CHAPTER 144

NEARSHORE CURRENTS SOUTHEASTERN STRAIT OF GEORGIA

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ABSTRACT

Nearshore water transport in the vicinity of Birch Bay and Cherry Point, Washington was investigated during the spring of 1971. The techniques used were: surface floats with variable depth drags, dye patches, streams of paper sheets, wind direction and velocity data, infrared and color aerial photography, and salinity and temperature readings from water samples. Birch Bay flood tide transports water into the bay, and ebb tide carries it out. The latter water either eddies off Point Whitehorn or moves out into the Strait of Georgia. Flood tide at Cherry Point transports water to the Point Whitehorn eddy or into Birch Bay, while on the ebb tide water moves from Cherry Point toward the vicinity of Neptune Beach and Sandy Point.

INTRODUCTION

Recent concerns regarding possible water pollution in the Strait of Georgia have led to an increased amount of scientific inquiry into the environmental factors affecting the nearshore oceanography of water transport. The authors have attempted to look into these factors over one ten-mile portion of Washington coastal water along the southeastern shore of the Strait of Georgia. More specifically, we have concerned outselves with Birch Bay and the coast south including an industrial area in the vicinity of Cherry Point (Fig.1). A sanitary sewer outfall located in Birch Bay has been proposed, and an oil refinery presently under construction will discharge its effluent at Cherry Point. Both projects have the potential of greatly affecting the ecology within nearby waters.

Environmental Overview:

A. Fraser River: Perhaps the single most dynamic factor affecting the Strait of Georgia is the Fraser River which drains much of interior British Columbia. Snow melt in the summer months adds great quantities of turbid fresh water to the Strait. Due to its lower density the river water creates a strongly stratified water column. Maximum flood water from the Fraser River may be observed to extend from its mouth near Vancouver, B.C. to Galiano Island on the opposite side of the Strait. Low density water also moves southward along the shore of the delta to the vicinity of Point Roberts off Birch Bay and Cherry Point (Kincaid et al, 1954; Sylvester et al, 1966; Waldichuk, 1968; Wennekens et al, 1955). Seasonal density stratification of coastal waters may be seen in figure 2 which utilizes data from a study done by the University of Washington (Sylvester et al, 1966) for the Intalco Corporation.

B. Surface Winds: Each past water pollution report on the subject area has presented early in its text the dichotomy between overall wind and tidal actions. The waves are the direct result of surface winds blowing across the water. Wave motion consists of nearly orbital movement of the water and transport in the direction of wave travel, both of which diminish rapidly with depth. Low density water and materials at or near the surface are thus transported in the wave direction.

Wind records for January at Bellingham show a high percentage of winds from the south, southeast, east and northeast. For July, west, southwest and south winds predominate (Phillips, 1966).

C. Coastal Geomorphology: The coastal landforms in the study area (Fig.1) are good indicators of the shoreward transport of sediment. Spits are common and provide tangible evidence. They show the resultant direction of transport of sediment along the shore by the wave generated processes--longshore drift and beach drift.

Sandy Point is a large spit actively building to the south from a bluff south of the Mobil Corporation refinery. The Birch Bay Village spit within Birch Bay makes up part of the shore of the bay.

Yasso (1965) expressed a headland bay beach by its plan geometry. This type of beach is developed adjacent to a headland and is the result of the predominant direction of wave approach. The shoreline of the headland bay beach can be best described in plan view as having the curve of a logarithmic spiral, with its center near the headland. Studies made on Birch Bay by C. E. Larsen (paper in progress) have identified Birch Bay as such a beach. The maximum distance for wind wave development for Birch Bay is to the west and northwest. Waves entering Birch Bay from these directions are refracted around the headland and cause waves to approach the beach obliquely on the south shore. Longshore and beach drifting are directed along the beach in a counter-clockwise gyre. Wave energy decreases from south to north so that coarse sediments make up the southern beaches while there is a decrease in grain size to the north.

D. Tides: The area under study is subject to diurnal tides, with approximately a 2.5-foot range at neap and a 12-foot range at spring. There is a marked diurnal inequality within these cycles. Tidal currents are the prime cause of lateral water transport in the region. It is these currents with which this study is largely concerned.

METHODS

Several techniques were employed to study the effect of tidal currents on the transport of water from proposed sewage and effluent outfall sites at Birch Bay and Cherry Point respectively. The 32-foot research vessel, Mijada, was anchored at each of the proposed sites at the beginning of a spring ebb or spring flood tide. Various markers were released in the water and, at given intervals, observers charted their position to gain an idea of the maximum transport effect of the tidal currents.

The Defence Research Establishment Pacific laboratory in Victoria, B.C. supplied fluorescene marker dyes. One container of dye was mixed with surface water in a one-gallon bucket and immediately poured into the water off of the stern of the anchored ship. This was repeated at regular intervals, and the progress of each dye patch was charted by the various observers. The first day dyes were released at one-hour intervals and observations from land were taken hourly. The dye disperses to the point where it is not visible from land in about 45 minutes, so on subsequent days the releasing and observation of the dye was done at half-hour intervals or less.

The second marking system employed was simply the releasing of sheets of paper from the stern of the anchored vessel. This was done at about 5-second intervals throughout the observation period. The paper was not visible from land, but it showed up well in aerial photographs and is an excellent indicator of the movement of surface water. Several types of paper were tried. Newspapers and computer print-out sheets were found to be too absorbant and sank readily from sight. A heavier grade of paper (water-stained scraps from the W.W.S.C. print shop) floated well and was the best paper for charting the currents.

