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Hydrology of Mangere Inlet

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ASPECTS OF THE HYDROLOGY OF THE MANGERE INLET - WAIROPA CHANNEL AREA, NORTHEAST MANUKAU HARBOUR

T. M. Hume

December, 1979

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ASPECTS OF THE HYDROLOGY OF THE MANGERE INLET - WAIROPA CHANNEL AREA, NORTHEAST MANUKAU HARBOUR

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INTRODUCTION

Several gas fired combined cycle power stations are proposed for the Auckland area. Each station is to have a generating capacity of up to 400 MW(e), be gas fired and utilise straight through cooling by sea water, salt water cooling ponds or cooling towers. As the stations are to be baseload stations they would have a continuous requirement of up to 10 cumecs of cooling water and continuously discharge a similar volume of heated salt water to the marine environment. Hot water discharge is likely to be 8°C above ambient. Station(s) proposed for the Westfield, Pikes Point and Onehunga areas have the Mangere Inlet to Onehunga Bay tidal reach as possible sites for marine cooling water outlet and intake. The Tamaki Inlet is a further possible site for marine cooling water intake (Fig. 1).

This report describes a variety of preliminary hydrological studies aimed at assessing the availability of marine cooling water in the Mangere Inlet to Onehunga Bay area. Field studies were carried out by the Water and Soil Section, Ministry of Works and Development, Auckland, with assistance from the Auckland Harbour Board and Bioresearches Limited. Raw data are held by Water and Soil Section, Ministry of Works and Development, Auckland.

BACKGROUND

Existing hydrological data for the Mangere Inlet-Wairopa Channel area are summarised in Appendix I.

The investigation area lies in the northern Manukau Harbour (Fig. 1). East of Mangere Bridge Mangere Inlet is formed of shallow tidal creeks and broad expanses of muddy intertidal flats (Fig. 2 and 11, Pl.1). A small island and crescentic shell banks occur in the eastern central bay. The northern border of the inlet has been altered extensively over the years by reclamations for motorways, rubbish tips and wharf and marine facilities. The tidal flushing capacity of the inlet has been decreased because of this. Onehunga Bay comprises the area between White Bluff and Mangere Bridge. In this area the main channel is flanked by shallow intertidal flats (Figs.2 & 11). West of White Bluff, Onehunga Bay opens into the main body of the Manukau Harbour and is linked to the Harbour entrance Channels (Fig. 1). At low water these channels are separated by the sandy intertidal Te Tau bank.

Tidal currents dominate the hydrodynamics of the area. However, a variety of minor water movements also occur due to wind generated waves and estuarine circulation. Fresh water inflow into the area is generally small but can increase markedly for short periods of time due to storm water run off from the surrounding urban catchment. Tides are semi-diurnal with a mean spring and mean neap ranges of 1.98 metres and 3.42 metres respectively. Measurements made at Old Mangere Bridge (Auckland Harbour Board, 1978; Appendix I) show that for mean spring ebb tidal flow tidal currents reach 0.93 m/sec (mean in vertical), the discharge is greatest at 2 hours 20 min after high water when it equals 1160 cumecs and that the total mass of water exchanged during ebb flow is 13.054×10^6 cubic metres.

TEMPERATURE AND SALINITY

Temperature salinity (T/S) surveys were made at Old Mangere Bridge over a full tidal cycle on 5 June 1979 and quasi-synoptic measurements were made between Cape Horn and Mangere Inlet at high and low water on 6 June 1979. Water temperatures were continuously monitored at New Mangere Bridge for the period 3-31 May 1979.

At Mangere Bridge (5 June 1979) mean salinity ranged 26 to 30.7‰ over the tidal cycle (Fig. 3). At high water salinity changed little with depth (about 0.5‰) but at low water a marked stratification is indicated by the 3.5‰ salinity gradient. As expected the less saline water appears on the surface.

Quasi-synoptic T/S measurements between Cape Horn and the eastern boundary of Mangere Inlet show salinity increased seawards with a change of 7.5‰ (22-29.5‰) at low tide and 5.5% (27-32.5‰) at high tide (Appendix 2A and B; Figs 3 and 4). The change in salinity between low and high tide at the same location was about 3‰ west of Mangere Inlet but increased to over 7‰ inside Mangere Inlet; probably indicative of poorer flushing within the inlet (Fig. 5). Salinity changes with depth varied with location, the greatest being recorded at low tide (Fig. 5). Water temperature changed little horizontally or vertically with values ranging from 11-13°C (Appendix 2 A and B; Fig. 6). The greatest range of values occurred in the upper Mangere Inlet where day time solar heating of shallow waters and mud flats probably produced the increased water temperatures at low water and colder night time air temperatures the marked drop in water temperature at high water (Fig 6).

