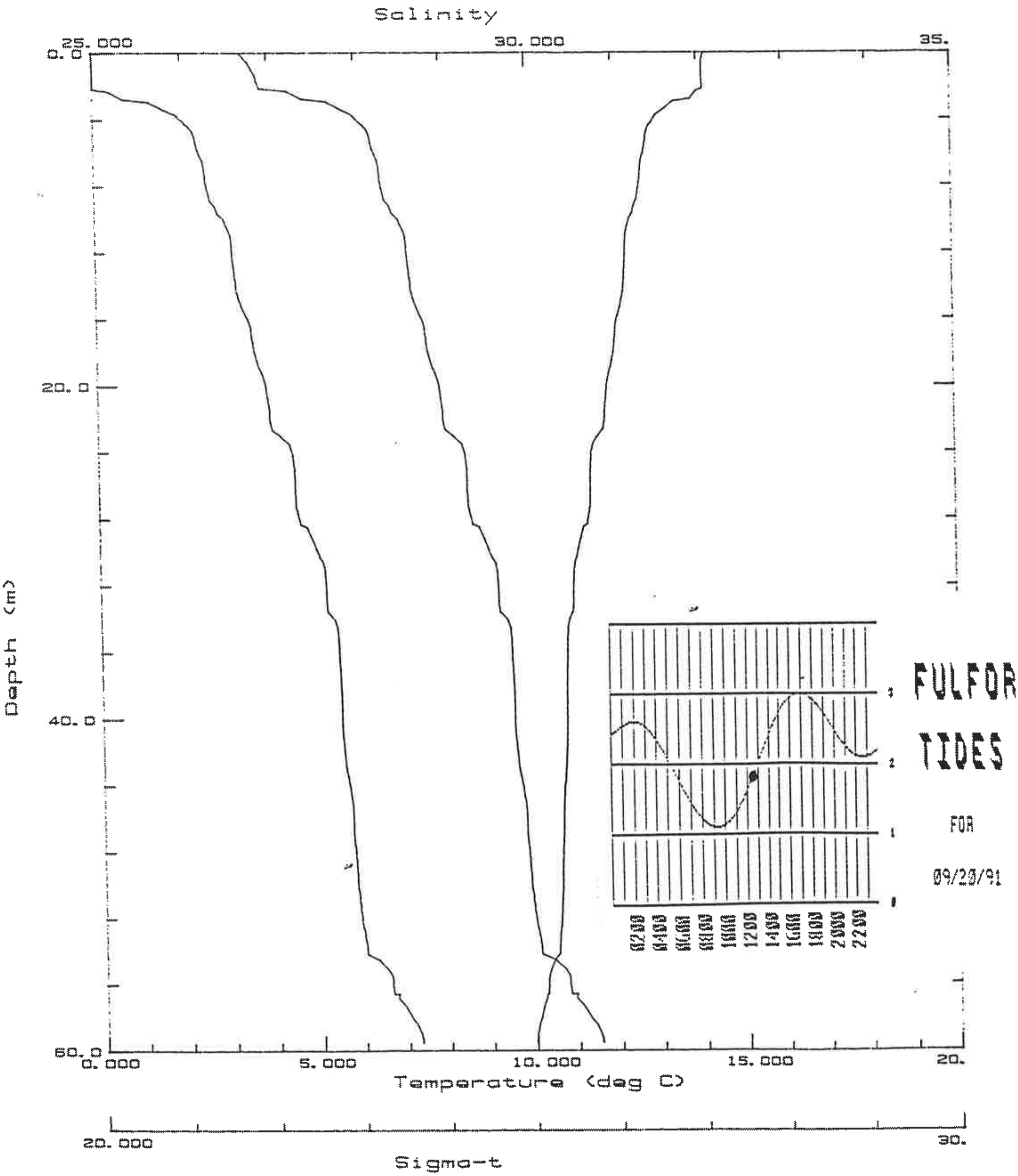


FIGURE 45.

DASEPN3.avg: SEPARATION PT. NORTH. CAST 3

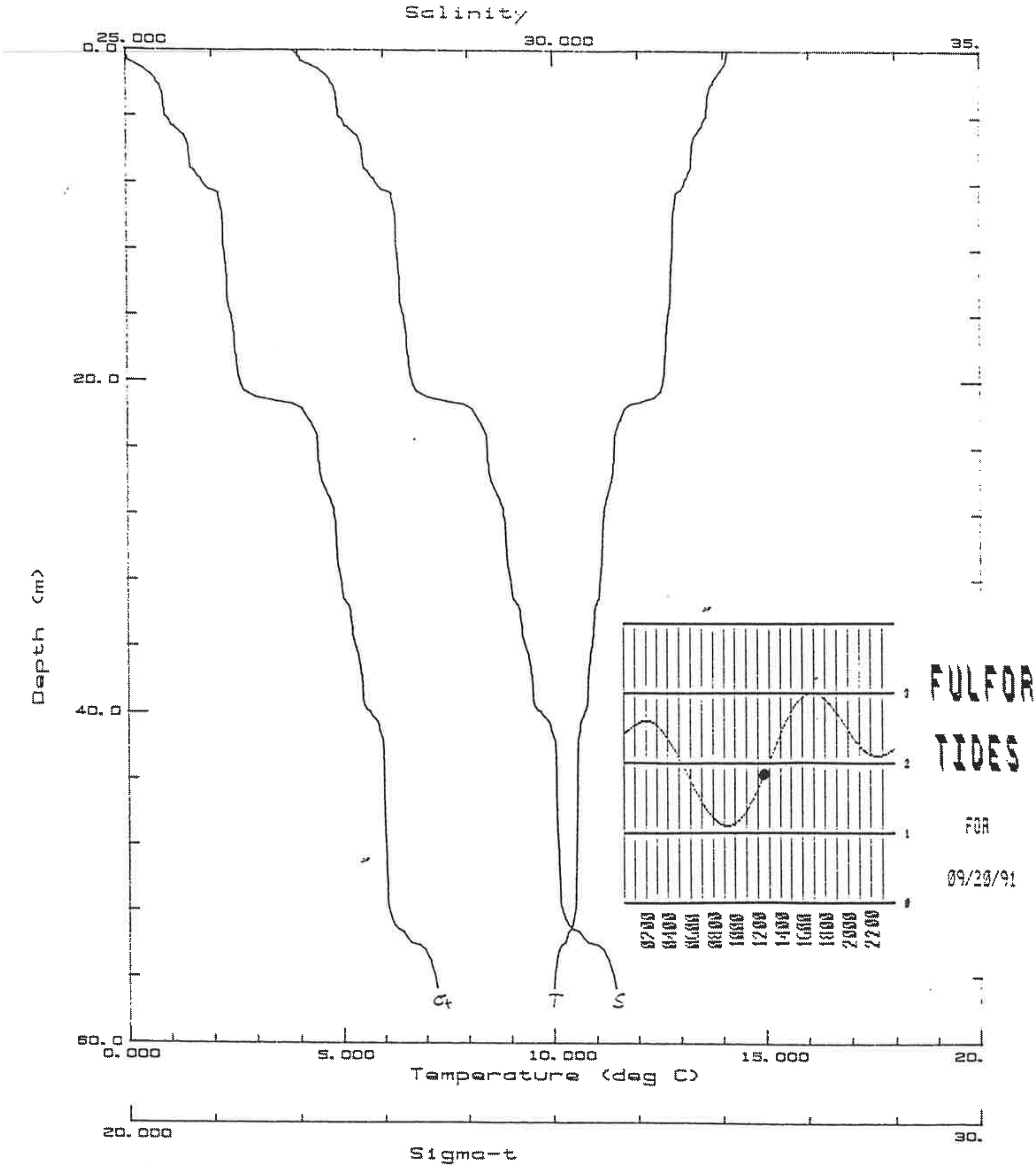


FIGURE 46.

DASEPM3.avg: SEPARATION PT. MIDDLE, CAST 3

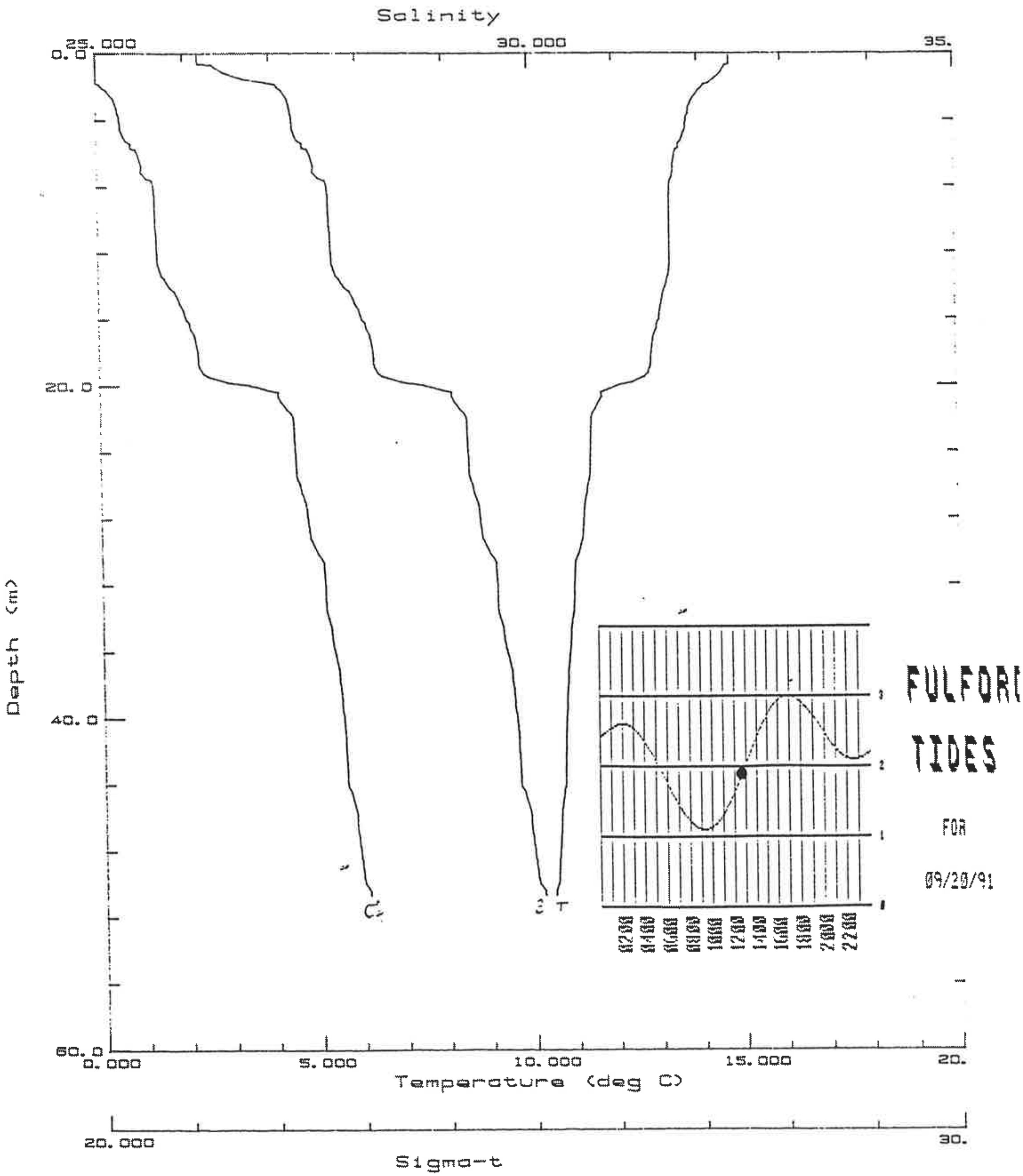


FIGURE 47.

OACOW10. avg: CHERRY POINT. CAST 4

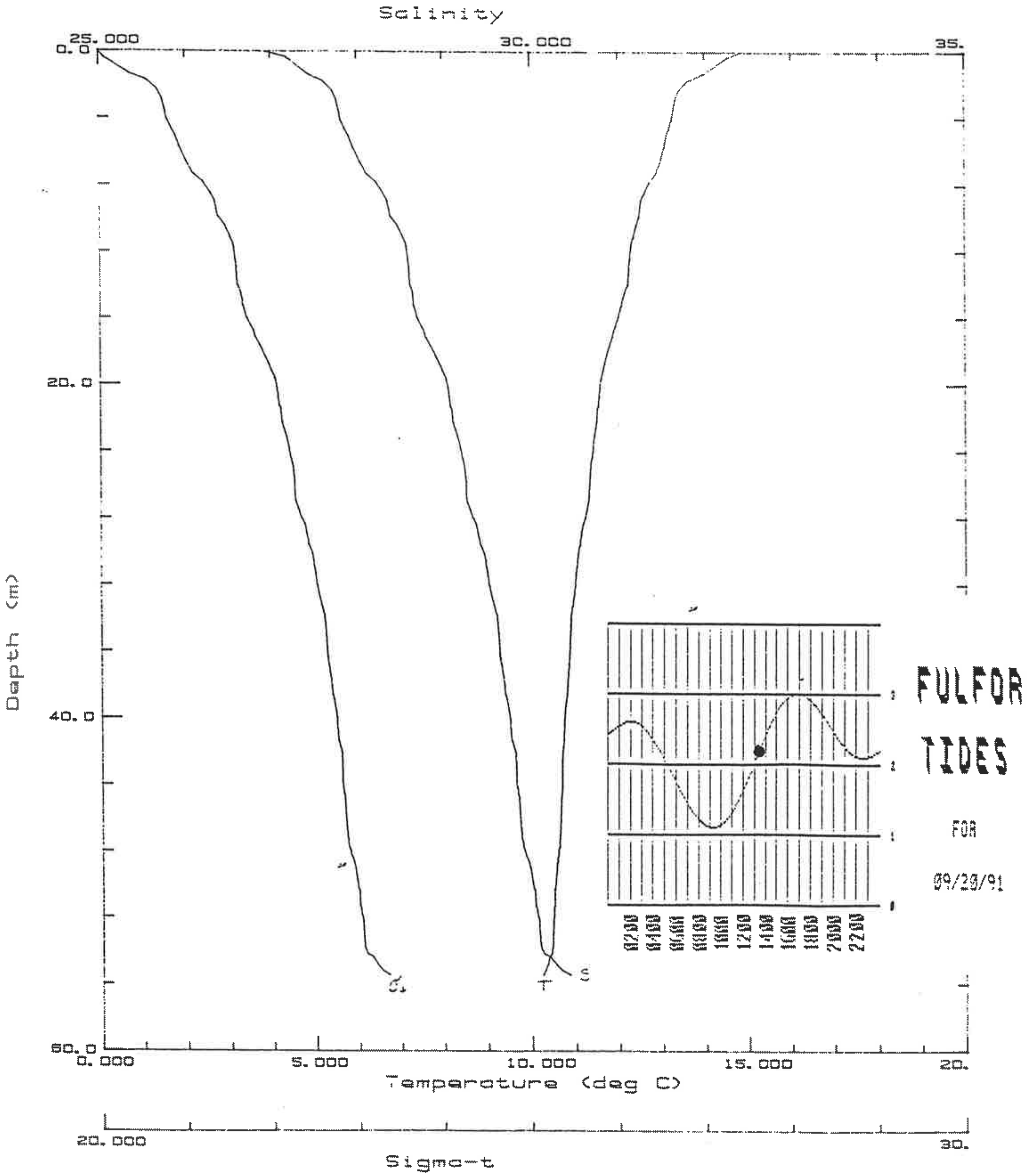


FIGURE 48.

DACHN1.avg: COWICHAN HEAD NORTH. CAST 1

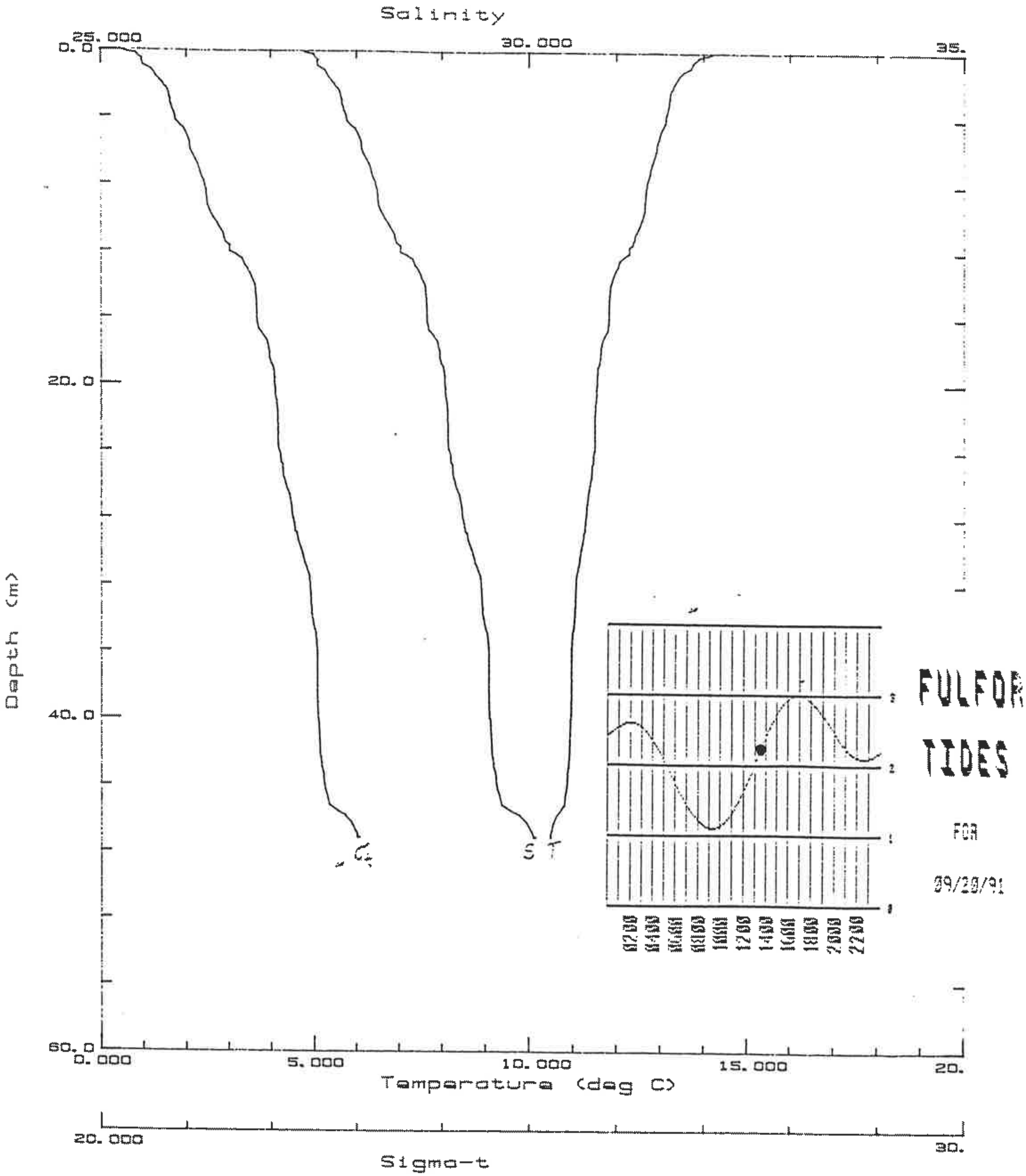


FIGURE 49.