The markers which were most easily sighted by the land-based observers consisted of wooden floats with weighted drags suspended at set depths below the surface, patterned after Scrimger (1960). The floats were 4-foot square sheets of 3/8" plywood. A 2-foot mast on each float was made of 3/4" dowelling. Each float was painted with different colors and designs and had various flags on the mast for easy identification. Suspended at set depths from the floats, by nylon cord, were drags made of two 4'x1' boards of 3/8" plywood joined so that there were four mutually perpendicular vanes, each 1'x2'. Each drag was held down by two four-pound lead weights tied to its base.

Three floats were used on each occasion. One had the drag nailed to the bottom of the float and was designated as the surface float. The two other floats had the drags suspended at various depths, depending on the depth of the water. At the Cherry Point site the vessel was in 50 feet of water, so the drags were set at 16 feet and 25 feet. At Birch Bay, in 25 feet of water, the drags were suspended at 8 feet and 16 feet below the surface.

Several methods were employed to chart the progress of the various markers in the tidal currents. The primary method involved two observers stationed on land, each with a clear view of the anchored ship and the floats. As the floats moved, however, it was sometimes necessary for one of the observers to move down-current to another position in order to stay within sight of them. The observers each had a plane-table on which was mounted a map of the area being studied. Overlying the map was a sheet of Mylar drawing plastic on which the sighted positions of the markers at various times were noted and labeled. Alidades were used to locate the markers and to plot the lines of sight to the markers on the Mylar. Each observer also had a 2-way citizen's band radio with which they were in contact with the R/V Mijada. At given intervals, on signal from aboard the Mijada, each observer plotted and labeled the line of signt from his position to each float. Subsequent calculations utilizing the data from both observers aided in plotting the location of each float at each sighting. In this way the direction and rate of movement of each of the floats was charted.

As was stated earlier, the paper markers were never visible from land and the dye markers were only visible for about 45 minutes, so the floats were the only markers whose positions could be consistently charted from land. Another problem was the glare of the sun in the afternoons. It often made the locating of the floats difficult for the land observers. This problem was solved by having the R/V Mijada run down to the floats. The position of the boat could then be plotted by the land observers. This necessitated less regular observations, as the Mijada moved from float to float.

An airplane was available for use on two of the four days on which observations were made. On each of those days the plane made two flights at 2,000 and 4,500 feet over the area being studied. One flight was made one hour after slack tide and one flight at mid-tide. Aerial pictures were taken on each flight utilizing both infrared and color photography. The floats were plainly visible, and the dye was more easily visible from the air than from land. The paper markers were seen as a very fine line, charting the path of the surface water from the boat down-current. The ebb tide also exhibited bands where tidal currents of the warmer, shallow, bay water flowed out over the colder water of the Georgia Strait.

Float positions were also determined through the use of a sextant and a three-armed protractor. In this case the ship had to locate each marker. Upon pulling up to a float, someone on the ship would hold the sextant horizontally and read the angles between three prominant landmarks; first the angle between one of the outside landmarks and the center one of the three, then the angle between the center one and the landmark to the other side. By setting each of these angles between the arms of the three-armed protractor, the exact position of the ship and therefore the float could be determined. This method was tested and found to be as accurate as using the two land-based observers, so on the final day the group relied entirely on this method and the former land-based observers were aboard the ship to help take water samples.

Wind observations were taken using the ship's anemometer periodically during three days on which currents were being observed. Wind observations from the Blaine Air Force Radar Station, located in Birch Bay, for the years of 1968 and 1969 were also made available. They are thrice daily (0730, 1430, 2330) readings of wind velocity and directions. A computer program was developed to give average wind directions and velocities by the month and time of day, month only, and season only.

Water samples were collected in Birch Bay and at Cherry Point using Van Dorn bottles. The bottles were attached to a cable operated by a winch off the stern of the boat. The cable was clearly marked at ten-foot intervals, so the depth of the bottle could accurately be determined. Salinity and temperature values were obtained from each water sample. A salinity titration kit (LaMotte Chemical Products Co. model POL-H) was employed in the salinity determinations made aboard the R/V Mijada. Sampling stations are shown in figure 3.

OBSERVATIONS

Observations were made during the spring (maximum range) flood and ebb tides at the proposed outfall locations for Birch Bay's prospective sewage treatment plant and ARCO's industrial waste disposal to learn the maximum effect of tidal currents on the transportation of water at each of these sites.

On Sunday, March 21, 1971 high tide occurred at 8:38 a.m. and was +8.2 in Birch Bay. The R/V Mijada was anchored over the proposed sewage outfall location and the floats were released at 10:00 a.m. Dye was dropped at 11:00 and 12:00. The airplane flew over at 12:00 noon and 2:00 p.m.

Figure 4 is an aerial photo taken from 2,000 ft. at 12:00 noon. The dyes are not visible, but a faint line of paper can be seen in the photo, tracing the path of the surface water with the ebb tide current. The eight and sixteen foot floats can also be seen in the photo. These two floats moved at about the same rate of speed throughout the day. The surface float moved much faster. Figure 5 is an infrared photograph taken at 12:10 p.m. This time the plane was at 4,500 feet above sea level. The surface float can be seen in this photo. After only two hours, the surface float has traveled 2½ times as far as the floats with deeper drags. An outline of the warmer water from the bay as it flowed out into the Strait of Georgia is obvious in the photo. The land observers also noted that there were bands of calmer water along the paths of the floats, the currents manifesting themselves on the surface. Their "path" of calm water divided as it came out of the bay. Part of it continued south into the Strait while the other part turned in a large eddy south of Point Whitehorn. The surface float followed the current south into the Strait. The eight-foot float followed the eddying current. The sixteen-foot float dragged on the bottom coming around Point Whitehorn and had to be retrieved. The surface float was retrieved too, since it was travelling rapidly into the Strait. The R/V Mijada was able to follow the trail of paper markers to locate the surface float. There was also much debris concentrated along the path of the current.

Both the surface float and the sixteen-foot float were retrieved at 1:00 p.m. and were placed close to the position of the eight-foot float. From that time until 4:30 p.m. all three floats eddied off the southern side of Point Whitehorn, as can be seen in figure 7.

On April 4, 1971, a high tide of +6.8 feet occurred at 11:26 a.m. The R/V Mijada was anchored near the ARCO pier, close to the proposed effluent disposal site, and had markers in the water by 11:56 a.m. The airplane was scheduled to fly over at 1:30 p.m. Since the dye markers had dispersed too much to show up on the previous photos, they were released this time at fifteen minute intervals. The first dye was released at 12:45 p.m. and the fourth and last at 1:30 p.m., just before the plane flew over. Figure 6 is an aerial photo taken 2,000 feet above sea level at 1:30 p.m. The dyes can be seen to be spreading downwind as well as being carried south by the ebbing tidal current. As in Birch Bay the surface float moved the most rapidly.

The direction of the currents is southerly, parallel to the coastline. At 3:00 p.m. the surface float ran into the Intalco pier and had to be retrieved by the R/V Mijada. It was placed in the water farther from shore, so it would clear the pier.

At 10:32 a.m. on Saturday, April 24, 1971, there was a -1.9 foot low tide. An extra surface drag float was dropped just south of Point Whitehorn, in order to determine what would be the path of any water which had been in the eddy at ebb tide. The tidal current on the flood tide ran from south to north and carried the float into Birch Bay (Fig. 8). Later in the day the currents carried the float back out of the bay. The surface, sixteen and twenty-five-foot floats were dropped at 11:30 a.m. No dye or paper markers were used. The paths of the surface, sixteen and twenty-five-foot floats reversed, and with the ebb, the floats headed south. The aforementioned reversal of direction of the surface float out of the bay occurred in the middle of the flood tide. This is evidence of more complex tidal currents within the bay.

On Sunday, April 25, 1971, there was a low tide of -0.9 feet at 12:24 p.m. daylight saving time. At 12:40 p.m. the R/V Mijada was anchored over the proposed sewage outfall location at Birch Bay and the surface, eight and sixteen-foot floats were released. There were strong (10-20 knot) westerly winds on that day. By 2:00 p.m. all three floats had blown aground. The eight and sixteen-foot floats were retrieved and the eight-foot float was taken farther from shore and reset. Within an hour and a half it had blown aground again.

The surface and eight-foot floats were retrieved from the beach and placed in the water farther into the bay. They were retrieved before running aground. The effect of the strong westerly wind was more influential on the floats than were the tidal currents on this day.

CONCLUSIONS

Although the factors affecting the movement of surface waters are numerous, the most effective are tidal movements and effective wind direction. Only tidal movement and effective wind direction are reported on in detail in this paper. The conclusions of this paper are based on their combined effects as shown by actual measurement and observation of coastal processes.

It should be borne in mind that most effluents discharged into these waters will be warmer and less saline, therefore less dense, than the colder and more saline (denser) marine waters (Waldichuk, 1968). The effluents (and buoyant particulate matter) will rise and remain near the surface until effective mixing occurs. As noted in figure 2 and verified by our water samples, there is little stratification of the waters in the Strait of Georgia during the winter, but layering does occur there in the summer months (Sylvester, et al, 1966). Due consideration of these conditions should be included in any environmental planning that involves the Birch Bay-Cherry Point region.

Ebb Tide Transport

A. Birch Bay sewage outfall: Water leaving Birch Bay on an ebb tide (Fig. 7) can be thought of as a banded flow. The extensive intertidal zone creates an easily discernible band of water which has becomes less dense by the inflow of fresh water from numerous small streams and drainage ditches around the bay. The rapid warming of water in the shallow zone also enhances the decrease in water density.

This band of water generally conforms to the curve of the Birch Bay shoreline. It constitutes the surface water from the shore to approximately 3000 feet offshore and leaves the bay in a clock-wise gyre. At Point Whitehorn, the low density water enters the Strait of Georgia at an angle of about S45°W where it is deflected by the main force of a southward tidal current. It moves with the higher density, colder and more saline, waters of the Strait in the form of a large eddy. This eddy movement is visible both from the bluffs of Point Whitehorn and in aerial photographs (Fig. 5). Of special interest in this study was the debris in the center of the eddy. This material did not disperse during the ebb tide and was easily positioned to enter Birch Bay again on the next flood tide. Surface water, as shown by the movement of paper released from the research vessel, was carried deeply into the Strait only when the winds were directed offshore.

Effluent discharged into Birch Bay at the outfall location proposed by the consultants retained by the Birch Bay Water District is located at a greater depth than the low density water band leaving the bay. Should a high degree of mixing not be attained by the diffuser at this depth, material carried by the less dense fresh water from the sewer system will tend to collect in the water band leaving the bay. Although mixing may occur in the Strait of Georgia it is doubtful at this point that a complete exchange of water is attained. Further, evidence of surface materials concentrating in the center of offshore eddys suggests the possibility of this material re-entering the bay on the next flood tide.