DACHS1.avg: COWICHAN HEAD SOUTH. CAST 1

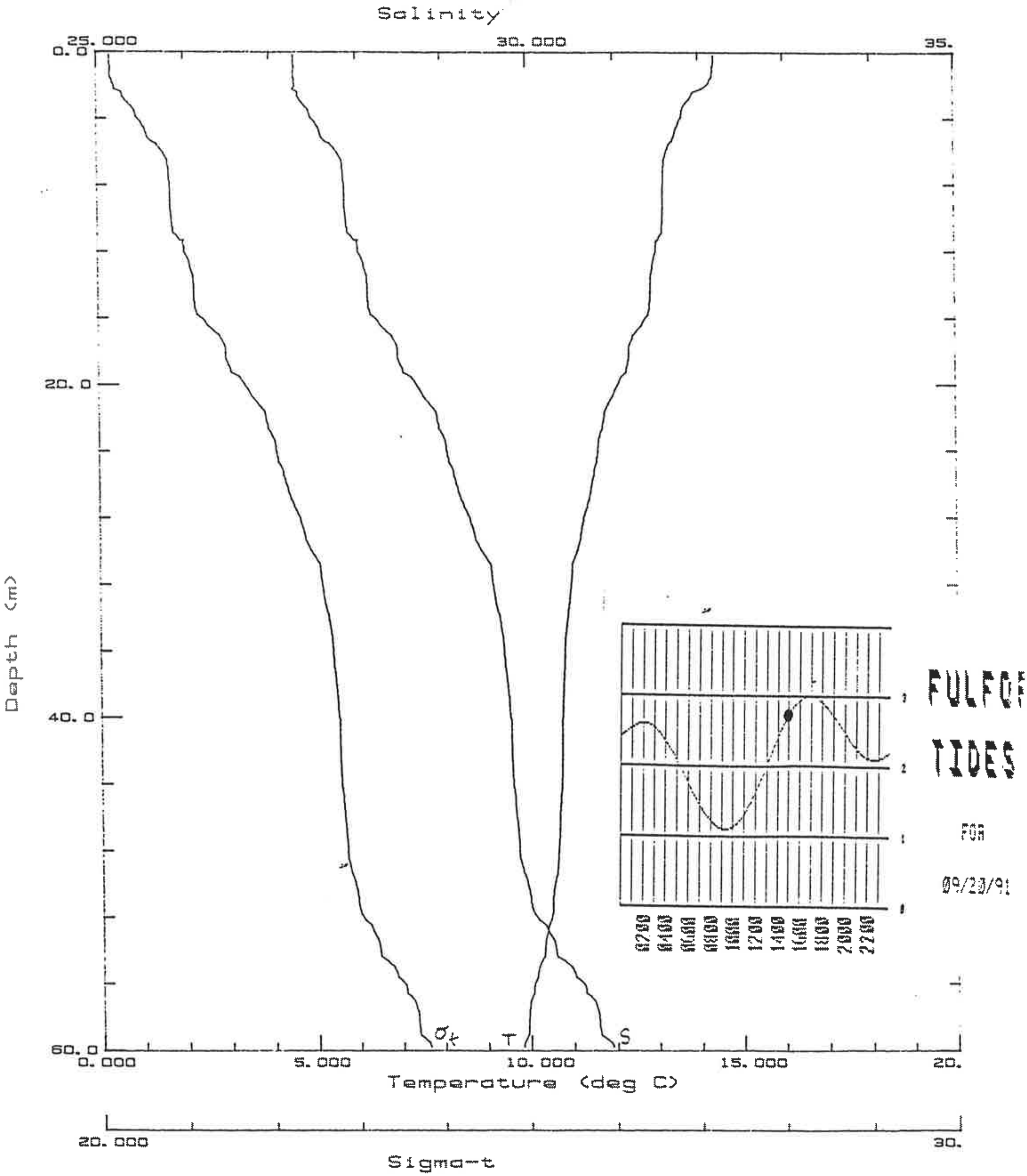
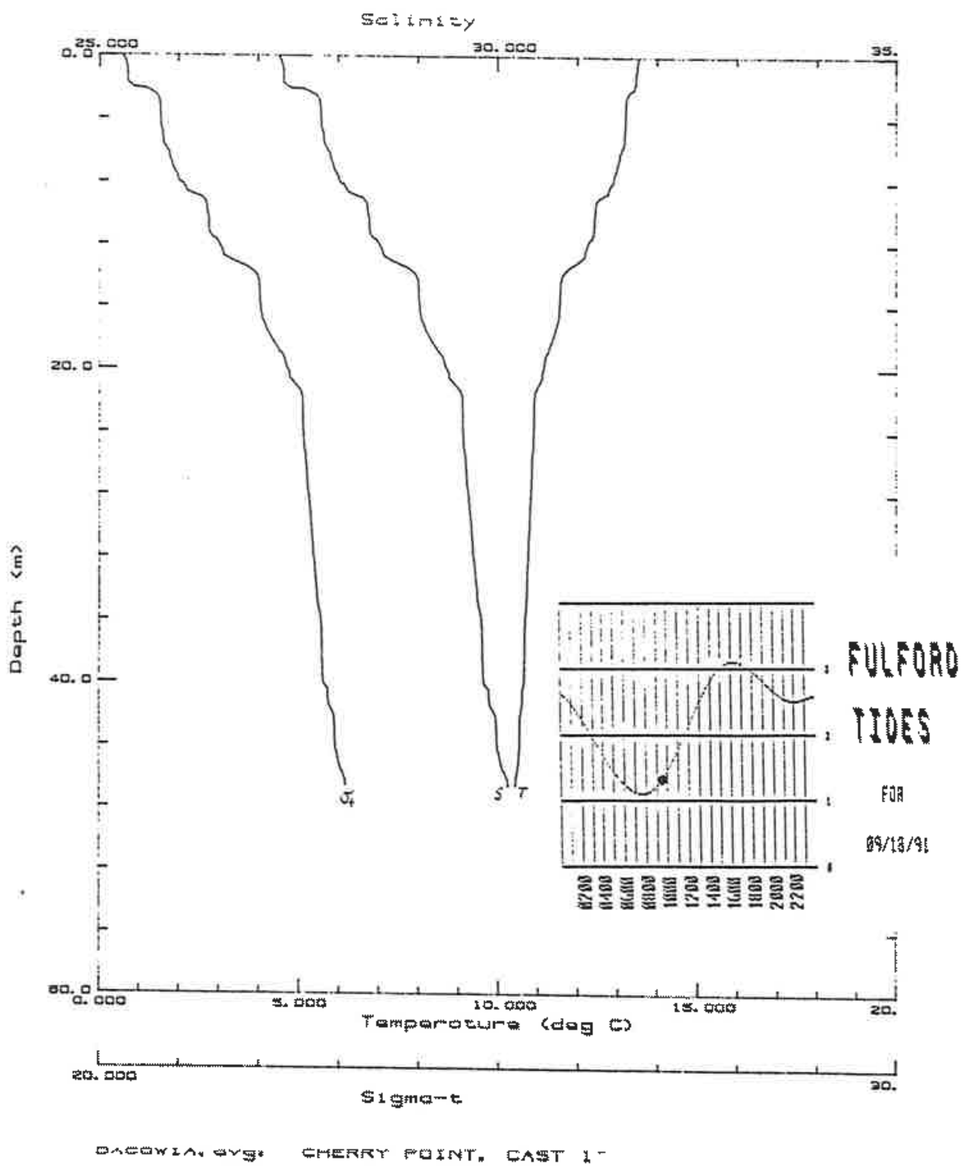


FIGURE 50.

DAMAR5.avg: MARINA MIDDLE, CAST 5



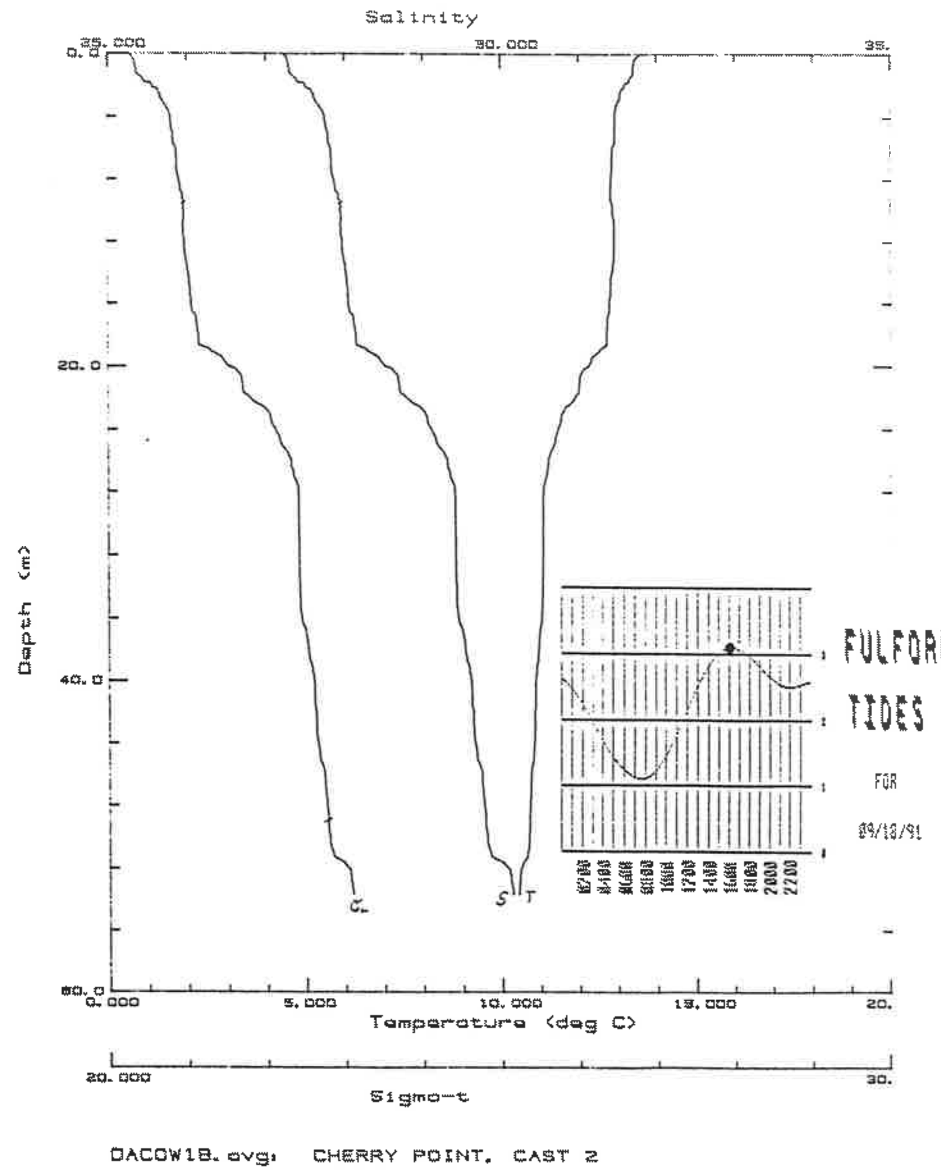
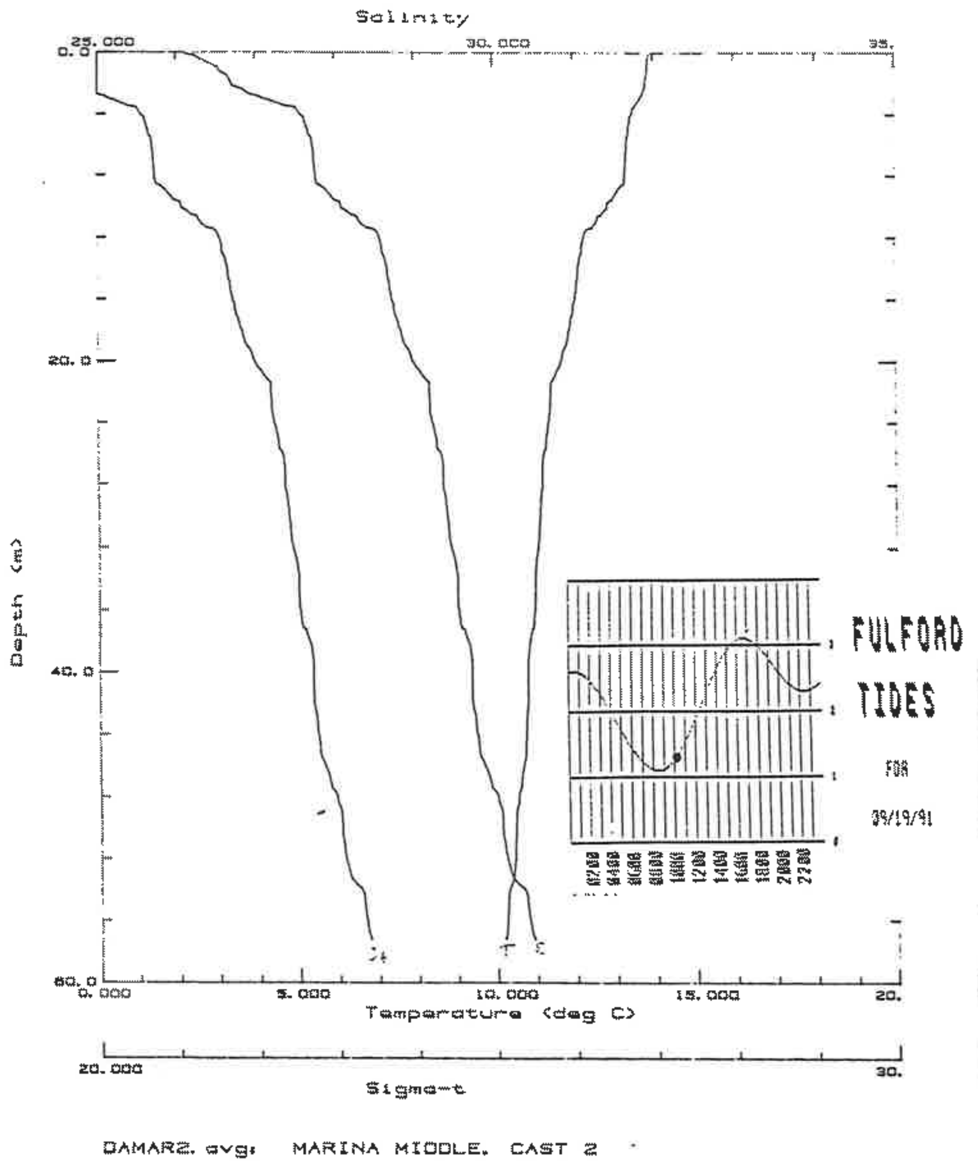


Figure 51. Vertical Profiles at Ebb and Flood Tides for Station COW 1, Sept. 18, 1991.



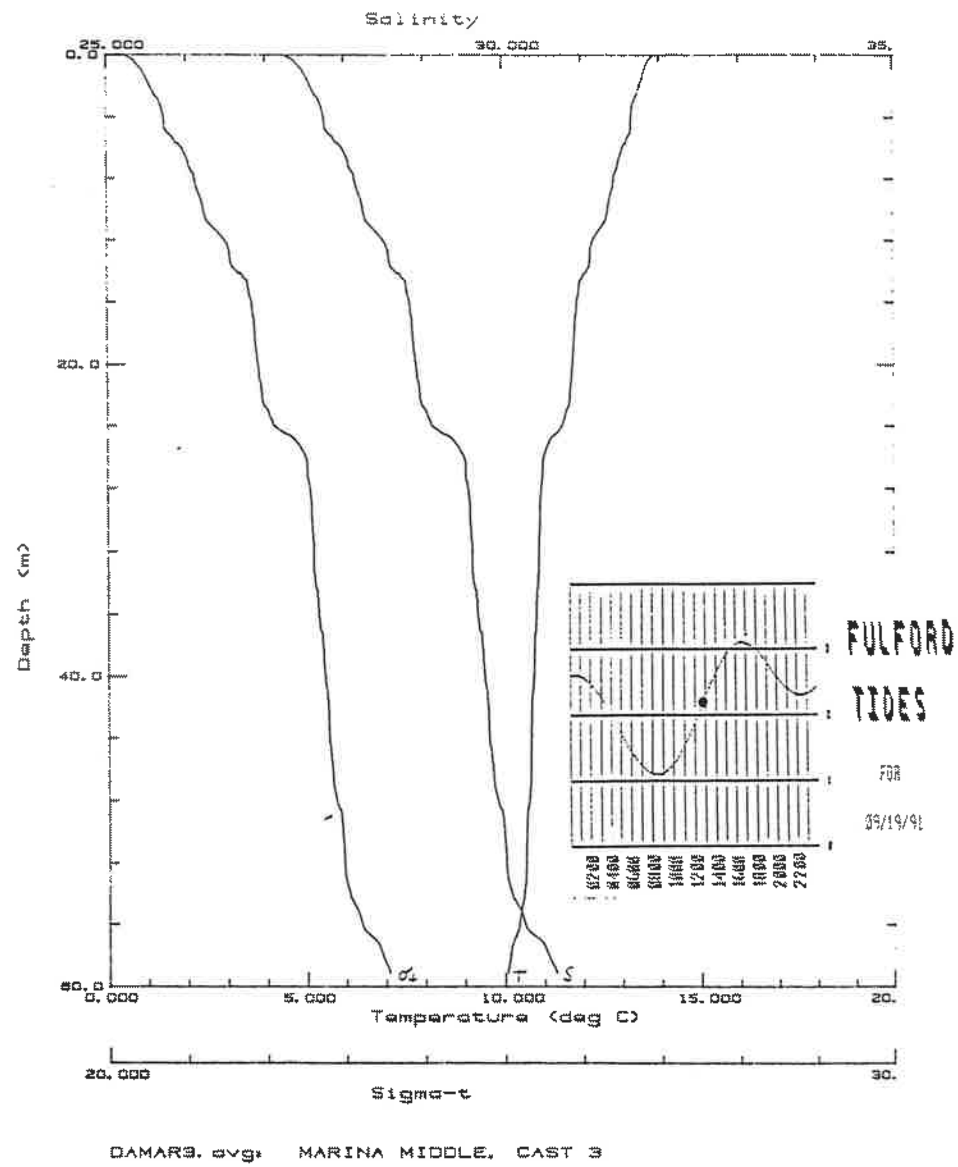


Figure 52. Vertical Profiles at Ebb and Flood Tides for Station MARM, Sept. 19, 1991.

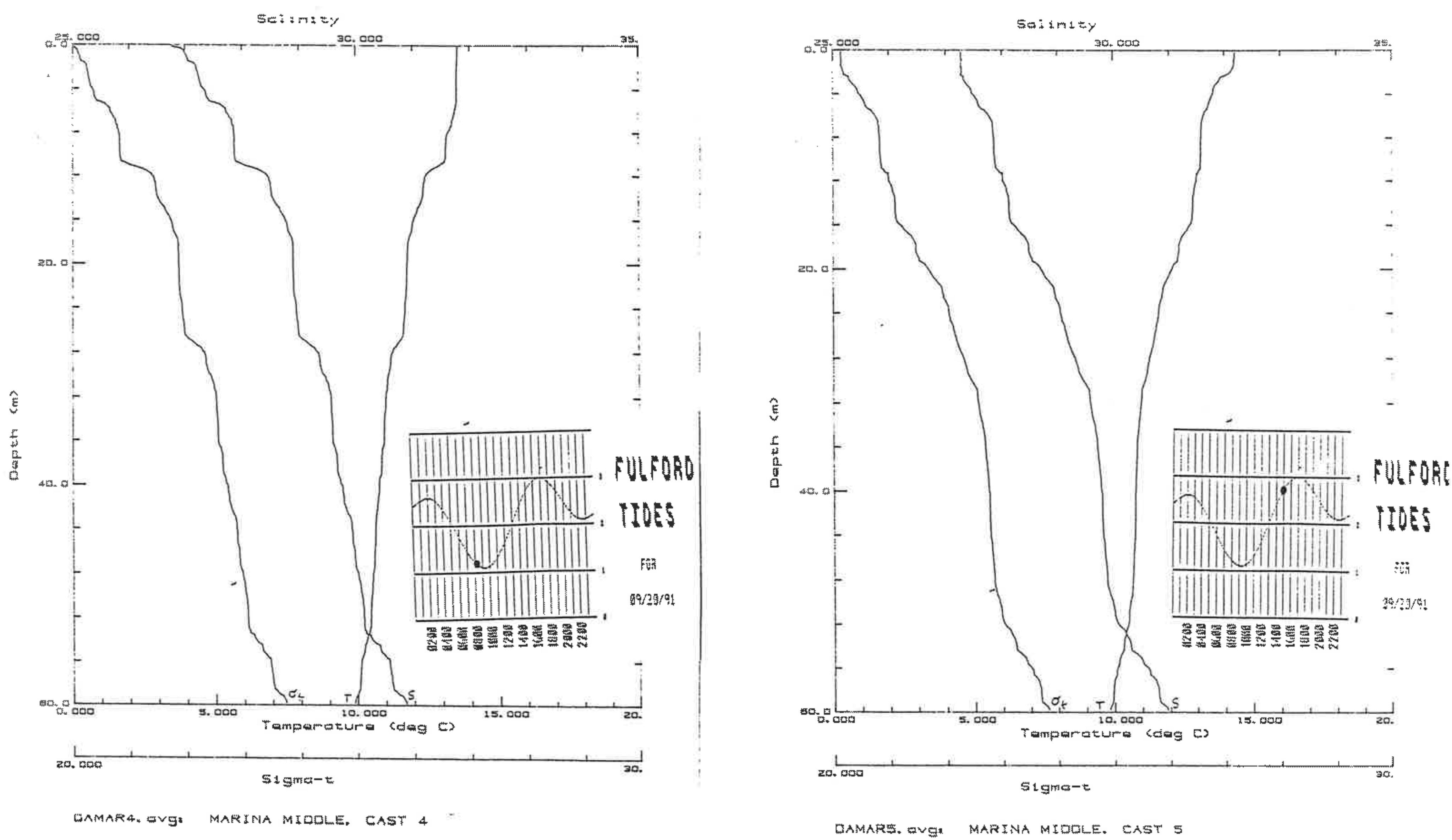


Figure 53. Vertical Profiles at Ebb and Flood Tides for Station MARM, Sept. 20, 1991.

APPENDIX I.

DROGUE STUDY
CURRENT VELOCITIES

SURFACE CURRENTS, SEPTEMBER 18, 1991
DROGUE STUDY CURRENT VELOCITIES

TIME	DROGUE	UTM NORTH	UTM EAST	CURRENT VELOCITY (CM/S)
1210	44	5397151	458933	0.00
1248	44	5397817	459800	47.95
1349	44	5397684	459282	14.61
1536	44	5396706	458839	16.72
1650	44	5397934	458829	27.66
1737	44	5398442	459424	27.74
1215	12	5398201	458287	0.00
1253	12	5398301	457922	16.60
1415	12	5397259	457844	21.24
843	11	5397217	459056	0.00
926	11	5397016	458865	10.75
1044	11	5398109	460569	43.26
1136	11	5397658	459246	44.80
1424	11	5397277	458152	11.49
1508	11	5398058	457718	33.84
1547	11	5398178	458669	40.96
1618	11	5398375	459403	40.86
1658	11	5396742	460400	79.72
910	10	5397035	459337	0.00
1032	10	5397843	458309	26.58
1202	10	5397552	458672	8.62
1225	10	5396820	458795	53.79
1305	10	5397256	458725	18.40
1353	10	5398695	457975	56.34
903	7	5397064	459037	0.00
1005	7	5397916	459161	23.14
1157	7	5398736	458684	14.12
1229	7	5397831	458428	48.98
1308	7	5398497	458560	29.02
1409	7	5397911	458374	16.80
1437	7	5398444	458301	32.02
1512	7	5398535	458579	13.93
1541	7	5397575	459322	69.77
1631	7	5398617	459253	34.81
1720	7	5399142	458540	30.12
858	6	5397088	458617	0.00
947	6	5397321	458958	14.05
1103	6	5397588	458983	5.88
1232	6	5397755	459225	5.51
1258	6	5398351	458809	46.59
1342	6	5398099	458726	10.05
1441	6	5398151	458402	9.27
1526	6	5397546	458529	22.90
1626	6	5397784	458505	6.64
1728	6	5397356	458318	12.56
915	4	5397026	459633	0.00
940	4	5396863	459643	10.89
1039	4	5396211	459897	19.77
1142	4	5397689	460372	41.07
1402	4	5397449	459273	13.39
1449	4	5397150	459361	11.05
1519	4	5396863	459182	18.79

DEEP (10m) CURRENTS, SEPTEMBER 18, 1991
DROGUE STUDY CURRENT VELOCITIES

TIME	DROGUE	UTM NORTH	UTM EAST	CURRENT VELOCITY (CM/S)
1414	32	5397934	458433	0.00
1517	32	5396906	458372	27.24
1644	32	5396334	458990	16.13
1800	32	5397213	460103	31.10
1402	29	5397993	458962	0.00
1512	29	5398273	458826	7.41
1715	29	5399372	459096	15.33
1741	29	5398256	458504	80.98
1454	25	5399298	457224	0.00
1608	25	5398903	456855	12.17
1409	23	5396645	460168	0.00
1433	23	5397203	459712	50.04
1543	23	5397286	458812	21.52
1621	23	5398425	459626	61.40
1706	23	5396954	458823	62.07
1210	22	5396966	458130	0.00
1245	22	5398595	458934	86.51
1314	22	5398617	457750	68.06
1350	22	5397802	457814	37.85
1526	21	5397251	459175	0.00
1646	21	5397039	459261	4.77
1750	21	5397636	459723	19.66
758	12	5397139	458536	0.00
842	12	5396877	458889	16.65
935	12	5397489	458309	26.51
1049	12	5399015	456970	45.72
1129	12	5398390	456757	27.51
916	9	5397026	459633	0.00
943	9	5397225	458992	41.43
1054	9	5397538	459217	9.05
1123	9	5397538	459217	0.00
1241	9	5397110	458714	14.11
1310	9	5397219	457915	46.34
1340	9	5397341	458280	21.38
1536	8	5397033	458813	0.00
1647	8	5398820	458534	42.46
1758	8	5398574	457923	15.46
858	5	5397088	458617	0.00
1001	5	5398203	460270	52.75
1118	5	5396901	459274	35.48
1250	5	5396780	459210	2.48
911	3	5397035	459337	0.00
1021	3	5398077	460235	32.75
1059	3	5396994	460035	48.30
1237	3	5397067	461333	22.11
1303	3	5396442	459946	97.52
905	1	5397064	459037	0.00
954	1	5396068	459609	39.07
1111	1	5396140	459745	3.33
1241	1	5396471	460086	8.80
1307	1	5396870	458712	91.72
1347	1	5396904	458801	3.97

SURFACE CURRENTS, SEPTEMBER 19, 1991
DROGUE STUDY CURRENT VELOCITIES

TIME	DROGUE	UTM NORTH	UTM EAST	CURRENT VELOCITY (CM/S)
1545	24	5398376	456778	0.00
1631	24	5400181	456076	70.17
1711	24	5399474	455007	53.40
1447	23	5398741	456720	0.00
1556	23	5399937	455493	41.39
1142	22	5398593	456931	0.00
1323	22	5398758	458019	18.16
1438	22	5399727	457283	27.04
1550	19	5398874	457058	0.00
1643	19	5399880	456010	45.68
1703	19	5398318	455841	130.93
1139	18	5398399	456822	0.00
1317	18	5398529	457343	9.13
1414	18	5398942	457063	14.59
1517	18	5400146	456195	39.27
1239	17	5398235	456738	0.00
1342	17	5398466	456971	8.68
1409	17	5398887	456839	27.24
1509	17	5399828	455789	39.17
1248	14	5398581	456836	0.00
1346	14	5398647	457028	5.83
1412	14	5399094	456931	29.32
1513	14	5399977	456184	31.60
747	12	5398390	456917	0.00
828	12	5398165	456816	10.03
858	12	5398909	457387	52.10
948	12	5398341	457584	20.04
1113	12	5397428	456772	23.96
731	8	5397662	458207	0.00
817	8	5397782	458107	5.66
844	8	5397404	458280	25.66
939	8	5397870	458741	19.86
1131	8	5396634	458943	18.64
742	7	5398205	456784	0.00
826	7	5398189	456792	0.68
900	7	5398542	457319	31.09
946	7	5398120	457639	19.19
1118	7	5397779	458997	25.37
1228	7	5398568	458957	18.81
1547	5	5398688	456807	0.00
1628	5	5399413	455884	47.71
1708	5	5399567	455154	31.09
725	4	5397264	458135	0.00
820	4	5399581	456978	78.48
847	4	5397787	457877	123.87
936	4	5397200	458844	38.48
1126	4	5396829	459511	11.56
1222	4	5397436	459386	18.44

DEEP (10m) CURRENTS, SEPTEMBER 19, 1991
DROGUE STUDY CURRENT VELOCITIES

TIME	DROGUE	UTM NORTH	UTM EAST	CURRENT VELOCITY (CM/S)
1321	19	5398260	457574	0.00
1420	19	5398459	457244	10.89
1527	19	5399329	456549	27.70
1617	19	5399612	456217	14.54
1657	19	5399620	455949	11.17
1342	16	5398466	456971	0.00
1416	16	5398776	457012	15.33
1524	16	5399586	456660	21.65
1610	16	5400044	456352	20.00
1009	15	5398378	456930	0.00
1102	15	5399499	457250	36.66
1212	15	5398085	457543	34.38
1340	14	5397912	457226	0.00
1423	14	5398265	457227	13.68
1530	14	5398710	456345	24.57
1313	13	5398736	456587	0.00
1403	13	5398734	456698	3.70
1601	13	5398939	455759	13.58
1636	13	5398791	455425	17.40
742	11	5398205	456784	0.00
833	11	5398610	456619	14.29
904	11	5398624	456526	5.06
1001	11	5398266	456709	11.76
1104	11	5397942	457344	18.86
1215	11	5397969	457876	12.50
1336	11	5397870	457653	5.02
1426	11	5398112	457217	16.62
1530	11	5398710	456345	27.54
1607	11	5399340	455886	35.11
1634	11	5399164	455593	21.10
1716	11	5398723	455489	17.98
725	9	5397264	458135	0.00
823	9	5397977	457589	25.81
855	9	5398590	457587	31.93
950	9	5398571	457298	8.78
1108	9	5398478	457057	5.52
1209	9	5398818	457447	14.14
1545	8	5398376	456778	0.00
1621	8	5398618	456498	17.13
1725	8	5399212	455859	22.72
840	6	5397595	458419	0.00
942	6	5397321	458089	11.53
1121	6	5397445	458411	5.81
1218	6	5397247	458396	5.81
1329	6	5399285	458546	47.97
731	5	5397662	458207	0.00
810	5	5398214	458006	25.10
851	5	5398539	457997	13.22
954	5	5398757	458530	15.23
747	3	5398390	456917	0.00
831	3	5398654	456847	10.35
907	3	5398999	456662	18.12
1005	3	5399055	456319	9.99
1058	3	5398994	456190	4.49
1202	3	5398869	456278	3.98

SURFACE CURRENTS, SEPTEMBER 20, 1991
DROGUE STUDY CURRENT VELOCITIES

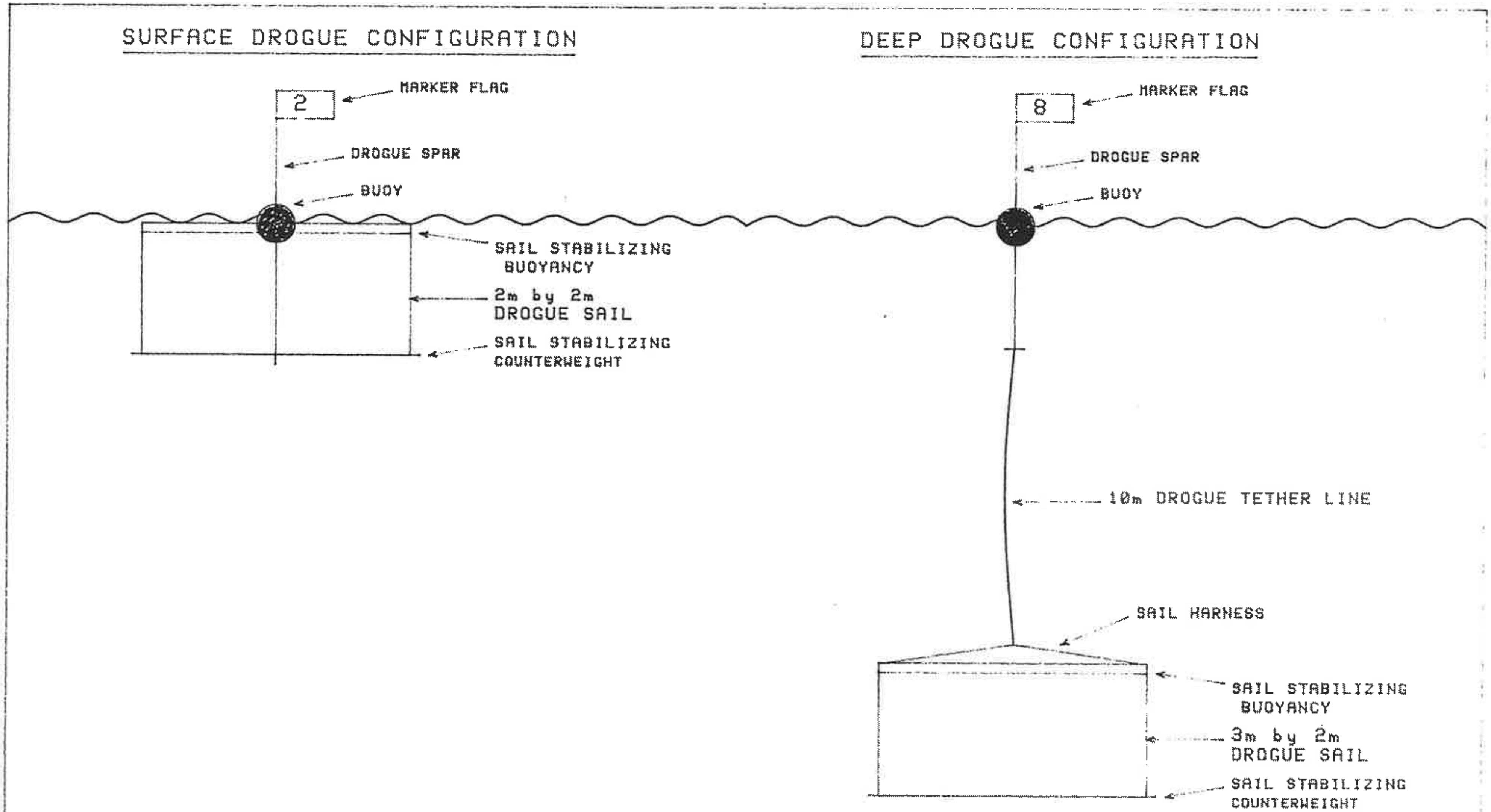
TIME	DROGUE	UTM NORTH	UTM EAST	CURRENT VELOCITY (CM/S)
1554	21	5398594	456718	0.00
1710	21	5399643	454967	44.76
1401	20	5399297	457356	0.00
1443	20	5399733	457193	18.47
1526	20	5399911	457127	7.36
1319	19	5398755	456880	0.00
1406	19	5398904	457133	10.41
1447	19	5399208	456934	14.77
1533	19	5399760	456277	31.09
1630	19	5400309	455025	39.97
1317	17	5398389	456809	0.00
1409	17	5398315	456842	2.60
1451	17	5398816	456933	20.21
1536	17	5399422	456298	32.51
1635	17	5399964	455094	37.30
1415	16	5398747	456902	0.00
1453	16	5398568	456743	10.50
1537	16	5398971	456199	25.64
1639	16	5399505	455079	33.35
949	14	5398278	456860	0.00
1030	14	5398723	457448	29.98
1221	14	5398881	458534	16.48
1154	13	5398452	456778	0.00
1305	13	5398863	457365	16.82
1357	13	5398756	457501	5.55
1445	13	5399129	457188	16.91
1531	13	5399918	456598	35.70
1646	13	5400898	456233	23.24
743	10	5398606	456791	0.00
858	10	5398483	456716	3.20
934	10	5398814	456776	15.57
1035	10	5398762	456735	1.81
1204	10	5399026	456871	5.56
1259	10	5399180	457315	14.24
727	7	5397353	458195	0.00
827	7	5397995	457849	20.26
922	7	5397751	458032	9.24
1021	7	5397302	458827	25.79
1145	7	5397875	459492	17.42
1247	7	5397980	459076	11.53
747	6	5398847	456868	0.00
844	6	5398747	456665	6.62
937	6	5398926	456635	5.71
1037	6	5398916	456707	2.02
1158	6	5399461	457195	15.05
1253	6	5398881	457940	28.61
1350	6	5398931	458190	7.45
737	4	5398400	456729	0.00
835	4	5398209	457423	20.68
924	4	5397794	458008	24.40
841	3	5398494	456874	0.00
931	3	5398950	457496	25.71
1026	3	5398406	458096	24.54
1130	3	5399066	458626	22.04