B. Atlantic Richfield effluent outfall: Water movement on the ebb tide as recorded from the Atlantic Richfield outfall location (Fig. 8) is rather simple. All floats maintained a nearly uniform distance from shore. This condition brought the floats to the vicinity of the Intalco pier and waste outfall to the southeast. This fact, combined with similar results measured from the Mobil Oil Co. pier (Kincaid et al, 1954) leads to the conclusion that water movement near Cherry Point is generally parallel to the shore. With this condition a case can exist where, with increased industrialization, one outfall may merge with the outfall of the neighboring industry.

Flood Tide Transport

A. Birch Bay Sewer outfall: Strong wind conditions on the day of float observations were not ideal for the actual measurement of tidal currents. However, information may be gleaned from the flood tide data from Cherry Point to Birch Bay (Fig 7 and 8). Surface water enters the bay from the south near Point Whitehorn and continues into the bay for some distance.

During our float studies, winds were of sufficient velocity from the effective wind direction to carry all floats ashore at Birch Bay State Park. This was also the case with floats dropped off near the mouth of the bay. Such an occurrence offers an example of the effects of wind wave action on materials carried into the bay during the flood tide.

Contrary to recommendations made during an earlier short-term float study (Berschauer and Olson, 1970) wastes discharged at the outfall site will be directed into the bay during flood tide.

B. Atlantic Richfield outfall: Flood tide transport of water, as shown in figure 8, follows the same basic pattern as does the ebb transport, i.e., movement tends to parallel the shoreline. In this case, however, transport is to the north towards Birch Bay rather than to the south. During the optimum tidal range of spring tides, water from Cherry Point can be expected to reach the mouth of Birch Bay. Float positions in this study indicated that this same water, and material carried by it, enter into the initial eddy formation off Point Whitehorn. Once more this offers the opportunity for wind wave activity to have an effect by either directing surface waste upon the beaches at Point Whitehorn, or by allowing it to enter Birch Bay. The flood tide movement of water intermediate between Cherry Point and Birch Bay enters the bay near Point Whitehorn and continues to near the proposed Birch Bay sewer outfall. Water initially near Point Whitehorn at the onset of flood tide may reasonable be expected to be carried along the southern shore of the bay for a yet greater distance. This condition would make contamination of these waters hazardous to the resort community of Birch Bay.

SUMMARY

The conclusions presented in this study show: (1) the proposed sanitary sewer outfall for the community of Birch Bay is located in such a position as to allow the reentry by tidal action of discharged wastes into the bay.

Materials released on a flood tide would be carried deep within the bay. On-shore winds may then drive material ashore on resort beaches. Ebb tide conditions at the bay are such that total exchange of water may not be complete. The mixing of water leaving the bay is only partially achieved. A substantial amount of surficial water is held in the center of an eddy movement south of Point Whitehorn where it may re-enter the bay on the following flood tide. (2) Wastes discharged by industrial sites in the vicinity of Cherry Point can be expected to parallel the shore under the effects of tidal currents. Water passing one industrial outfall can reach the adjacent outfall. Water receiving effluent at Cherry Point on a flood tide is easily carried to the mouth of Birch Bay where it can be driven ashore by effective winds. Water moving to the south on the ebb tide reaches the vicinity of Neptune Beach and Sandy Point.

ACKNOWLEDGEMENTS

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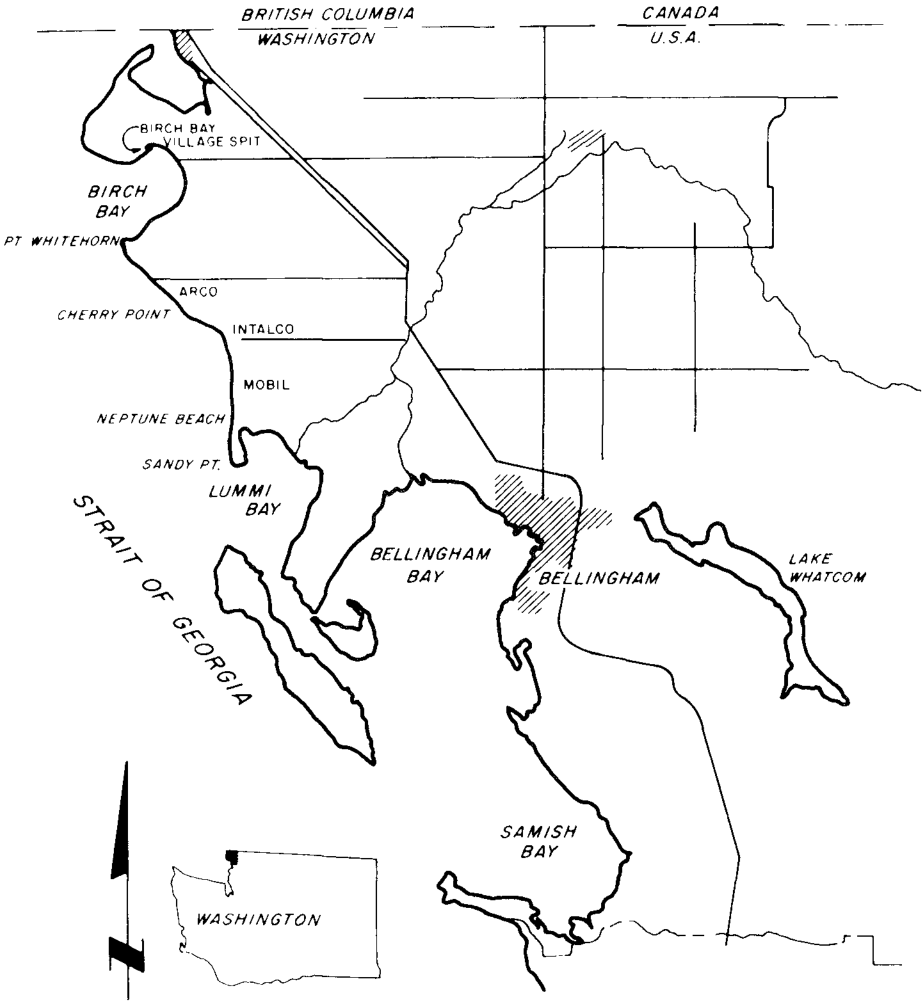

Figure 1 Location map of Birch Bay and Cherry Point, Washington.