DEEP (10m) CURRENTS, SEPTEMBER 20, 1991
DROGUE STUDY CURRENT VELOCITIES

TIME	DROGUE	UTM NORTH	UTM EAST	CURRENT VELOCITY (CM/S)
1412	21	5399485	456419	0.00
1456	21	5398321	456836	46.83
1543	21	5398808	456335	24.78
1715	21	5398956	455401	17.13
1302	19	5399364	456543	0.00
1404	19	5399090	456825	10.57
1449	19	5399041	456882	2.78
1541	19	5399000	456779	3.55
1704	19	5399230	456200	12.51
1312	18	5397978	457850	0.00
1346	18	5397922	457870	2.91
1436	18	5397929	457771	3.31
1522	18	5398112	457509	11.58
1723	18	5398422	456789	10.80
1359	15	5399252	457430	0.00
1441	15	5399156	457330	5.50
1549	15	5399872	456828	21.43
1657	15	5400063	456284	14.13
743	11	5398606	456791	0.00
850	11	5398992	456174	18.10
945	11	5399275	455918	11.56
1042	11	5399803	455681	16.92
1056	11	5398444	456948	0.00
1153	11	5398452	456778	4.98
1308	11	5398128	456997	8.69
747	9	5398847	456868	0.00
846	9	5399275	456476	16.40
942	9	5399461	456342	6.82
1040	9	5399548	456172	5.49
1206	9	5399532	456343	3.33
737	8	5398400	456729	0.00
852	8	5398875	456229	15.33
939	8	5398508	456434	14.91
1033	8	5398270	457041	20.12
1150	8	5397956	457504	12.11
727	5	5397353	458195	0.00
830	5	5398186	457582	27.36
928	5	5398425	457510	7.17
1028	5	5398663	457720	8.82
1200	5	5398918	457915	5.82
1255	5	5399026	457847	3.87

APPENDIX II.

WINDOW SHADE
DROGUE CONFIGURATIONS.



WINDOW SHADE DROGUE CONFIGURATIONS

APPENDIX III.

CLIMATE NORMALS FOR COWICHAN BAY
1951-1980

APPENDIX III.

CLIMATE NORMALS FOR COWICHAN BAY
1951 - 1980.

Place Cowichan Bay

Lat. 48°44′ N., Long. 123°35′ W.

Elevation 104 m (340 ft)

Temperature (°C)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Code
Mean daily	2.4	4.5	5.5	8.3	11.6	14.4	17.0	16.9	14.5	10.1	5.6	3.5	9.5	1
Mean daily (max)	4.8	7.5	9.3	12.7	16.3	19.0	22.2	21.9	19.1	13.8	8.4	5.7	13.4	1
Mean daily (min)	−0.1	1.4	1.7	3.8	6.8	9.7	11.7	11.8	9.8	6.3	2.8	1.3	5.6	1
Extreme maximum	15.0	17.8	20.0	23.9	29.4	32.8	35.6	34.4	31.7	24.0	17.2	15.5	35.6	–
Years of record	62	62	62	62	62	62	62	62	62	62	62	62	–	–
Extreme minimum	−16.1	−11.7	−9.4	−3.9	−1.1	0.6	4.4	4.4	0.0	−4.4	−13.3	−15.0	−16.1	–
Years of record	62	62	62	62	62	62	62	62	62	62	62	62	–	–
Rainfall (mm)														
Mean monthly	142.1	99.9	84.4	47.9	35.5	33.4	21.4	29.0	43.8	90.5	144.5	162.4	934.8	1
Max. in 24 hours	96.5	56.1	48.3	36.1	39.9	37.6	26.7	57.2	56.6	54.9	63.0	63.8	96.5	–
Years of record	62	62	62	62	62	62	62	62	62	62	62	61	–	–
Days with rain	17	15	15	12	11	9	6	8	9	14	18	19	153	1
Snowfall (cm)														
Mean monthly	27.3	10.4	7.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.4	18.8	66.5	1
Max. in 24 hours	38.1	50.8	29.2	5.1	0.0	0.0	0.0	0.0	0.0	T	17.0	41.9	50.8	–
Years of record	62	62	62	62	62	62	62	62	62	62	62	61	–	–
Days with snow	5	2	1	*	0	0	0	0	0	0	1	3	12	1
Days with precipitation	20	16	16	12	11	9	6	8	9	14	18	20	159	1

* = amounts less than 0.5 except zero
T = Trace

From CHS (1984).

DUNCAN NORTH COWICHAN JOINT UTILITIES BOARD
COWICHAN BAY
OCEANOGRAPHIC AND EFFLUENT DISPOSAL STUDIES

APPENDIX 2

DILUTION MODELLING

UNIVERSAL DATA FILE: COWSUMAV

```
COWICHAN BAY OUTFALL - SUMMER CONDITIONS
0 1 0 0 0 0 0 0
    0.2080         20        0.1        90.        50.0
                  90.        1.0
         4    1.09000        11.
     00.00    27.3000       13.8      0.067
     10.00    28.2000       12.8      0.034
     25.00    29.1000       11.5      0.034
     50.00    29.9000       10.5      0.025
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UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: COWSUMAV

CASE I.D. COWICHAN BAY OUTFALL - SUMMER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	11.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.5204	SIGMAT UNITS
FROUDE NUMBER	=	8.9	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	27.30	13.80	20.32	.067
10.00	28.20	12.80	21.20	.034
25.00	29.10	11.50	22.13	.034
50.00	29.90	10.50	22.92	.025

TOTAL EFFLUENT FLOW	=	.2080	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU- TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.40	.00	1.32	1.32	.025
.00	50.00	.100	1.01	22.25	.00	1.32	1.32	.025
.01	49.56	.267	2.79	7.91	.02	.51	.51	.025
.07	48.46	.619	7.85	2.78	.02	.27	.27	.026
*****MERGING BEGINS								
.22	47.04	1.005	16.11	1.32	.02	.21	.21	.026
.34	45.97	1.284	22.15	.93	.02	.20	.20	.026
1.44	37.96	3.697	62.63	.16	.03	.17	.18	.029
*****NOMINAL TRAPPING LEVEL REACHED								
2.18	33.62	5.797	83.79	.00	.03	.15	.15	.031
4.30	27.14	51.304	177.15	-.12	.03	.02	.04	.033

COMPUTATIONS CEASE: VERTICAL PLUME VELOCITY IS LESS THAN 0

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED

TRAPPING LEVEL = 33.63 M BELOW SURFACE; DILUTION = 83.74

CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:COWICHAN - SUMMER - AVERAGE DAILY FLOWS

Current (cm/s)	:	15.45
Effective diffuser width (m)	:	24.797
Max. dist. from diffuser (m)	:	2000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	83.74
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE +=======+	INITIAL DIL +==========+	DISP DIL +=======+	DIE DIL +======+	TOTAL DIL +========+
1.000E+02	8.374E+01	1.103E+00	1.109E+00	1.024E+02
2.000E+02	8.374E+01	1.409E+00	1.230E+00	1.451E+02
3.000E+02	8.374E+01	1.781E+00	1.364E+00	2.034E+02
4.000E+02	8.374E+01	2.185E+00	1.512E+00	2.767E+02
5.000E+02	8.374E+01	2.617E+00	1.677E+00	3.675E+02
6.000E+02	8.374E+01	3.093E+00	1.859E+00	4.816E+02
7.000E+02	8.374E+01	3.578E+00	2.062E+00	6.178E+02
8.000E+02	8.374E+01	4.091E+00	2.287E+00	7.833E+02
9.000E+02	8.374E+01	4.623E+00	2.536E+00	9.816E+02
1.000E+03	8.374E+01	5.176E+00	2.812E+00	1.219E+03
1.100E+03	8.374E+01	5.772E+00	3.118E+00	1.507E+03
1.200E+03	8.374E+01	6.386E+00	3.458E+00	1.849E+03
1.300E+03	8.374E+01	6.988E+00	3.834E+00	2.244E+03
1.400E+03	8.374E+01	7.603E+00	4.252E+00	2.707E+03
1.500E+03	8.374E+01	8.230E+00	4.715E+00	3.249E+03
1.600E+03	8.374E+01	8.899E+00	5.228E+00	3.896E+03
1.700E+03	8.374E+01	9.590E+00	5.798E+00	4.656E+03
1.800E+03	8.374E+01	1.030E+01	6.429E+00	5.544E+03
1.900E+03	8.374E+01	1.102E+01	7.129E+00	6.580E+03
2.000E+03	8.374E+01	1.176E+01	7.906E+00	7.787E+03

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 2000 m

UNIVERSAL DATA FILE: COWWINAV

```
COWICHAN BAY OUTFALL - WINTER CONDITIONS
0 1 0 0 0 0 0 0
    0.2080         20        0.1       90.       50.0
                  90.        1.0
         4   1.09000          9.
     00.00   29.5000        8.70     0.067
     10.00   29.5700        8.55     0.034
     25.00   29.7700        8.46     0.034
     50.00   30.0000        8.00     0.025
```

UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: COWWINAV
CASE I.D. COWICHAN BAY OUTFALL - WINTER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	9.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.7022	SIGMAT UNITS
FROUDE NUMBER	=	8.9	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	29.50	8.70	22.89	.067
10.00	29.57	8.55	22.97	.034
25.00	29.77	8.46	23.14	.034
50.00	30.00	8.00	23.38	.025

TOTAL EFFLUENT FLOW	=	.2080	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU-TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.68	.00	1.32	1.32	.025
.00	50.00	.100	1.01	22.52	.00	1.32	1.32	.025
.01	49.56	.267	2.79	8.02	.02	.52	.52	.025
.07	48.46	.618	7.84	2.83	.02	.27	.27	.026
*****MERGING BEGINS								
.22	47.03	1.005	16.22	1.36	.02	.21	.21	.026
.34	45.99	1.271	22.15	.99	.02	.20	.20	.026
1.35	38.19	3.340	62.61	.30	.03	.19	.20	.029
*****NOMINAL TRAPPING LEVEL REACHED								
4.19	20.98	10.514	152.01	.00	.03	.14	.15	.034
5.30	16.19	15.018	177.05	-.05	.03	.11	.12	.034

COMPUTATIONS CEASE: VERTICAL PLUME VELOCITY IS LESS THAN 0

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED
TRAPPING LEVEL = 21.04 M BELOW SURFACE; DILUTION = 151.70

◄CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:COWICHAN - WINTER - AVERAGE DAILY FLOWS

Current (cm/s)	:	17
Effective diffuser width (m)	:	29.514
Max. dist. from diffuser (m)	:	2000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	151.7
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
1.000E+02	1.517E+02	1.059E+00	1.099E+00	1.765E+02
2.000E+02	1.517E+02	1.281E+00	1.207E+00	2.345E+02
3.000E+02	1.517E+02	1.561E+00	1.326E+00	3.139E+02
4.000E+02	1.517E+02	1.874E+00	1.456E+00	4.139E+02
5.000E+02	1.517E+02	2.203E+00	1.600E+00	5.346E+02
6.000E+02	1.517E+02	2.553E+00	1.757E+00	6.804E+02
7.000E+02	1.517E+02	2.925E+00	1.930E+00	8.566E+02
8.000E+02	1.517E+02	3.323E+00	2.120E+00	1.069E+03
9.000E+02	1.517E+02	3.716E+00	2.329E+00	1.313E+03
1.000E+03	1.517E+02	4.137E+00	2.559E+00	1.606E+03
1.100E+03	1.517E+02	4.567E+00	2.811E+00	1.947E+03
1.200E+03	1.517E+02	5.007E+00	3.088E+00	2.345E+03
1.300E+03	1.517E+02	5.480E+00	3.392E+00	2.820E+03
1.400E+03	1.517E+02	5.969E+00	3.726E+00	3.374E+03
1.500E+03	1.517E+02	6.464E+00	4.093E+00	4.014E+03
1.600E+03	1.517E+02	6.951E+00	4.496E+00	4.741E+03
1.700E+03	1.517E+02	7.447E+00	4.939E+00	5.580E+03
1.800E+03	1.517E+02	7.951E+00	5.426E+00	6.544E+03
1.900E+03	1.517E+02	8.469E+00	5.960E+00	7.658E+03
2.000E+03	1.517E+02	9.018E+00	6.548E+00	8.957E+03

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 2000 m

UNIVERSAL DATA FILE: SATSUMAV

```
SATELLITE CHANNEL OUTFALL - SUMMER CONDITIONS
0 1 0 0 0 0 0 0
    0.2080          20        0.1        90.        50.0
                   90.        1.0
         4   1.09000          11.
     00.00   27.0000        13.30     0.0670
     10.00   28.1000         12.7     0.0340
     25.00   29.5000         10.8     0.0340
     50.00   30.1000         10.5     0.0250
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UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: SATSUMAV
CASE I.D. SATELLITE CHANNEL OUTFALL - SUMMER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	11.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.5204	SIGMAT UNITS
FROUDE NUMBER	=	8.9	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	27.00	13.30	20.19	.067
10.00	28.10	12.70	21.15	.034
25.00	29.50	10.80	22.56	.034
50.00	30.10	10.50	23.08	.025

TOTAL EFFLUENT FLOW	=	.2080	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU-TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.56	.00	1.32	1.32	.025
.00	50.00	.100	1.01	22.40	.00	1.32	1.32	.025
.01	49.56	.267	2.79	7.97	.02	.51	.52	.025
.07	48.46	.619	7.85	2.81	.02	.27	.27	.026
*****MERGING BEGINS								
.22	47.03	1.007	16.22	1.33	.02	.21	.21	.026
.34	45.98	1.277	22.15	.96	.02	.20	.20	.026
1.39	38.08	3.499	62.62	.23	.03	.19	.19	.029
*****NOMINAL TRAPPING LEVEL REACHED								
2.81	29.54	7.338	105.30	.00	.03	.14	.15	.032
4.76	22.91	41.448	177.11	-.22	.03	.03	.04	.034

COMPUTATIONS CEASE: VERTICAL PLUME VELOCITY IS LESS THAN 0

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED
TRAPPING LEVEL = 29.68 M BELOW SURFACE; DILUTION = 104.63

◄CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:SATELLITE - SUMMER - AVERAGE DAILY FLOWS

Current (cm/s)	:	16.16
Effective diffuser width (m)	:	26.338
Max. dist. from diffuser (m)	:	4000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	104.63
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
+======+	+=========+	+======+	+=====+	+=======+
1.000E+02	1.046E+02	1.082E+00	1.104E+00	1.250E+02
2.000E+02	1.046E+02	1.353E+00	1.219E+00	1.725E+02
3.000E+02	1.046E+02	1.686E+00	1.345E+00	2.373E+02
4.000E+02	1.046E+02	2.051E+00	1.485E+00	3.187E+02
5.000E+02	1.046E+02	2.439E+00	1.639E+00	4.184E+02
6.000E+02	1.046E+02	2.852E+00	1.809E+00	5.400E+02
7.000E+02	1.046E+02	3.303E+00	1.997E+00	6.903E+02
8.000E+02	1.046E+02	3.751E+00	2.205E+00	8.653E+02
9.000E+02	1.046E+02	4.230E+00	2.434E+00	1.077E+03
1.000E+03	1.046E+02	4.721E+00	2.687E+00	1.327E+03
1.100E+03	1.046E+02	5.235E+00	2.966E+00	1.625E+03
1.200E+03	1.046E+02	5.783E+00	3.274E+00	1.981E+03
1.300E+03	1.046E+02	6.348E+00	3.614E+00	2.401E+03
1.400E+03	1.046E+02	6.900E+00	3.990E+00	2.880E+03
1.500E+03	1.046E+02	7.462E+00	4.404E+00	3.439E+03
1.600E+03	1.046E+02	8.035E+00	4.862E+00	4.087E+03
1.700E+03	1.046E+02	8.633E+00	5.367E+00	4.848E+03
1.800E+03	1.046E+02	9.261E+00	5.924E+00	5.741E+03
1.900E+03	1.046E+02	9.903E+00	6.540E+00	6.777E+03
2.000E+03	1.046E+02	1.056E+01	7.219E+00	7.976E+03
2.100E+03	1.046E+02	1.123E+01	7.969E+00	9.363E+03
2.200E+03	1.046E+02	1.191E+01	8.797E+00	1.096E+04
2.300E+03	1.046E+02	1.261E+01	9.711E+00	1.281E+04
2.400E+03	1.046E+02	1.332E+01	1.072E+01	1.494E+04
2.500E+03	1.046E+02	1.404E+01	1.183E+01	1.738E+04
2.600E+03	1.046E+02	1.477E+01	1.306E+01	2.019E+04
2.700E+03	1.046E+02	1.552E+01	1.442E+01	2.341E+04
2.800E+03	1.046E+02	1.628E+01	1.592E+01	2.711E+04
2.900E+03	1.046E+02	1.705E+01	1.757E+01	3.134E+04
3.000E+03	1.046E+02	1.783E+01	1.940E+01	3.619E+04
3.100E+03	1.046E+02	1.862E+01	2.141E+01	4.172E+04
3.200E+03	1.046E+02	1.943E+01	2.364E+01	4.805E+04
3.300E+03	1.046E+02	2.024E+01	2.609E+01	5.527E+04
3.400E+03	1.046E+02	2.107E+01	2.880E+01	6.350E+04
3.500E+03	1.046E+02	2.191E+01	3.180E+01	7.289E+04
3.600E+03	1.046E+02	2.276E+01	3.510E+01	8.357E+04
3.700E+03	1.046E+02	2.362E+01	3.875E+01	9.574E+04
3.800E+03	1.046E+02	2.449E+01	4.277E+01	1.096E+05
3.900E+03	1.046E+02	2.537E+01	4.721E+01	1.253E+05
4.000E+03	1.046E+02	2.626E+01	5.212E+01	1.432E+05