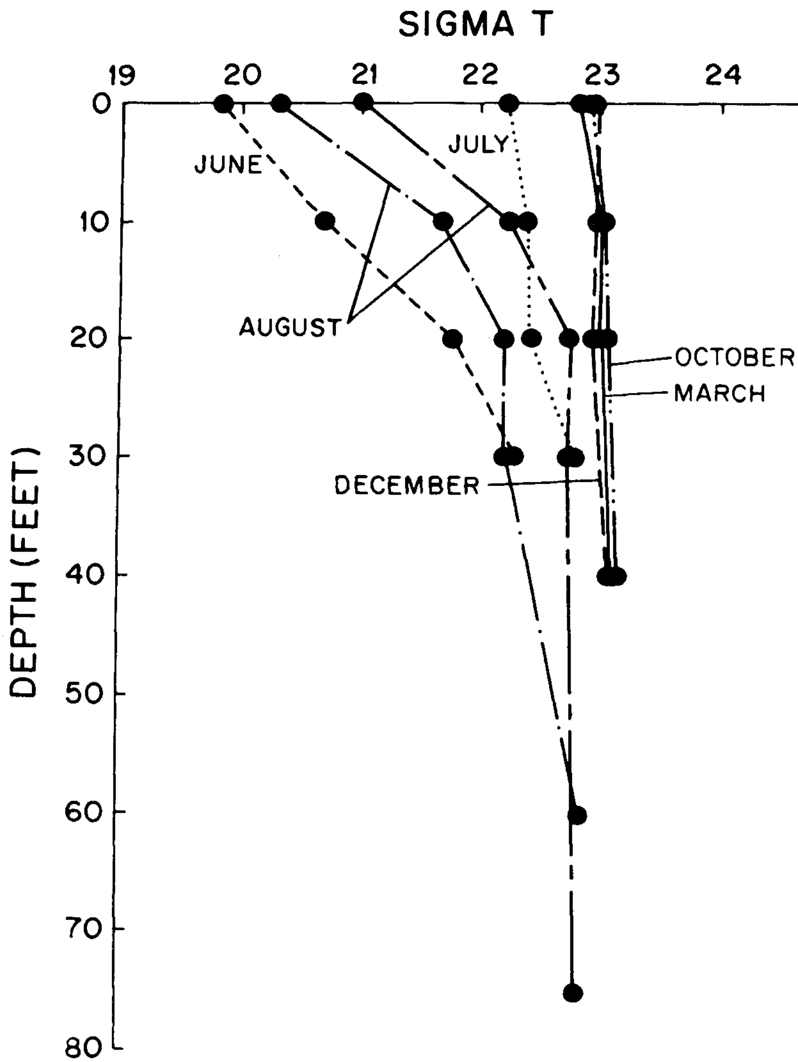

Figure 2 Density (sigma t) stratification in Georgia Strait (after Sylvester et al, 1966).

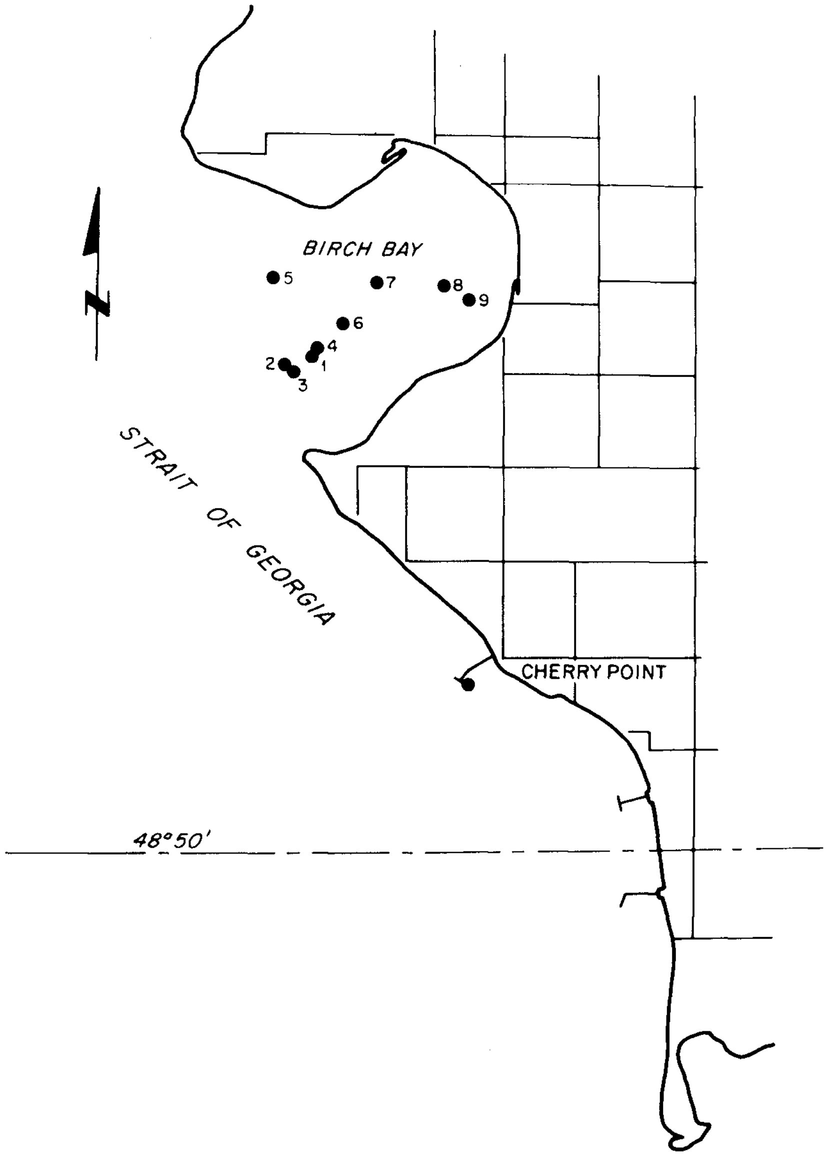

Figure 3 Water sampling stations.

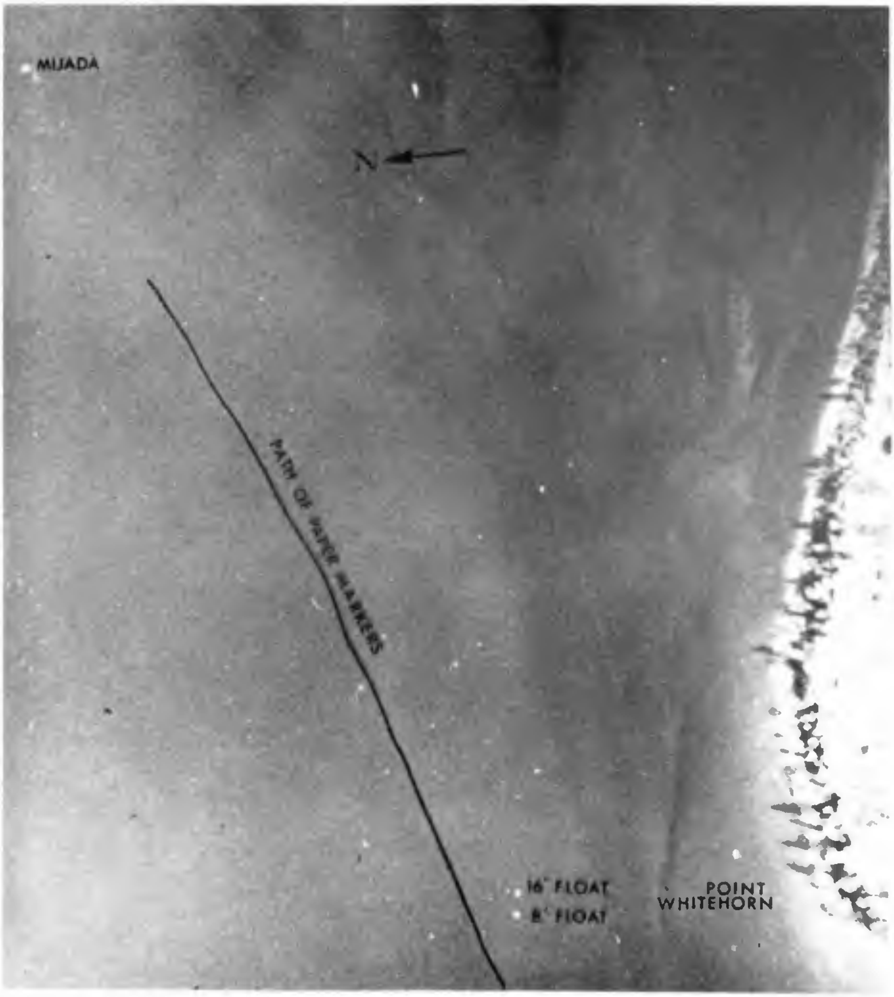

Figure 4 Aerial photo of path of ebb tide floating paper, taken from 2,000 feet over Point Whitehorn.