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 4000 m

UNIVERSAL DATA FILE: SATWINAV

```
SATELLITE CHANNEL OUTFALL - WINTER CONDITIONS
0 1 0 0 0 0 0 0
    0.2080          20          0.1         90.        50.0
                   90.          1.0
         4     1.09000           9.
     00.00     29.6600         8.58      0.0674
     10.00     29.7300         8.55      0.0340
     25.00     29.9300         8.46      0.0340
     50.00     30.1600         8.00      0.0250
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UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: SATWINAV
CASE I.D. SATELLITE CHANNEL OUTFALL - WINTER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	9.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.7022	SIGMAT UNITS
FROUDE NUMBER	=	8.9	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	29.66	8.58	23.03	.067
10.00	29.73	8.55	23.09	.034
25.00	29.93	8.46	23.26	.034
50.00	30.16	8.00	23.51	.025

TOTAL EFFLUENT FLOW	=	.2080	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU-TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.80	.00	1.32	1.32	.025
.00	50.00	.100	1.01	22.65	.00	1.32	1.32	.025
.01	49.56	.267	2.79	8.06	.02	.52	.52	.025
.07	48.46	.617	7.84	2.85	.02	.27	.27	.026
*****MERGING BEGINS								
.22	47.02	1.009	16.33	1.36	.02	.21	.21	.026
.34	45.99	1.269	22.15	.99	.02	.20	.20	.026
1.35	38.20	3.332	62.60	.30	.03	.20	.20	.029
*****NOMINAL TRAPPING LEVEL REACHED								
4.21	20.81	10.604	153.05	.00	.03	.14	.15	.034
5.28	16.23	14.905	177.03	-.05	.03	.12	.12	.034

COMPUTATIONS CEASE: VERTICAL PLUME VELOCITY IS LESS THAN 0

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED
TRAPPING LEVEL = 20.99 M BELOW SURFACE; DILUTION = 152.10

◄CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:SATELLITE - WINTER - AVERAGE DAILY FLOWS

Current (cm/s)	:	17
Effective diffuser width (m)	:	29.604
Max. dist. from diffuser (m)	:	4000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	152.1
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
1.000E+02	1.521E+02	1.059E+00	1.099E+00	1.769E+02
2.000E+02	1.521E+02	1.280E+00	1.207E+00	2.349E+02
3.000E+02	1.521E+02	1.559E+00	1.326E+00	3.143E+02
4.000E+02	1.521E+02	1.871E+00	1.456E+00	4.144E+02
5.000E+02	1.521E+02	2.200E+00	1.600E+00	5.352E+02
6.000E+02	1.521E+02	2.548E+00	1.757E+00	6.811E+02
7.000E+02	1.521E+02	2.920E+00	1.930E+00	8.572E+02
8.000E+02	1.521E+02	3.317E+00	2.120E+00	1.070E+03
9.000E+02	1.521E+02	3.709E+00	2.329E+00	1.314E+03
1.000E+03	1.521E+02	4.128E+00	2.559E+00	1.607E+03
1.100E+03	1.521E+02	4.557E+00	2.811E+00	1.948E+03
1.200E+03	1.521E+02	4.996E+00	3.088E+00	2.346E+03
1.300E+03	1.521E+02	5.467E+00	3.392E+00	2.820E+03
1.400E+03	1.521E+02	5.954E+00	3.726E+00	3.375E+03
1.500E+03	1.521E+02	6.449E+00	4.093E+00	4.015E+03
1.600E+03	1.521E+02	6.935E+00	4.496E+00	4.743E+03
1.700E+03	1.521E+02	7.429E+00	4.939E+00	5.582E+03
1.800E+03	1.521E+02	7.932E+00	5.426E+00	6.546E+03
1.900E+03	1.521E+02	8.448E+00	5.960E+00	7.659E+03
2.000E+03	1.521E+02	8.996E+00	6.548E+00	8.958E+03
2.100E+03	1.521E+02	9.554E+00	7.192E+00	1.045E+04
2.200E+03	1.521E+02	1.012E+01	7.901E+00	1.217E+04
2.300E+03	1.521E+02	1.070E+01	8.679E+00	1.413E+04
2.400E+03	1.521E+02	1.129E+01	9.534E+00	1.638E+04
2.500E+03	1.521E+02	1.189E+01	1.047E+01	1.895E+04
2.600E+03	1.521E+02	1.251E+01	1.151E+01	2.188E+04
2.700E+03	1.521E+02	1.313E+01	1.264E+01	2.523E+04
2.800E+03	1.521E+02	1.376E+01	1.388E+01	2.905E+04
2.900E+03	1.521E+02	1.440E+01	1.525E+01	3.340E+04
3.000E+03	1.521E+02	1.505E+01	1.675E+01	3.834E+04
3.100E+03	1.521E+02	1.571E+01	1.840E+01	4.397E+04
3.200E+03	1.521E+02	1.637E+01	2.022E+01	5.035E+04
3.300E+03	1.521E+02	1.705E+01	2.221E+01	5.760E+04
3.400E+03	1.521E+02	1.774E+01	2.440E+01	6.583E+04
3.500E+03	1.521E+02	1.843E+01	2.680E+01	7.515E+04
3.600E+03	1.521E+02	1.914E+01	2.944E+01	8.570E+04
3.700E+03	1.521E+02	1.985E+01	3.234E+01	9.765E+04
3.800E+03	1.521E+02	2.057E+01	3.553E+01	1.112E+05
3.900E+03	1.521E+02	2.130E+01	3.903E+01	1.265E+05
4.000E+03	1.521E+02	2.204E+01	4.287E+01	1.437E+05

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 4000 m

UNIVERSAL DATA FILE: cowsum1

```
COWICHAN BAY OUTFALL - SUMMER CONDITIONS
0 1 0 0 0 0 0 0 0
    0.4660          20        0.1        90.        50.0
                   90.        1.0
         4     1.09000        11.
     00.00     27.3000       13.8      0.067
     10.00     28.2000       12.8      0.034
     25.00     29.1000       11.5      0.034
     50.00     29.9000       10.5      0.025
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UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: cowsum1

CASE I.D. COWICHAN BAY OUTFALL - SUMMER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	11.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.5204	SIGMAT UNITS
FROUDE NUMBER	=	20.0	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	27.30	13.80	20.32	.067
10.00	28.20	12.80	21.20	.034
25.00	29.10	11.50	22.13	.034
50.00	29.90	10.50	22.92	.025

TOTAL EFFLUENT FLOW	=	.4660	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU-TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.40	.00	2.97	2.97	.025
.00	50.00	.100	1.01	22.25	.00	2.95	2.95	.025
.00	49.55	.277	2.79	7.91	.02	1.07	1.07	.025
.05	48.33	.731	7.85	2.77	.02	.43	.43	.026
*****MERGING BEGINS								
.10	47.50	1.010	11.56	1.86	.02	.33	.33	.026
.37	44.18	1.940	22.15	.89	.02	.28	.28	.027
*****NOMINAL TRAPPING LEVEL REACHED								
2.02	29.24	7.041	62.20	.00	.03	.20	.20	.032
2.04	29.07	7.137	62.64	-.01	.03	.20	.20	.032

COMPUTATIONS CEASE: VERTICAL PLUME VELOCITY IS LESS THAN 0

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED

TRAPPING LEVEL = 29.34 M BELOW SURFACE; DILUTION = 61.94

◄CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:COWICHAN BAY - SUMMER

Current (cm/s)	:	16.2
Effective diffuser width (m)	:	26.041
Max. dist. from diffuser (m)	:	2000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	61.94
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
1.000E+02	6.194E+01	1.083E+00	1.104E+00	7.404E+01
2.000E+02	6.194E+01	1.356E+00	1.218E+00	1.023E+02
3.000E+02	6.194E+01	1.691E+00	1.344E+00	1.408E+02
4.000E+02	6.194E+01	2.059E+00	1.483E+00	1.892E+02
5.000E+02	6.194E+01	2.450E+00	1.637E+00	2.484E+02
6.000E+02	6.194E+01	2.865E+00	1.807E+00	3.207E+02
7.000E+02	6.194E+01	3.319E+00	1.994E+00	4.099E+02
8.000E+02	6.194E+01	3.770E+00	2.201E+00	5.139E+02
9.000E+02	6.194E+01	4.252E+00	2.429E+00	6.396E+02
1.000E+03	6.194E+01	4.747E+00	2.680E+00	7.881E+02
1.100E+03	6.194E+01	5.266E+00	2.958E+00	9.648E+02
1.200E+03	6.194E+01	5.818E+00	3.265E+00	1.176E+03
1.300E+03	6.194E+01	6.385E+00	3.603E+00	1.425E+03
1.400E+03	6.194E+01	6.940E+00	3.976E+00	1.709E+03
1.500E+03	6.194E+01	7.506E+00	4.388E+00	2.040E+03
1.600E+03	6.194E+01	8.083E+00	4.843E+00	2.424E+03
1.700E+03	6.194E+01	8.688E+00	5.345E+00	2.876E+03
1.800E+03	6.194E+01	9.320E+00	5.898E+00	3.405E+03
1.900E+03	6.194E+01	9.967E+00	6.510E+00	4.019E+03
2.000E+03	6.194E+01	1.063E+01	7.184E+00	4.729E+03

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 2000 m

UNIVERSAL DATA FILE: COWWIN2

COWICHAN BAY OUTFALL - WINTER CONDITIONS

```
0 1 0 0 0 0 0 0
    0.4660          20          0.1         90.        50.0
                   90.          1.0
         4    1.09000           9.
     00.00    29.5000          8.70       0.067
     10.00    29.5700          8.55       0.034
     25.00    29.7700          8.46       0.034
     50.00    30.0000          8.00       0.025
```

UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: COWWIN2
CASE I.D. COWICHAN BAY OUTFALL - WINTER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	9.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.7022	SIGMAT UNITS
FROUDE NUMBER	=	19.9	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	29.50	8.70	22.89	.067
10.00	29.57	8.55	22.97	.034
25.00	29.77	8.46	23.14	.034
50.00	30.00	8.00	23.38	.025

TOTAL EFFLUENT FLOW	=	.4660	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU-TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.68	.00	2.97	2.97	.025
.00	50.00	.100	1.01	22.52	.00	2.95	2.95	.025
.00	49.55	.277	2.79	8.02	.02	1.07	1.07	.025
.04	48.34	.730	7.84	2.83	.02	.43	.43	.026
*****MERGING BEGINS								
.10	47.50	1.008	11.55	1.91	.02	.34	.34	.026
.37	44.21	1.912	22.15	.97	.02	.28	.28	.027
1.79	29.91	5.661	62.61	.25	.03	.26	.26	.032
*****NOMINAL TRAPPING LEVEL REACHED								
3.97	12.84	12.316	109.00	.00	.03	.20	.20	.034

COMPUTATIONS CEASE: PLUMES SURFACE

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED
TRAPPING LEVEL = 13.02 M BELOW SURFACE; DILUTION = 108.53

CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:COWICHAN BAY - WINTER

Current (cm/s)	:	17
Effective diffuser width (m)	:	31.316
Max. dist. from diffuser (m)	:	2000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	108.53
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
1.000E+02	1.085E+02	1.053E+00	1.099E+00	1.255E+02
2.000E+02	1.085E+02	1.261E+00	1.207E+00	1.652E+02
3.000E+02	1.085E+02	1.526E+00	1.326E+00	2.196E+02
4.000E+02	1.085E+02	1.824E+00	1.456E+00	2.883E+02
5.000E+02	1.085E+02	2.139E+00	1.600E+00	3.713E+02
6.000E+02	1.085E+02	2.471E+00	1.757E+00	4.712E+02
7.000E+02	1.085E+02	2.820E+00	1.930E+00	5.909E+02
8.000E+02	1.085E+02	3.202E+00	2.120E+00	7.369E+02
9.000E+02	1.085E+02	3.576E+00	2.329E+00	9.039E+02
1.000E+03	1.085E+02	3.972E+00	2.559E+00	1.103E+03
1.100E+03	1.085E+02	4.381E+00	2.811E+00	1.337E+03
1.200E+03	1.085E+02	4.800E+00	3.088E+00	1.609E+03
1.300E+03	1.085E+02	5.238E+00	3.392E+00	1.928E+03
1.400E+03	1.085E+02	5.700E+00	3.726E+00	2.305E+03
1.500E+03	1.085E+02	6.176E+00	4.093E+00	2.744E+03
1.600E+03	1.085E+02	6.647E+00	4.496E+00	3.243E+03
1.700E+03	1.085E+02	7.118E+00	4.939E+00	3.816E+03
1.800E+03	1.085E+02	7.597E+00	5.426E+00	4.473E+03
1.900E+03	1.085E+02	8.083E+00	5.960E+00	5.229E+03
2.000E+03	1.085E+02	8.590E+00	6.548E+00	6.104E+03

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 2000 m

UNIVERSAL DATA FILE: satsum1

```
SATELLITE CHANNEL OUTFALL - SUMMER CONDITIONS
0 1 0 0 0 0 0 0
    0.4660            20         0.1         90.        50.0
                     90.         1.0
         4    1.09000            11.
     00.00    27.0000          13.30      0.0670
     10.00    28.1000           12.7      0.0340
     25.00    29.5000           10.8      0.0340
     50.00    30.1000           10.5      0.0250
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UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: satsum1
CASE I.D. SATELLITE CHANNEL OUTFALL - SUMMER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	11.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.5204	SIGMAT UNITS
FROUDE NUMBER	=	20.0	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	27.00	13.30	20.19	.067
10.00	28.10	12.70	21.15	.034
25.00	29.50	10.80	22.56	.034
50.00	30.10	10.50	23.08	.025

TOTAL EFFLUENT FLOW	=	.4660	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU- TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.56	.00	2.97	2.97	.025
.00	50.00	.100	1.01	22.40	.00	2.95	2.95	.025
.00	49.55	.277	2.79	7.97	.02	1.07	1.07	.025
.04	48.33	.730	7.85	2.80	.02	.43	.43	.026
*****MERGING BEGINS								
.10	47.50	1.009	11.56	1.89	.02	.33	.34	.026
.37	44.19	1.925	22.15	.93	.02	.28	.28	.027
1.89	29.51	6.226	62.62	.13	.03	.23	.23	.032
*****NOMINAL TRAPPING LEVEL REACHED								
2.54	24.60	8.412	75.51	.00	.03	.20	.21	.034
4.01	18.75	126.261	177.16	-.27	.03	.01	.03	.034

COMPUTATIONS CEASE: VERTICAL PLUME VELOCITY IS LESS THAN 0

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED
TRAPPING LEVEL = 24.62 M BELOW SURFACE; DILUTION = 75.47

◄CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:SATELLITE CHANNEL - SUMMER

Current (cm/s)	:	17
Effective diffuser width (m)	:	27.412
Max. dist. from diffuser (m)	:	4000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	75.47
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
1.000E+02	7.547E+01	1.067E+00	1.099E+00	8.844E+01
2.000E+02	7.547E+01	1.307E+00	1.207E+00	1.190E+02
3.000E+02	7.547E+01	1.607E+00	1.326E+00	1.608E+02
4.000E+02	7.547E+01	1.938E+00	1.456E+00	2.130E+02
5.000E+02	7.547E+01	2.291E+00	1.600E+00	2.766E+02
6.000E+02	7.547E+01	2.663E+00	1.757E+00	3.531E+02
7.000E+02	7.547E+01	3.067E+00	1.930E+00	4.469E+02
8.000E+02	7.547E+01	3.481E+00	2.120E+00	5.570E+02
9.000E+02	7.547E+01	3.907E+00	2.329E+00	6.868E+02
1.000E+03	7.547E+01	4.354E+00	2.559E+00	8.408E+02
1.100E+03	7.547E+01	4.811E+00	2.811E+00	1.021E+03
1.200E+03	7.547E+01	5.292E+00	3.088E+00	1.233E+03
1.300E+03	7.547E+01	5.801E+00	3.392E+00	1.485E+03
1.400E+03	7.547E+01	6.324E+00	3.726E+00	1.778E+03
1.500E+03	7.547E+01	6.834E+00	4.093E+00	2.111E+03
1.600E+03	7.547E+01	7.353E+00	4.496E+00	2.495E+03
1.700E+03	7.547E+01	7.881E+00	4.939E+00	2.938E+03
1.800E+03	7.547E+01	8.422E+00	5.426E+00	3.449E+03
1.900E+03	7.547E+01	8.998E+00	5.960E+00	4.048E+03
2.000E+03	7.547E+01	9.587E+00	6.548E+00	4.737E+03
2.100E+03	7.547E+01	1.019E+01	7.192E+00	5.530E+03
2.200E+03	7.547E+01	1.080E+01	7.901E+00	6.439E+03
2.300E+03	7.547E+01	1.142E+01	8.679E+00	7.482E+03
2.400E+03	7.547E+01	1.206E+01	9.534E+00	8.676E+03
2.500E+03	7.547E+01	1.270E+01	1.047E+01	1.004E+04
2.600E+03	7.547E+01	1.336E+01	1.151E+01	1.160E+04
2.700E+03	7.547E+01	1.403E+01	1.264E+01	1.338E+04
2.800E+03	7.547E+01	1.471E+01	1.388E+01	1.541E+04
2.900E+03	7.547E+01	1.540E+01	1.525E+01	1.772E+04
3.000E+03	7.547E+01	1.610E+01	1.675E+01	2.035E+04
3.100E+03	7.547E+01	1.681E+01	1.840E+01	2.334E+04
3.200E+03	7.547E+01	1.753E+01	2.022E+01	2.674E+04
3.300E+03	7.547E+01	1.826E+01	2.221E+01	3.060E+04
3.400E+03	7.547E+01	1.900E+01	2.440E+01	3.498E+04
3.500E+03	7.547E+01	1.975E+01	2.680E+01	3.994E+04
3.600E+03	7.547E+01	2.050E+01	2.944E+01	4.556E+04
3.700E+03	7.547E+01	2.127E+01	3.234E+01	5.192E+04
3.800E+03	7.547E+01	2.205E+01	3.553E+01	5.912E+04
3.900E+03	7.547E+01	2.284E+01	3.903E+01	6.726E+04
4.000E+03	7.547E+01	2.363E+01	4.287E+01	7.646E+04

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 4000 m

UNIVERSAL DATA FILE: satwin2

```
SATELLITE CHANNEL OUTFALL - WINTER CONDITIONS
0 1 0 0 0 0 0 0
    0.4660          20        0.1        90.        50.0
                   90.        1.0
         4    1.09000          9.
     00.00    29.6600        8.58     0.0674
     10.00    29.7300        8.55     0.0340
     25.00    29.9300        8.46     0.0340
     50.00    30.1600        8.00     0.0250
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UMERGE VERSION 1.0 AUGUST 1985.

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UNIVERSAL DATA FILE: satwin2

CASE I.D. SATELLITE CHANNEL OUTFALL - WINTER CONDITIONS

ASPIRATION ENTRAINMENT COEFFICIENT	=	.10	(DEFAULT)
NUMBER OF STEPS ALLOWED	=	5000	(DEFAULT)
ITERATION PRINTOUT FREQUENCY	=	150	(DEFAULT)
PRINT ARRAY AA (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AB (0=NO, 1=YES)	=	0	(DEFAULT)
PRINT ARRAY AC (0=NO, 1=YES)	=	0	(DEFAULT)

INITIAL TEMPERATURE OF THE PLUME	=	9.00	DEGREES CENTIGRADE
INITIAL SALINITY OF THE PLUME	=	1.09	PPT
INITIAL DENSITY OF THE PLUME	=	.7022	SIGMAT UNITS
FROUDE NUMBER	=	19.8	

DEPTH (M)	SALIN (PPT)	TEMP (C)	SIGMAT	U (M/S)
.00	29.66	8.58	23.03	.067
10.00	29.73	8.55	23.09	.034
25.00	29.93	8.46	23.26	.034
50.00	30.16	8.00	23.51	.025

TOTAL EFFLUENT FLOW	=	.4660	CMS
NUMBER OF PORTS	=	20	
PORT DIAMETER	=	.1000	M
PORT SPACING	=	1.00	M
VERTICAL PORT ANGLE FROM HORIZONTAL	=	90.0	DEGREES
PORT DEPTH	=	50.00	M

FIRST LINE OF OUTPUT ARE INITIAL CONDITIONS

X (M)	Z (M)	PLUME DIAMETER (M)	DILU-TION	DENDIFF (SIGMAT)	HORIZ VEL (M/S)	VERT VEL (M/S)	TOTAL VEL (M/S)	AMBIENT CURRENT (M/S)
.00	50.00	.100	1.00	22.80	.00	2.97	2.97	.025
.00	50.00	.100	1.01	22.65	.00	2.95	2.95	.025
.00	49.55	.277	2.79	8.06	.02	1.07	1.07	.025
.04	48.34	.730	7.84	2.85	.02	.43	.43	.026
*****MERGING BEGINS								
.10	47.50	1.007	11.55	1.93	.02	.34	.34	.026
.36	44.22	1.909	22.15	.98	.02	.28	.28	.027
1.78	29.93	5.647	62.60	.25	.03	.26	.26	.032
*****NOMINAL TRAPPING LEVEL REACHED								
3.95	12.90	12.256	108.98	.00	.03	.20	.20	.034

COMPUTATIONS CEASE: PLUMES SURFACE

PLUMES MERGED BEFORE TRAPPING LEVEL REACHED

TRAPPING LEVEL = 12.95 M BELOW SURFACE; DILUTION = 108.86

◄CALCULATION OF DILUTION DUE TO DISPERSION AND DIEOFF

TITLE:SATELLITE CHANNEL - WINTER

Current (cm/s)	:	17
Effective diffuser width (m)	:	31.256
Max. dist. from diffuser (m)	:	4000
Incremental steps (m)	:	100
Initial dilution from DILN1	:	108.86
Dieoff decay rate -> T90 (hours)	:	4

DISTANCE	INITIAL DIL	DISP DIL	DIE DIL	TOTAL DIL
1.000E+02	1.089E+02	1.053E+00	1.099E+00	1.259E+02
2.000E+02	1.089E+02	1.262E+00	1.207E+00	1.658E+02
3.000E+02	1.089E+02	1.527E+00	1.326E+00	2.204E+02
4.000E+02	1.089E+02	1.826E+00	1.456E+00	2.894E+02
5.000E+02	1.089E+02	2.141E+00	1.600E+00	3.728E+02
6.000E+02	1.089E+02	2.473E+00	1.757E+00	4.731E+02
7.000E+02	1.089E+02	2.824E+00	1.930E+00	5.933E+02
8.000E+02	1.089E+02	3.206E+00	2.120E+00	7.400E+02
9.000E+02	1.089E+02	3.580E+00	2.329E+00	9.078E+02
1.000E+03	1.089E+02	3.977E+00	2.559E+00	1.108E+03 (1.13)
1.100E+03	1.089E+02	4.387E+00	2.811E+00	1.342E+03
1.200E+03	1.089E+02	4.807E+00	3.088E+00	1.616E+03
1.300E+03	1.089E+02	5.245E+00	3.392E+00	1.937E+03
1.400E+03	1.089E+02	5.709E+00	3.726E+00	2.316E+03
1.500E+03	1.089E+02	6.185E+00	4.093E+00	2.756E+03
1.600E+03	1.089E+02	6.656E+00	4.496E+00	3.258E+03
1.700E+03	1.089E+02	7.128E+00	4.939E+00	3.833E+03
1.800E+03	1.089E+02	7.608E+00	5.426E+00	4.494E+03
1.900E+03	1.089E+02	8.095E+00	5.960E+00	5.252E+03
2.000E+03	1.089E+02	8.603E+00	6.548E+00	6.132E+03
2.100E+03	1.089E+02	9.134E+00	7.192E+00	7.152E+03
2.200E+03	1.089E+02	9.675E+00	7.901E+00	8.321E+03
2.300E+03	1.089E+02	1.023E+01	8.679E+00	9.662E+03
2.400E+03	1.089E+02	1.079E+01	9.534E+00	1.120E+04
2.500E+03	1.089E+02	1.136E+01	1.047E+01	1.295E+04
2.600E+03	1.089E+02	1.194E+01	1.151E+01	1.495E+04
2.700E+03	1.089E+02	1.253E+01	1.264E+01	1.724E+04
2.800E+03	1.089E+02	1.313E+01	1.388E+01	1.984E+04
2.900E+03	1.089E+02	1.373E+01	1.525E+01	2.280E+04
3.000E+03	1.089E+02	1.435E+01	1.675E+01	2.617E+04
3.100E+03	1.089E+02	1.498E+01	1.840E+01	3.001E+04
3.200E+03	1.089E+02	1.561E+01	2.022E+01	3.436E+04
3.300E+03	1.089E+02	1.625E+01	2.221E+01	3.930E+04
3.400E+03	1.089E+02	1.691E+01	2.440E+01	4.490E+04
3.500E+03	1.089E+02	1.757E+01	2.680E+01	5.125E+04
3.600E+03	1.089E+02	1.823E+01	2.944E+01	5.844E+04
3.700E+03	1.089E+02	1.891E+01	3.234E+01	6.658E+04
3.800E+03	1.089E+02	1.960E+01	3.553E+01	7.579E+04
3.900E+03	1.089E+02	2.029E+01	3.903E+01	8.620E+04
4.000E+03	1.089E+02	2.099E+01	4.287E+01	9.796E+04

MAXIMUM DISTANCE FROM DIFFUSER HAS BEEN REACHED 4000 m

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Appendix 4 Emerging Contaminants

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Re: Emerging Contaminants of Concern

There is a growing concern for the potential impact to the marine environment from "emerging contaminants". The term "emerging contaminants" refers to substances that are released into the environment for which no regulations are established. Due to their large number (1000's), published data concerning occurrence and potential toxicological effects is limited. The contamination source for the aquatic environment is mainly effluents from sewage treatment plants (STPs) and combined sewage overflows (CSOs). Although reported concentrations tend to be generally low for many of these compounds, questions have been raised over the potential impacts of emerging pollutants in the environment on human and animal health after long-term exposure. Additionally, the extent to which the current water and wastewater treatment infrastructures can effectively remove these compounds is also limited (Oulton et al., 2010). A review of substances of concern (including emerging contaminants), sources and likely occurrence, known toxicity, as well as treatment options for removal in municipal wastewater in Canada has been done for the national 2006 CCME wastewater strategy (CCME, 2005)

Emerging pollutants include a wide range of substances, including; pharmaceuticals and personal care products (PPCPs), illicit drugs and drugs of abuse, hormones and steroids, benzothiazoles, benzotriazoles, polychlorinated naphthalenes (PCNs), perfluorochemicals (PFCs), polychlorinated alkanes (PCAs), polydimethylsiloxanes (PDMSs), synthetic musks, quaternary ammonium compounds (QACs), bisphenol A (BPA), triclosan (TCS), triclocarban (TCC), as well as polar pesticides, veterinary products, industrial compounds/by-products, food additives and engineered nano-materials (Lapworth et al., 2012) and PAHs, particularly in the Arctic (De Laender et al., 2011).

A review of known persistence and toxicity of many of these compound groups is given in Thomaidis et al. (2012), along with comments regarding removal of these compound groups by sewage treatment. In addition, a summary of contaminants considered to be of most concern on the BC coast is included in Appendix 1, including the source and concerns of specific groups of contaminants and the current Canadian regulatory standards.

The Vancouver Aquarium's proposed BC Pollution Watch Project (PWP, Appendix 2), and the complimentary Salish Sea Ambient Monitoring Exchange (SSAMEx, a collaboration of methodology and data sharing for monitoring agencies: Appendix 3) are developing a regional monitoring program for the Salish Sea. The list of contaminant groups that will be focused on the programs is included in Appendix 1, and is recommended as a good template for regulatory agencies concerned with emerging contaminant issues.

Two contaminant groups which can be considered "emerging" have been relatively well-studied, probably because they are the most ubiquitous and common globally. These include the flame-retardants (PBDEs), and the hydrocarbons (PAHs). These two groups should be an integral part of any monitoring program for comprehensive urban discharges (such as sewage outfalls or CSOs). In addition, PCBs have been well studied as persistent and bio-accumulative organic compounds and thus provide an important model for understanding food-chain uptake kinetics and circulation properties of other, emerging persistent organic pollutants. Although PCBs are considered "legacy" compounds banned since the 1970s, high concentrations are still found in marine mammals and some fish in B.C. (Cullon et al. 2005; Ross et al., 2013). The continued cycling of PCBs throughout the environment in all environmental media presents an ongoing problem on the west coast of Canada that is not adequately addressed by current sediment quality guidelines (Alava et al., 2012; Natale, 2007; Hickie et al., 2007). These should also be part of a comprehensive urban discharge monitoring program. The sediment distributions and uptake into the food chain in coastal BC of these three contaminant groups will be examined in more detail below.

A number of less studied persistent pollutant are now being measured in both municipal effluent and the receiving environment. Some substances of particular concern include:

Steroids	Both natural and synthetic, some of which are endocrine disruptors;
PFCs	Highly persistent with some removed by sewage treatment, and some not);
PDMSs	At least 94% of PDMSs are unchanged during wastewater treatment, because of high chemical and thermal stabilities, but tend to have a short (less than 1 month) half-life in sediments (Clarke and Smith, 2011);
Synthetic Musks	Highly lipophilic, so they tend to accumulate in sediments, sludges, and biota; musk galaxolide is among the most frequently reported compounds (Richardson, 2012).
Pharmaceuticals	The most frequently reported group of compounds, including analgesics, anti-inflammatory drugs, antibiotics, anti-epileptics (carbamazepine) and barbiturates (primidone). Numerous pharmaceuticals, including carbamazepine, clofibric acid, diclofenac, fenofibric acid, gemfibrozil, and naproxen were ubiquitous in German sewage treatment plant effluent and river waters (Murray et al. 2010).

Bisphenol A and nonylphenol (NP), Two phenolic compounds, both known endocrine disruptors;

tri(2- chloroethyl) phosphate, a flame retardant among the most frequently reported compounds (Richardson, 2012).

Diuretics, blood lipid regulators, beta blockers, analgesics, antibiotics and fragrances are also detected frequently in WWTP samples (Teijon et al., 2010).

Monitoring this wide range of substances in a serious challenge for regulatory programs. An integrated approach must be developed which includes using biological-effect techniques with chemical measurements, and second, assessment tools are required. Proposals for both of these have been initiated by International Council for the Exploration of the Sea (ICES) and Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) working groups and workshops (Thain et al., 2008).

PBDEs (see also Appendix 1)

PBDEs have been widely used as flame retardants, and are presently found at relatively high concentrations in urban settings, particularly wastewater (Song et al., 2006; Moon et al., 2007; Dinn et al., 2012a) and Combined Sewer Overflows (CSOs), and thus adjacent receiving environments (Oberg et al. 2002; Hale et al. 2006; Macdonald et al. 2007; Johannessen et al. 2008; Peng et al. 2009; Grant et al., 2010). Sediment PBDEs tend to be dominated by heavier-brominated congeners (mostly PBDE 209) near sources, with distillation and debromination evident away from sources (Grant et al., 2010; Salvado et al., 2012). The heavier PBDE congeners are most strongly correlated with sediment grain size (Lebeuf, 2004; Li et al., 2010; Burd et al., 2014), followed by %TOC, emphasizing the strong particle affinity of these compounds.

PBDEs are an emerging health threat for marine organisms in BC and elsewhere (Ross et al., 2009a b), particularly at the higher trophic levels (salmonids and mammals). PBDEs are taken up more intensively than PCBs in benthos (Dinn et al., 2012a: Burd et al., 2014), possibly because of the primary association of PBDEs with "fresh" organic detritus (such as outfall organic particulates) in marine sediments, and because benthic fauna tend to feed selectively on high quality, fresh organic carbon sources (Gunnarsson et al., 2000; Burd et al., 2014). At the CRD Macaulay outfall off Victoria, sediment PBDE concentrations are similar to effluent, since the outfall is the only major sediment input source (Dinn et al., 2012b). In turn, sediment PBDE concentrations reflect benthic invertebrate food concentrations. Conversely, near Iona outfall off Vancouver, outfall particulates containing high PBDE concentrations are rapidly buried in sediments by river-borne particulates (Burd et al., 2013), as well as coarser sands which accumulate around the outfall causeway. Therefore, sediment PBDEs near the Iona outfall are much lower than in the outfall particulates and do not reflect food contaminants levels.

The PBDE congener balance in sediment-feeding benthos tends to reflect the sediment composition, thus including considerable concentrations of the most heavily brominated and common sediment congener (PBDE 209) (Moon et al. 2007, and see Munschy et al., 2011, Baron et al., 2013, Ciparis and Hale, 2005; Klosterhaus et al., 2011). However, Li et al. (2010) suggest that marine benthos take up PBDE 209, but fishes do not, having instead relatively much higher concentrations of lower brominated forms. PBDE-209 is still documented at the top of aquatic food webs (Ross et al. 2009a, b), although at variable and often low concentrations (Sormo et al., 2006; Christensen et al. 2013). Much of the concentration of lower brominated PBDEs in tissues may be explained by debromination of the heavier brominated forms such and PBDE 209 (Ikonomou et al., 2006). Therefore, the continued use of PBDE 209 industrially in North America may result in a latent pool of more toxic and bio-accumulative byproducts in future (Ross et al., 2013). Burd et al. (2014) suggest that there is a huge biological reservoir of PBDEs in sediment biota in the Strait of Georgia, which is likely to increase with the on-going input through outfalls of the heavy forms and subsequent debromination to more toxic and bio-accumulative forms. The extent to which these toxic contaminants will biomagnify at higher trophic levels remains a critical question to be addressed.

PAHs (see also Appendix 1)

Yunker et al. (1999) found the Fraser River to be the predominant source for natural and anthropogenic hydrocarbons to the Strait of Georgia, B.C. The natural hydrocarbon burden from the Fraser River is augmented principally by petroleum hydrocarbons and combustion PAHs from Vancouver. In Vancouver Harbour, the low rate of sediment accumulation coupled with surface mixing has led to the retention of contaminant PAHs within the surface mixed layer, while the rapid delivery of sediments from the Fraser

River has buried contaminant PAHs from historical ocean disposal in the Strait of Georgia (Yunker et al., 1999).

As legacy POPS have declined due to disuse, other on-going use contaminants have become more prominent in marine ecosystems. In general, PAH concentrations from fossil fuel consumption have recently been found to have increased substantially in Arctic waters and to dominate at the base of the sediment food chain in benthic invertebrates (De Laender et al., 2011). De Laender et al., 2011) illustrate that concentration of fossil fuel derived PAHs in lower trophic levels (invertebrates and fish) increased 10 to 30 fold over the past 25 years in the Canadian Arctic and now dominate the summed POPs in these biota. Furthermore, the use of biota-sediment accumulation factors (BSAFs based on equilibrium partitioning theory) using sediment organic content and tissue lipid concentrations do not always accurately predict PAH bioaccumulation in sediment invertebrates (Ferguson et al. 1998), thus making trophic transfer models difficult.

Eight of the 9 PAHs that increased over time in the Arctic have been shown to originate at least partly from fossil fuel combustion: 31 benzo[ghi]perylene, benzo[a]pyrene, benzo[a]anthrancene, antracene, pyrene, phenanthrene, fluoranthene, and benzo[e]pyrene (De Laender et al., 2011). The two PAHs for which the inferred water concentrations did not increase over time (fluorene, acenaphtylene) are PAHs that are generally not produced by fossil fuel burning but are used in chemical synthesis, e.g., as a precursor of pharmaceuticals.