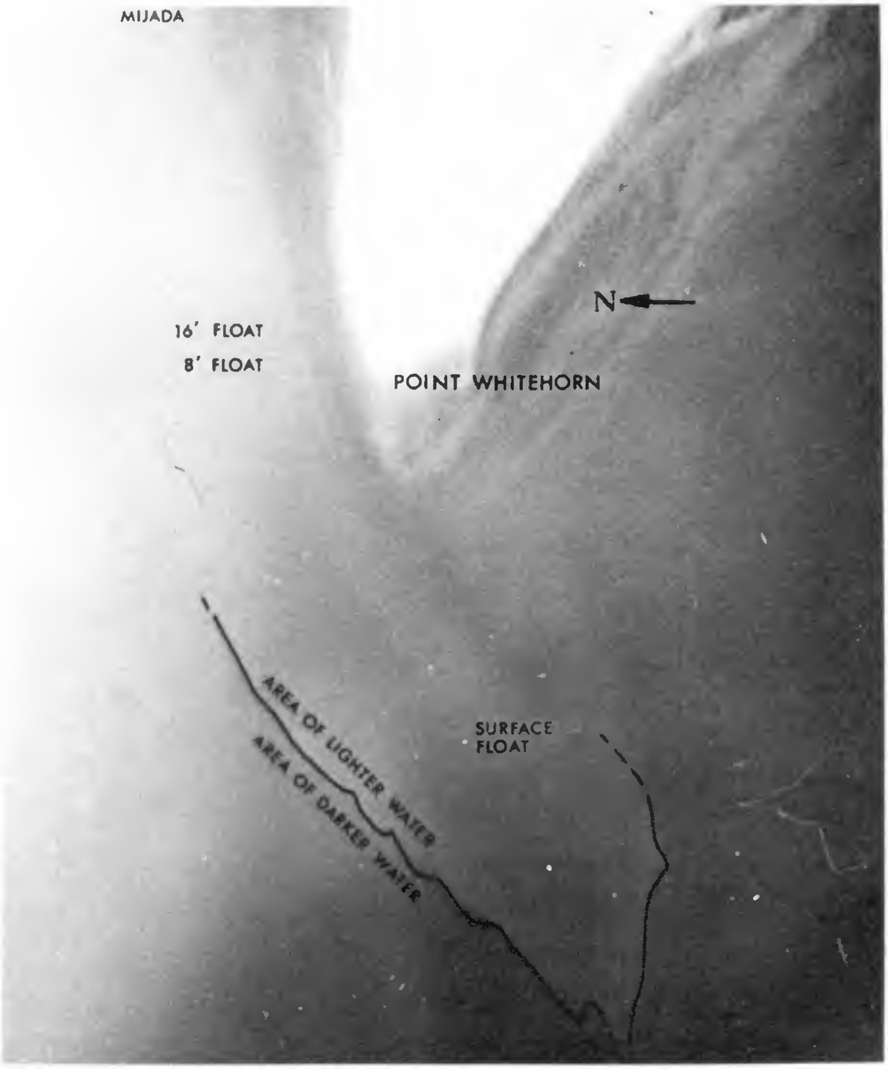

Figure 5 Infrared aerial photo, taken from 4,500 feet, of surface float location during ebb tide at Point Whitehorn.

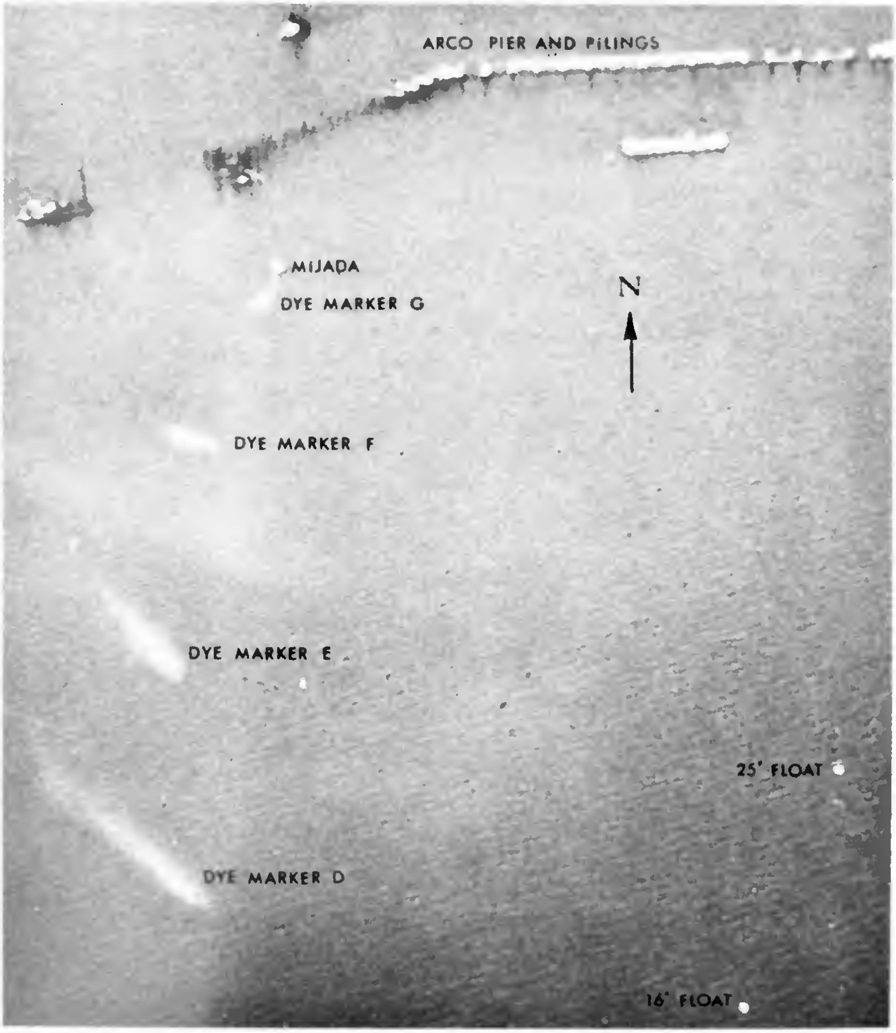

Figure 6 Aerial photo, taken at 2,000 feet, showing four dye patches released at 15 minute intervals from near the ARCO outfall site during ebb tide.