However, PAH modeled concentrations decreased with increasing trophic level in the Arctic, a process that is referred to as “biodilution”, and has been reported in other marine food webs as well, e.g., the Baltic sea (Nfon et al., 2008), Bohai bay China (Wan et al., 2007) and Tokio Bay (Takeuchi et al., 2009). However, organisms that rely directly on benthic invertebrates for food can be particularly vulnerable. For example, the partitioning of hydrocarbons between sediments and adjacent food webs provides an important exposure route for sea otters, which consume ~25% of their body weight per day in benthic invertebrates. Exceedances of PAH sediment quality guidelines designed to protect aquatic biota occur at 20% of the sea otter habitat sites examined in B.C., and suggest that sea otters are vulnerable to hydrocarbon contamination even in the absence of catastrophic oil spills (Harris et al., 2011).

PCBs (see also Appendix 1)

Before 2000, PCBs were the dominant POPS in tissues and sediments in marine habitats worldwide (Ross et al., 2000). De Laender et al. (2011) illustrate that in the Barents/Norwegian Sea fauna PCBs decreased 10-fold between 1985 and 2010. PCBs are not especially concentrated in sewage outfalls and may actually be diluted in effluent (Johannessen et al. 2008, Burd et al., 2014), particularly where there is considerable burial by outfall and natural riverine particulates (c.f. the Iona outfall). The legislative actions to ban the production and use of PCBs triggered by measured concentrations in mammals, appear to have been successful in some measure as concentrations at the top of the Arctic food web have dropped substantially over time (De Laender et al., 2011). Although PCB and related compounds are declining in harbour seals in the Salish Sea (Ross et al., 2013), the longest-lived mammals (such as killer whales) still exhibit dangerously high levels (Cullon et al. 2005; Ross et al., 2013). Historical “hotspots” still exist in B.C. marine sediments, particularly in busy harbours, such as Vancouver and Victoria harbours (Grant et al., 2010; Burd et al., 2014). This is likely due to historical reservoirs of PCBs in industrial sites which tend to have discharges or runoff to the marine environment. Elevated PCBs are also found in northern ports in the Strait of Georgia (Grant et al., 2010; UMI and Morrow 2007; McPherson et al., 2011), where new sources of PCBs may be limited, but burial in sediments of historical accumulations is slow due to limited natural sedimentation rates (Johannessen et al., 2005).

Based on food-web studies of PCB uptake in the Strait of Georgia, Cullon et al. (2012) found that the bulk of PCBs are found at the base of the food chain, in benthic invertebrates. Burd et al. (2014) showed that PCB uptake by bulk benthos is less than that of PBDEs due to feeding patterns. PCBs nevertheless showed a consistent or “minimum” baseline concentration in benthos tissues, even where sediment concentrations were lower than benthic tissues. This suggests a non-zero “starting” PCB concentration in newly settled juveniles. Since most benthic larval forms are non-feeding until settlement, they are unlikely to accumulate PCBs from the water column food web. Rather, the elevated PCB levels in benthos even in sediments with low concentrations probably reflects transfer to offspring from the parent body burden, as well as the ubiquitous distribution of the legacy PCBs throughout the ecosystem. Notable, the baseline PCB tissue concentration and uptake rate in benthos was more elevated in organically enriched samples near two major sewage outfalls and one organically enriched urban harbour (Burd et al., 2014 and see Gunnarsson et al. 1999). This suggests that a portion of the PCBs in non-enriched sediments may be biologically unavailable. Possibly the PCBs have been cycling through the ecosystem long enough that they are more bound to refractory (older) than to labile (fresher) organic carbon in marine sediments. Increased PCB uptake slopes in organically enriched sediments appears to be related to much more rapid biomass turnover near outfalls (Burd et al., 2013; Burd et al., 2014), suggesting that organisms process far more sediment PCBs on an annual basis near organic enrichment sources than in background areas.

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Appendix 1 – List of Contaminants of Concern

Persistent Organic CONTAMINANTS OF CONCERN

Polycyclic Aromatic Hydrocarbons (PAHs)

- *Categories:* hydrocarbons.
- *Source:* PAHs are often byproducts of petroleum processing or combustion; some PAHs are used to make dyes, plastics, and pesticides. Forest fires and prairie fires, agricultural burning, and fossil-fuels are the major contributors of PAHs to the environment.
- *Persistence:* There exist thousands of PAHs in the environment, with individual PAHs varying in behaviour. Lighter PAH compounds are generally more water soluble and can therefore be more bioavailable to aquatic life where they may pose risk of acute toxicity. However, breakdown times are much shorter than for heavier compounds. PAHs with more than four rings, being less volatile and soluble, favor adherence to solid particles. They are generally found in soil and sediment as complex mixtures. Alkylated PAHs are more persistent than their parent PAHs.
- *Toxicity:* Many of these compounds are highly carcinogenic at relatively low levels. The heavier PAH compounds tend to be associated with more chronic health effects. US EPA has identified 16 priority PAHs that are thought to be carcinogenic through multiple routes of exposure, and can affect the immune, reproductive, nervous and endocrine systems. The most toxic PAH is benzo(a)pyrene.
- *Legislation:* CEPA 1999 Schedule 1 - List of Toxic Substances: new restrictions in Europe (ECHA: EU No 1272/2013).
- *British Columbia*: http://www.env.gov.bc.ca/wat/wq/BCguidelines/pahs/pahs-03.htm ; DFO http://www.dfo-mpo.gc.ca/Library/278588.pdf
- *BC research:* Harris,K.A., Yunker,M.B., Dangerfield,N., and Ross,P.S. 2011. Sediment-associated aliphatic and aromatic hydrocarbons in coastal British Columbia, Canada: concentrations, composition, and associated risks to protected sea otters. Environ.Pollut. **159**: 2665-2674.

Polychlorinated biphenyls (PCBs)

- *Category:* Industrial heat resistant lubricant and transformer oil used in the past.
- *Source:* These compounds have been used as heat exchange fluids, in electric transformers and capacitors, and as additives in paint, carbonless copy paper, and plastics.
- *Persistence:* Their persistence in the environment corresponds to the degree of chlorination, and half-lives can vary from weeks to decades.
- *Toxicity*: Of the 209 different types of PCBs, 13 exhibit a dioxin-like toxicity. PCBs are toxic to fish, causing reproductive failures at relatively low doses. Large numbers of people have been exposed to low to moderate levels of PCBs through food contamination. Since PCBs are persistent, bioaccumulative and toxic, they accumulate in aquatic food webs and attain high levels in some marine mammals. PCBs have been associated with toxic effects in marine mammals such as

endocrine disruption, which can cause impairment of reproduction, development, and other hormonally mediated processes, and immunotoxicity, giving rise to an increased susceptibility to infectious diseases and cancers.

- *Legislation*: Listed under Annex A with specific exemptions and under Annex C of the Stockholm Convention. The import, manufacture, and sale (for re-use) of PCBs were made illegal in Canada in 1977 and release to the environment of PCBs was made illegal in 1985. However, Canadian legislation has allowed owners of PCB equipment to continue using PCB equipment until the end of its service life. The storage of PCBs has been regulated since 1988. Handling, transport and destruction of PCBs are also regulated, mostly under provincial regulations. Canada is signatory to several international agreements on the phase-out of a number of persistent toxic substances including PCBs. Environment Canada has therefore repealed the *Chlorobiphenyls Regulations* and the *Storage of PCB Material Regulations* on September 5, 2008 and made the *PCB Regulations* under the *Canadian Environmental Protection Act*, 1999 (CEPA 1999) that set specific dates for the destruction of PCBs in service and in storage.
- *British Columbia*: ftp://canuck.seos.uvic.ca/docs/SoG-DFO-PinO-2013/Frouin_2013_Progress-in-Oceanography.pdf . Ross, PS, GM Ellis, MG Ikonomou, LG Barrett-Lennard and RF Addison. 2000. High PCB concentrations in free-ranging Pacific Killer Whales, Orcinus orca: Effects of age, sex and dietary preference. Marine Pollution Bulletin 40:504-515.

Polychlorinated dibenzo-p-dioxins (PCDDs)

- *Categories:* Dioxins, by-products.
- *Source:* These chemicals are produced unintentionally due to incomplete combustion, as well during the manufacture of pesticides and other chlorinated substances. They are emitted from the low-temperature incineration of hospital, municipal, and hazardous wastes, and also from automobile emissions, peat, coal, and burning of salt laden wood in coastal pulp and paper boilers, iron sintering and electric arc furnace steel manufacturing. There were releases of large amounts of dioxins from pulp and paper mills in Canada prior to regulations restricting the use of elemental liquid chlorine.
- *Persistence:* There are 75 different dioxins, of which seven are considered to be of concern. High capacity to accumulate in biological tissues.
- *Toxicity:* Dioxins have been associated with a number of adverse effects in humans, including immune and enzyme disorders and chloracne, and they are classified as possible human carcinogens.
- *Legislation:* Listed under Annex C of the Stockholm Convention. Dioxins and furans are slated for virtual elimination under the Canadian Environmental Protection Act, the federal Toxic Substances Management Policy and the CCME Policy for the Management of Toxic Substances.
- *British Columbia*: “The most contaminated coastal marine areas of British Columbia appear to be Howe Sound at Squamish and Hecate Strait.[…] Sediment samples collected from the Atlantic coast were much less contaminated than those from the Pacific coast.” Canadian Sediment Quality

Guidelines for the Protection of Aquatic Life (CCME, 2001). http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2000/PDF/RES2000_171e.pdf

- *BC research:* Yunker,M.B., Cretney,W.J., and Ikonomou,M. 2002. Chlorinated dibenzo-*p*-dioxins and dibenzofurans trends in sediment and crab hepatopancreas for pulp mill and harbour sites in British Columbia. Environ.Sci.Technol. **36(9)**: 1869-1878.

Polychlorinated dibenzofurans (PCDFs)

- *Categories:* Furans, By-products
- *Source:* These compounds are produced unintentionally from many of the same processes that produce dioxins, and also during the production of PCBs. They have been detected in emissions from waste incinerators, automobiles and from pulp mills. There were releases of large amounts of dioxins from pulp and paper mills in Canada prior to regulations restricting the use of elemental liquid chlorine.
- *Persistence:* Furans persist in the environment for long periods. High capacity to accumulate in biological tissues.
- *Toxicity:* Furans are structurally similar to dioxins and share many of their toxic effects. There are 135 different types, and their toxicity varies. Furans are classified as possible human carcinogens. Food, particularly animal products, is the major source of exposure for humans. Furans have also been detected in breast-fed infants.
- *Legislation:* Listed under Annex C of the Stockholm Convention. Dioxins and furans are slated for virtual elimination under the Canadian Environmental Protection Act, the federal Toxic Substances Management Policy and the CCME Policy for the Management of Toxic Substances.
- *British Columbia*: "The most contaminated coastal marine areas of British Columbia appear to be Howe Sound at Squamish and Hecate Strait.[…] Sediment samples collected from the Atlantic coast were much less contaminated than those from the Pacific coast." Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CCME, 2001). http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2000/PDF/RES2000_171e.pdf
- *BC research:* Yunker,M.B., Cretney,W.J., and Ikonomou,M. 2002. Chlorinated dibenzo-*p*-dioxins and dibenzofurans trends in sediment and crab hepatopancreas for pulp mill and harbour sites in British Columbia. Environ.Sci.Technol. **36(9)**: 1869-1878.

Brominated Flame Retardants

- *Categories:* Polybrominated Diphenylethers (PBDEs), Hexabromocyclododecane (HBCD), Tetrabromobisphenol A (TBBP-A).
- *Source:* flame retardants appear in manufactured materials, such as furnishings, electronics, plastics and textiles; a major source is diffuse leaching from products into wastewater streams from users, households and industries.

- *Persistence:* Many of the BFRs are considered toxic, persistent and bioaccumulative. Largely distributed in organisms (including marine mammals) from various geographic regions. Long-range atmospheric transport and deposition.
- *Toxicity:* PBDEs bioaccumulate in blood, breast milk, and fat tissues. Health effects of PBDE exposure include damage to the neurological, reproductive, immune, and hormonal systems. The most widely used chemical in this group, decaBDE, is also a suspected carcinogen. HBCD causes reproductive toxicity. TBBPA degrades to bisphenol A and to TBBPA dimethyl ether; TBBPA has demonstrated toxicity in a variety of aquatic and terrestrial species, its chronic toxicity is predicted at very low concentrations.
- *Legislation:* PBDEs "toxic", as defined under the Canadian Environmental Protection Act, 1999. Regulations prohibit the manufacture of all PBDEs in Canada, and restricting the import, use and sale of PBDEs found in commercial mixtures of greatest concern (Penta- and OctaBDE). DecaBDE is under assessment. Stockholm Convention on Persistent Organic Pollutants decided in May 2013 to list hexabromocyclododecane in Annex A (for elimination) to the Convention with specific exemptions. TBBPA is currently in the pre-registration phase of REACH. The Government of Canada is considering the implementation of risk management measures to reduce releases of TBBPA from industrial source if required, while maintaining the use of TBBPA where deemed necessary.
- *British Columbia*: DFO http://www.dfo-mpo.gc.ca/Library/341729.pdf; http://www.orcanetwork.org/habitat/imageshab/RossPBDE.pdf
- *BC research:* Ross,P.S., Noël,M., Lambourn,D., Dangerfield,N., Calambokidis,J., and Jeffries,S. 2013. Declining concentrations of persistent PCBs, PBDEs, PCDEs, and PCNs in harbor seals from the Salish Sea. Progress in Oceanography **115:** 160-170.

Perfluorinated compounds (PFCs)

- *Categories:* Perfluorooctane sulfonic acid (PFOS) and its salts, perfluorooctane sulfonyl fluoride and Perfluorooctanoic acid (PFOA).
- *Source:* electronic parts, firefighting foam, photo imaging, hydraulic fluids and textiles. PFOS was the key ingredient in Scotchgard, a fabric protector made by 3M, and numerous stain repellents.
- *Persistence:* Persistent in the Environment. PFOA and PFOS are considered to be resistant to degradation in soil. Bioaccumulate and persist in protein-rich compartments of fish, birds, and marine mammals.
- *Toxicity:* toxicity, including neonatal mortality. Studies of PFOA indicate that it can cause several types of tumors and neonatal death and may have toxic effects on the immune, liver, and endocrine systems.
- *Legislation:* Added to Annex B of the Stockholm Convention on Persistent Organic Pollutants in May 2009. EPA has designated rules for the use of PFCs. EU and other countries developing strategies to reduce their use. The Government of Canada added PFOS, its salts, and its precursors to the Toxic Substances List under Schedule 1 of the Canadian Environmental Protection Act, 1999.

- *British Columbia*: DFO http://www.dfo-mpo.gc.ca/Library/328420.pdf ; http://www.ncbi.nlm.nih.gov/pubmed/14717162

Nonylphenols and octylphenol

- *Categories:* Alkylphenols.
- *Source:* including nonylphenol, are used to make alkylphenol ethoxylates (APEs), chemical compounds that are mainly used as synthetic surfactants used in detergents and cleaning products. Used as antioxidants, oil additives, detergents, emulsifiers, and solubilizers, precursors of non-ionic surfactants, cosmetic, pesticides.
- *Persistence:* can take months or longer to degrade in surface waters, soils, and sediments. Long distances transportation and global reach.
- *Toxicity:* endocrine disruptor due to its ability to mimic estrogen and in turn disrupt the natural balance of hormones in affected organisms. Prenatal and perinatal exposure to nonylphenol has been linked with developmental abnormalities. Nonylphenol exposure has also been associated with breast cancer.
- *Legislation:* European Union and Canada have banned the use of nonylphenol ethoxylates (NPEs) in detergents.
- *British Columbia*: http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1402&context=bio_fac
- *BC research:* Shang,D.Y., Macdonald,R.W., and Ikonomou,M.G. 1999. Persistence of nonylphenol ethoxylate surfactants and their primary degradation products in sediments from near a municipal outfall in the Strait of Georgia, British Columbia, Canada. Environ.Sci.Technol. **33**: 1366-1372.

Organochlorine Pesticides(OCPs)

- *Categories:* “legacy” pesticides.
- *Source:* organochlorine (OC) pesticides were widely used in agriculture and pest control until research and public concern regarding the hazards of their use led to government restrictions and bans. Despite restrictions and bans on the use of many organochlorine pesticides in the 1970s and 1980s, they continue to persist in the environment today.
- *Persistence:* Despite restrictions and bans on the use of many organochlorine pesticides in the 1970s and 1980s, they continue to persist in the environment today. Organochlorine pesticides are hydrophobic, lipophilic and extremely stable.
- *Toxicity:* Toxicity appears to be via disruption of neural function and specific disturbances vary by chemistry. Studies support both acute and chronic effects of OC pesticides, potentially via damage to reproductive and neurological functions, carcinogenesis and endocrine disruption.
- *Legislation:* Nine of the 12 most hazardous persistent organic pollutants (POPs) targeted by the Stockholm Convention in 2001 are OC pesticides.

- *British Columbia*: DFO http://www.dfo-mpo.gc.ca/Library/329206.pdf
- *BC research:* Cullon,D.L., Jeffries,S.J., and Ross,P.S. 2005. Persistent Organic Pollutants (POPs) in the diet of harbour seals *(Phoca vitulina)* inhabiting Puget Sound, Washington (USA) and the Strait of Georgia, British Columbia (Canada): A food basket approach. Environ.Toxicol.Chem. **24**: 2562-2572.

Neonicotinoid pesticides

- *Categories:* pesticides.
- *Source:* First introduced in the early 1990s as an alternative to the acutely toxic organophosphate and carbamate classes of pesticides, neonicotinoids are now the most widely used insecticides in the world. Neuro-active insecticides chemically similar to nicotine. The neonicotinoid imidacloprid is currently the most widely used insecticide in the world.
- *Persistence:* long-term persistence in soil and water.
- *Toxicity:* The neonicotinoids show reduced toxicity compared to previously used organophosphate and carbamate insecticides. The use of neonicotinoids was linked in a range of studies to a number of adverse ecological effects, including honey-bee colony collapse disorder (CCD) and loss of birds due to reduction in insect populations.
- *Legislation:* Temporary suspensions and bans on the use of different neonicotinoids in several countries.
- *References: http://onlinelibrary.wiley.com/doi/10.1111/1365-2664.12111/abstract*

Multiresidue Pesticides (MRES)

- *Categories:* Current use pesticides.
- *Source:* During the 1970s and 1980s after the detrimental effects of pesticides like DDT became known, OC pesticides were replaced with less persistent pesticides. These new pesticides had different physical-chemicals properties than OCs and different environmental fates.
- *Persistence:* Current use pesticides are generally more target specific and are less persistent in the environment than legacy pesticides.
- *Toxicity:* they may be more acutely toxic than old pesticides. Studies have shown that exposure to OP pesticides can affect the neurological and immune systems in animals. Once in the body, many OP compounds metabolize into dialkyl phosphate metabolites. Atrazine is linked to ovarian cancer and can be toxic to freshwater fish, invertebrates, and aquatic plants.
- *Legislation:* Some banned in the EU.
- *BC research:* Harris,K.A., Dangerfield,N., Woudneh,M., Brown,T.G., Verrin,S., and Ross,P.S. 2008. Partitioning of current-use and legacy pesticides in salmon habitat in British Columbia, Canada. Environ.Toxicol.Chem. **27**: 2253-2262. Tierney,K., Sampson,J., Ross,P., Sekela,M., and Kennedy,C. 2008. Salmon olfaction is impaired by an environmentally realistic pesticide mixture. Environmental Science & Technology **42**: 4996-5001.

Phthalate esters

- *Categories:* Phthalatdibutylphtahalate (DBP), diethylhexylphthalate (DEHP)- plasticizers.
- *Source:* Plastics that contain phthalates are commonly used in applications that include building materials, clothing, cosmetics, perfumes, food packaging, toys, and vinyl products; primarily used to make polyvinyl chloride (PVC) or vinyl flexible and pliant.
- *Persistence:* in anaerobic sediments will tend to persist for long periods.
- *Toxicity:* Endocrine disruptors, teratogenic effects, mortality.
- *Legislation:* Lower-molecular-weight phthalates (3-6 carbon atoms in their backbone) are being gradually replaced in many products in the United States, Canada, and European Union over health concerns.
- *British Columbia*: http://pubs.acs.org/doi/abs/10.1021/es0519637?journalCode=esthag

Chlorinated paraffins

- *Categories:* Short-Chain Chlorinated Paraffins (SCCP)s.
- *Source:* SCCPs are used as lubricants and coolants in metal cutting and metal forming operations and as secondary plasticizers and flame retardants in plastics.
- *Persistence:* They can remain in the environment for a significant amount of time and can bioaccumulate in animal tissues, increasing the probability and duration of exposure. Even relatively small releases of these chemicals from individual manufacturing, processing, or waste management facilities have the potential to accumulate over time to higher levels and cause significant adverse impacts on the environment.
- *Toxicity:* classified as toxic to aquatic organisms.
- *Legislation:* CEPA 1999 Schedule 1 - List of Toxic Substances. The EU has restricteded SCCP use in metalworking fluids. Currently EPA is taking an action plan, under which regulations to restrict or even ban all short-chain paraffins (together with eight phthalates, and two types of perfluorinated compounds: perfluorinated sulfonates and perfluoroalkyl carboxylates) are being considered.
- *British Columbia: http://www.dfo-mpo.gc.ca/Library/341729.pdf*

Pharmaceuticals and Personal Care Products

- *Categories:* Bisphenol A, 2-hydroxy-ibuprofen, Furosemide, Ibuprofen, Gemfibrozil, Naproxen, Glipizide, Triclocarban, Glyburide, Triclosan, Hydrochlorothiazide, Warfarin.
- *Source:* wastewaters from areas of intense urbanization and animal production.
- *Persistence:* Although some degrade quickly, can be considered pseudo-persistent in the environment because of continual inputs. The ability of triclosan (and others) to bioaccumulate is affected by its ionization state in different environmental conditions.

- *Toxicity:* variable. Hormone levels, carcinogenety, etc. Triclosan is toxic to aquatic bacteria at levels found in the environment. It is highly toxic to various types of algae and has the potential to affect the structure of algal commmunities, particularly immediately downstream of effluents from wastewater treatment facilities that treat household wastewaters. Triclosan has been observed in multiple organisms, including algae aquatic blackworms, fish and dolphins.
- *Legislation:* BPA considered "toxic substance" and added it to schedule 1 of the Canadian Environmental Protection Act, 1999. The Risk Assessment by EC proposed that triclosan meets the criterion as set out under paragraph 64(a) of CEPA 1999; it was also proposed that triclosan meets the criterion for bioaccumulation but not the criteria for persistence as set out in the *Persistence and Bioaccumulation Regulations* (Canada 2000).
- *British Columbia*: high levels of PPCPs observed in deep sediments from Puget Sound (SETAC, 2014).

Microplastics

- *Categories:* Micro-plastics have a range of compositions and can be demarcated by usage and origin as: i) 'primary', pellets used as a feedstock in the plastics industry, and in certain applications such as abrasives; and, ii) 'secondary', fragments resulting from the degradation and breakdown of larger items. Artificial particles < 5mm.
- *Source:* wastewaters (Land-based sources are considered to contribute the largest input of plastics), marine litter, shipping, fishing and the military transport. Micro-plastic particles can arise through four separate processes: i) deterioration of larger plastic fragments, cordage and films over time, with or without assistance from UV radiation, mechanical forces in the seas (e.g. wave action, grinding on high energy shorelines), or through biological activity (e.g. boring, shredding and grinding by marine organisms); ii) direct release of micro particles (e.g. scrubs and abrasives in household and personal care products, shot-blasting ship hulls and industrial cleaning products respectively, grinding or milling waste) into waterways and via urban wastewater treatment; iii) accidental loss of industrial raw materials (e.g. prefabricated plastics in the form of pellets or powders used to make plastic articles), during transport or transshipment, at sea or into surface waterways; iv) discharge of macerated wastes, e.g. sewage sludge.
- *Persistence:* high. Microplastics can be ingested by marine organisms.
- *Toxicity:* Entanglement and ingestion with the potential for: physical disruption and abrasion; toxicity of chemicals in the plastic; and, toxicity of absorbed persistent, bioaccumulating and toxic (PBT) substances.
- *Legislation:* none. Some companies have promised a voluntary phase-out of plastic microbeads.
- *British Columbia*: Desforges et al. 2014. Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. Marine Pollution Bulletin 79: 94-99.

Tributyltins (TBTs)

- *Categories:* Organotins
- *Source: T*ributyltin (TBT) is a pesticidal compound applied to the hulls of ships and small boats to protect against an accumulation of barnacles and other fouling organisms on underwater surfaces. TBT is one of a class of compounds called organotins and was introduced in the 1960s. Ships painted with TBT needed repainting every 4-5 years.
- *Persistence:* it is highly persistent, bioaccumulative and biomagnifies in the food chain.
- *Toxicity:* Compared to earlier copper-containing antifouling coatings, TBT was more toxic to fouling organisms and lasted longer. Toxic effects at all trophic levels. Endocrine disruptive (i.e. masculinization of gastropods), it affects immune system in vertebrates.
- *Legislation:* Completely banned in 2008 by the International Convention on the Control of Harmful Anti-fouling Systems on Ships of the International Maritime Organization.
- *British Columbia*: Thompson et al. 1998. Applied Organometallic Chemistry 12; Harding, L., et al. 1988. Levels of organotin in water, sediments and oysters (Crassostrea gigas) from Nanoose Bay, BC. Environment Canada, Environmental Protection, Pacific and Yukon Region, West Vancouver, BC; http://www.dfo-mpo.gc.ca/Library/166734.pdf

Appendix 2 – Pollution Watch Program (PWP), Vancouver Aquarium

Pollution Watch Project

Ocean Pollution Research Program

The new **Pollution Watch Project (PWP)** will evaluate status and trends of pollutants in coastal British Columbia. The project will:

- Measure **priority pollutants** in **sediments** and **invertebrates** in coastal areas;
- Establish **baselines** and create an early warning platform for **new pollutants**;
- Track **pollution trends** over time and space, and report these as part of a series of ‘ocean health indicators’;
- Evaluate the **biological effects** of contaminants of concern on indicator organisms.

Protecting ocean health begins with an understanding of habitat quality close to home.

Sediments and invertebrates

Sediments have formed the basis of pollution monitoring in other parts of the world. Sediment contaminant levels have informed managers and stakeholders on such important issues as trends in contaminant levels over time, the identification of local contaminant hotspots (sources or sinks), the identification of emerging pollutants of concern, and/or linkages to the health of fish and marine mammals.

Shellfish (e.g. blue mussels) have been routinely used in the USA and Europe to provide an early indication of coastal ocean habitat quality. These study animals filter hundreds of liters of water per day and provide an integrated contaminant signals which is more reliable than water samples.

The opportunity

The *Pollution Watch Project* is a priority program of the Vancouver Aquarium Ocean Pollution Research Program. The framework of the PWP will consist of i) a network of geographically-distributed sampling stations, ii) the collection of sediments and invertebrates from these stations, iii) a tier-based approach to matrix analysis for a variety of priority of pollutants, iv) user-friendly data synthesis and reporting in support of pollution status and trends. The PWP will be hosted at the Vancouver Aquarium, but built by a network of partners and supporters

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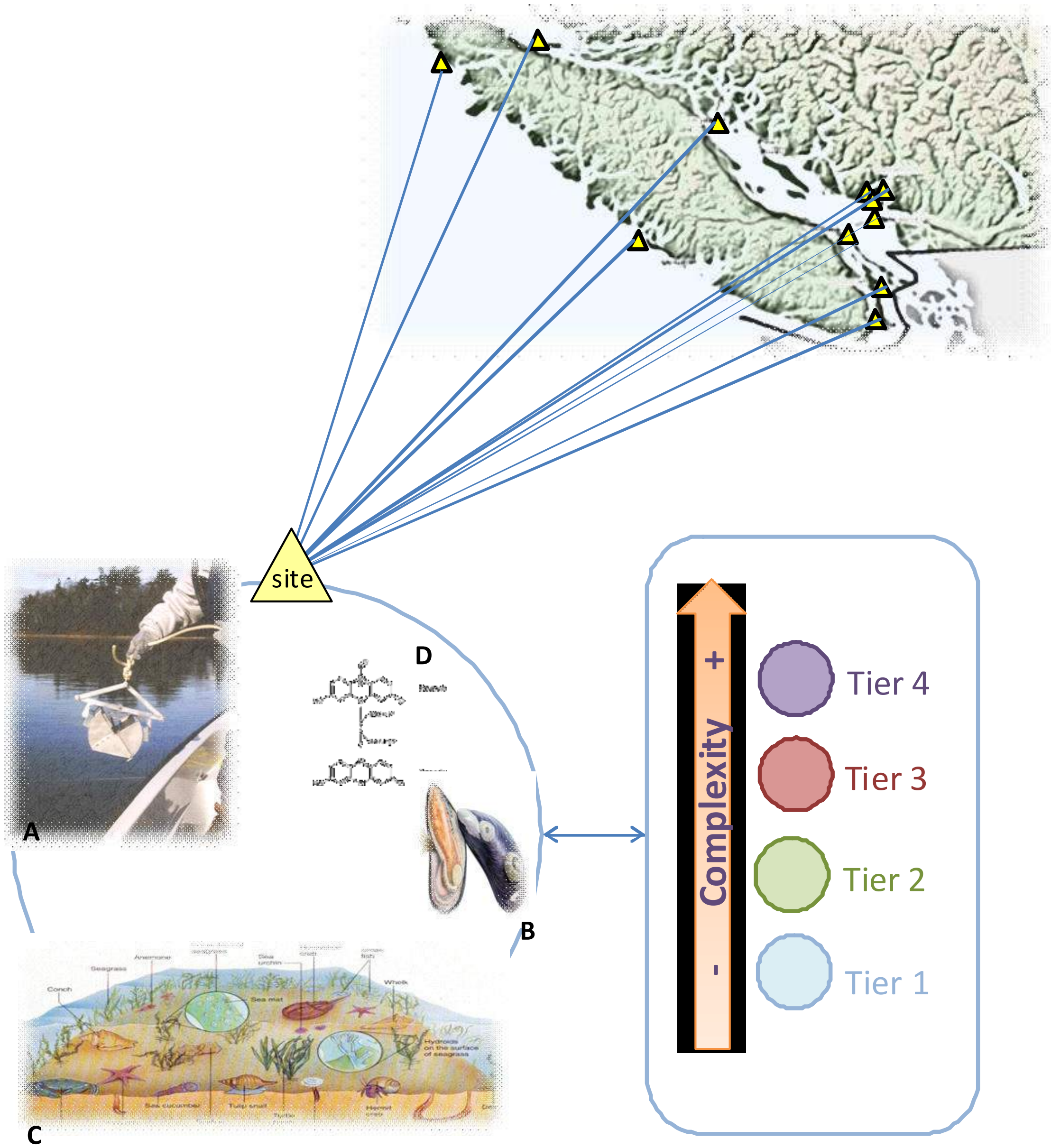
oceanpollution@vanaqua.org



Framework of the PWP. Components A (Contaminants in sediments), B (Bioaccumulation), C (Benthic Ecology), D (effects) and Tiers (1-4) for different sample sites in the BC Coast.

Table 1 Contaminants to be measured as part of the *Pollution Watch* Project will vary by monitoring station as per final study design, and will be contingent upon funding. For example, Tier 1 will consist of an elementary screen for a short list of contaminants, Tier 2 an intermediate list, and Tier 3 an advanced list with a wide range of contaminants of concern.

<table>
<tr><th>Matrix</th><th colspan="3">Tiers</th><th>Parameter</th></tr>
<tr><td rowspan="18">SEDIMENT

A</td><td rowspan="11">Tier 1</td><td rowspan="15">Tier 2</td><td rowspan="18">Tier 3</td><td>TOC</td></tr>
<tr><td>TIC</td></tr>
<tr><td>TN</td></tr>
<tr><td>C/N isotopes</td></tr>
<tr><td>AVS</td></tr>
<tr><td>pH</td></tr>
<tr><td>Granulometry</td></tr>
<tr><td>metals</td></tr>
<tr><td>PCBs</td></tr>
<tr><td>PBDEs</td></tr>
<tr><td>PAHs 2*</td></tr>
<tr><td rowspan="7"></td><td>PFCs</td></tr>
<tr><td>nonylphenols</td></tr>
<tr><td>octylphenol</td></tr>
<tr><td>OC Pesticides</td></tr>
<tr><td>Dioxins and Furans</td></tr>
<tr><td rowspan="2"></td><td>neonicotinoid pesticides</td></tr>
<tr><td>Multiresidue Pesticides (MRES)</td></tr>
</table>

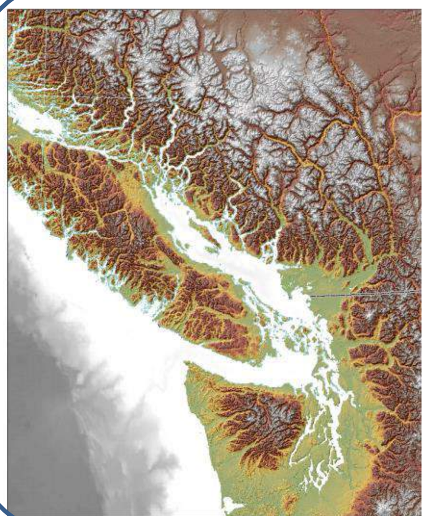
<table>
<tr><th>Matrix</th><th colspan="3">Tiers</th><th>Parameter</th></tr>
<tr><td rowspan="16">TISSUE

B</td><td rowspan="5">Tier 1</td><td rowspan="10">Tier 2</td><td rowspan="16">Tier 3</td><td>C/N isotopes</td></tr>
<tr><td>metals</td></tr>
<tr><td>PCBs</td></tr>
<tr><td>PAHS HR</td></tr>
<tr><td>PBDEs</td></tr>
<tr><td rowspan="11"></td><td>PFCs</td></tr>
<tr><td>Nonylphenol</td></tr>
<tr><td>octyphenol</td></tr>
<tr><td>OC Pesticides</td></tr>
<tr><td>Dioxins and Furans</td></tr>
<tr><td rowspan="6"></td><td>TBBP-A</td></tr>
<tr><td>HBCD</td></tr>
<tr><td>neonicotinoid pesticides</td></tr>
<tr><td>Multiresidue Pesticides</td></tr>
<tr><td>PPCP</td></tr>
<tr><td>Microplastics</td></tr>
</table>

Matrix	Tiers	Parameter

Appendix 3 – Salish Sea Ambient Monitoring Exchange (SSAMEx)

Salish Sea Ambient Monitoring Exchange



The new **Salish Sea Ambient Monitoring Exchange (SSAMEx)** represents a forum to harmonize and exchange ambient marine monitoring data in the trans-boundary waters of British Columbia and Washington State. The goals are to:

- Enhance **trans-boundary collaboration** in quality, methodology and sampling parameters for regional research goals
- **Facilitate exchange** of high quality monitoring data among partners
- **Fill data gaps** and establish **baselines** for ambient (background) habitat and biotic conditions throughout the Salish Sea;
- Document **time-trends** in background marine environmental conditions ;
- complement the BC coast-wide *Pollution Watch Project* (PWP) as part of the Ocean Pollution Research Program (OPRP) at the Vancouver Aquarium

Collaborative monitoring, research and data exchange

The program will rely upon existing monitoring programs, and aims to; 1) harmonize sampling and laboratory methods and quality control so they are inter-comparable, 2) negotiate the inclusion of a common suite of sampling tools, 3) expand geographic coverage of monitoring to allow temporal analysis of ecosystem functioning on a regional scale, 4) facilitate open data exchange between participants, 5) provide high quality data for archiving and dissemination by appropriate agencies, 6) facilitate and support specific research initiatives of interest to collaborators, and finally 7) provide regular, high level analysis and reporting of the data collected to participants.

The opportunity and benefits

SSAMEx follows a 10-year collaborative research program in BC focused on understanding particulates, organics and contaminant cycling and budgets in the Strait of Georgia. An important aim of the SSAMEx is to distinguish localised anthropogenic stressors from background changes in condition due to natural variability and/or climate change. Partners in Canada and the USA can contribute by a) collecting and analyzing monitoring data for sharing, b) in-kind monitoring support for other member organizations through directed sampling, ship time, field personnel, sample analyses, and c) direct financial support. Benefits of the program include informing; 1) decisions about source control, 2) engineering of discharges, 3) context for ecological relevance of localized discharges, prediction of thresholds/tipping points for critical effects, 4) regional fiscal savings for ambient monitoring programs

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SSAMEx: Building a research and data-sharing platform for multiple Salish Sea partners