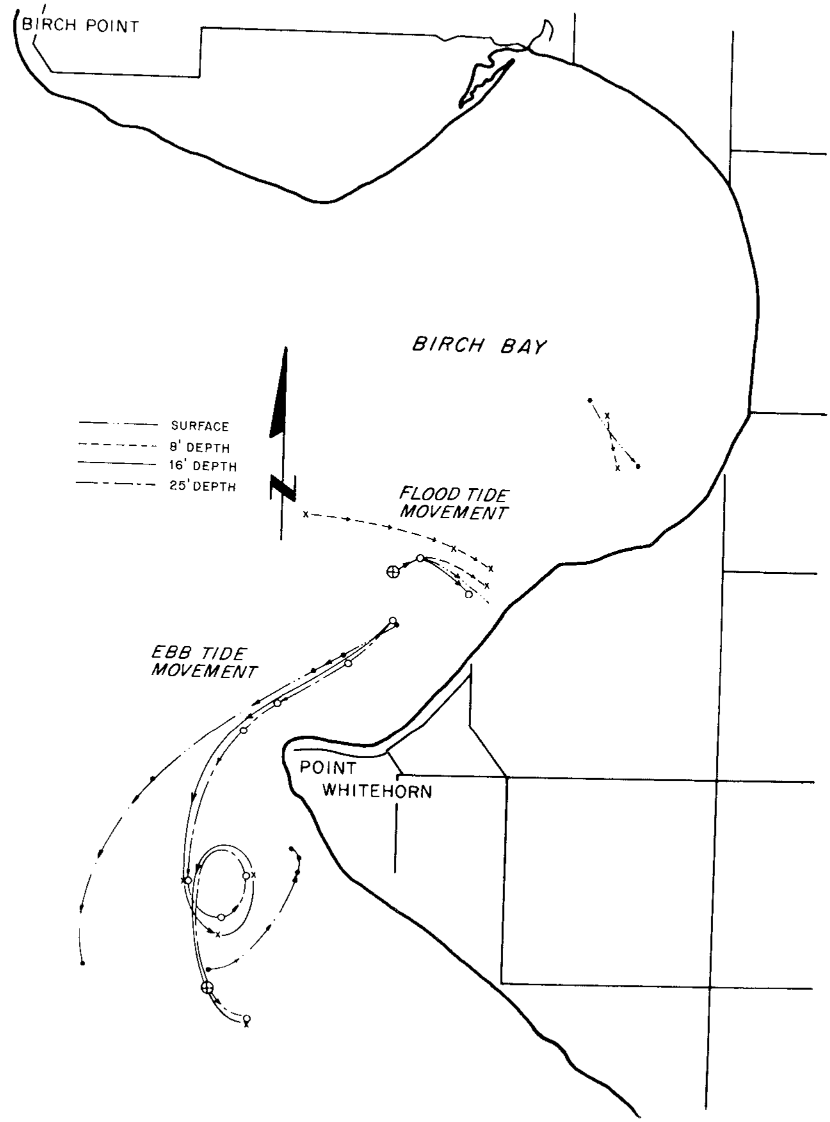

Figure 7 Float movements on flood and ebb tides at Birch Bay.

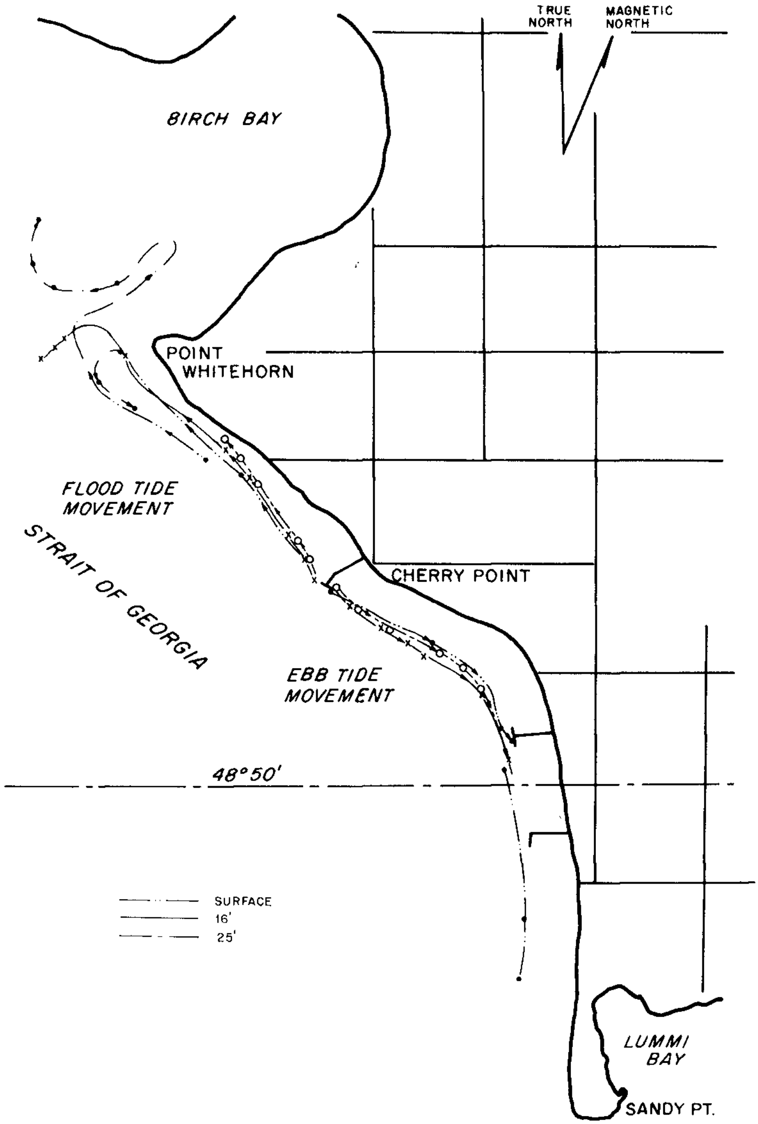

Figure 8 Float movement on flood and ebb tides at Cherry Point.