Water temperatures were recorded continuously at the New Mangere Bridge by an automatic chart recorder over the period 3-31 May 1979. Measurements were made at a central channel location by a sensor sited 2m from the sea bed. The record shows a wide range in water temperature (8.4-20.1°C) and several marked short term fluctuations of nearly 3°C in 24 hours. The more regular fluctuations in water temperature evident in the record probably reflect warming of inlet waters on some days and cooling at night, and exchange of Mangere Inlet and outer harbour waters over the tidal cycle.

DROGUE BUOY MEASUREMENTS

Drogue buoys were tracked over half tidal cycles in order to establish the pattern of water movements in the area. Survey control data used in these surveys is listed in Appendix III.

Drogues buoys comprising a $1m^2$ nylon "window shade" suspended 2 metres below a surface float (Hume, 1979a) were released from locations between Cape Horn and Mangere Inlet at high and low tide and their movement tracked using boat and sextant for the duration of the ebb (28 March 1979) and flood (5 April 1979) tides. Path-time histories for the drogue buoys along with wind and tide conditions are shown in Appendix IV and Fig. 7 Sheets 1-5. Tide ranges shown are those for the predicted tide as the Onehunga tide gauge was not operational during either survey.

On both the ebb and flood tides the drogue buoys moved in the main channels (cf Figs 1 and 7) indicating the tide dominated nature of the flow and little wind influence. The peak velocities obtained by the drogues and their total distance of travel are summarised in Table 1 along with estimates of peak velocity and distance of travel for mean spring and mean neap tidal flow conditions.

Ebb flow shows a tendancy to divide at Cape Horn into the Wairopa and Purakau Channels (cf Figs 1 and 7, Sheets 1-3). Flood flow shows noticeable drop in velocity on entering Mangere Inlet.

		EBB TIDE RELEASE 28 March 1979			FLOOD TIDE RELEASE 5 April 1979	
		White Bluff	Mangere Bridge	Mangere Inlet	Cape Horn	Mangere Bridge
Peak Velocity	Observed	1.11	1.20	1.04	0.48	0.38
(m/s)	Mean Spring (estim.)	0.89	0.96	0.84	0.91	0.72
	Mean Neap (estim.)	0.51	0.55	0.48	0.53	0.42
Total Distance of Travel	Observed	12.0	11.8	6.8	5.5	2.1
(km)	Mean Spring (estim.)	9.5	9.4	5.4	9.0	3.4
	Mean Neap (estim.)	5.5	5.4	3.1	5.2	2.0

Table 1.

Summary of data from ebb spring (tide range 4.3m) and neap flood (tide range 2.1m) tide drogue buoy surveys in the north eastern Manukau Harbour (cf Fig. 7). Estimates of the peak velocity and distance of travel for mean spring (tide range 3.42m) and mean neap (tide range 1.98m) tides have been made using the assumption that the velocity and distance on a particular tide is proportional to the tidal range.

DYE DISPERSION MEASUREMENTS

Dispersion rates were measured at selected locations in the area under flood and ebb tide conditions. For each survey an instantaneous point injection of a 2 litre slug of Rhodamine WT dye (40% liquid diluted with methanol in a ratio of R:M = 4:1), then the dye patch tracked for approximately two hours or until it dispersed completely. Releases were made at both slack water and mid tide. Vertical colour photography from a light aircraft (cf Hume and Clay, 1979) provided the size and shape of the dye patch at regular intervals (Fig. 8, Sheets 1-3). Additional photographs of landmarks on either side of the waterways provided the location of the dye patch. The shapes of the dye patches were drawn from colour photographic enlargements and planimetered to determine area. Scale was calculated from lens focal length and plane altitude or by scaling off distances between co-ordinated objects. At short elapsed times the dye patch outline is sharp, but at latter times the outline is not always clear and subjective judgement is involved. Because of high levels of turbidity in harbour waters dye can be observed only to a little more than one metre depth. Thus dye patch movements represent those due to near surface currents. Wind was slight (0-7 knots) during the surveys thus its effects on surface water movements are assumed to be negligible (cf Fig. 8, Sheets 1-3).

Flood Tide Dispersion - 4 April 1979

Dye released from Pikes Point moved rapidly eastwards up-channel with the plume showing some bifurcation at the junction of the Annes and Harania creek channels (cf Fig. 2). The majority of the dye spread up the Harania Creek channel and split into two ribbons that flanked the sides of the channel (cf Fig. 8, Sheet 1 and Pl 2) suggesting that on the flood tide water wells up out of the channels and onto the banks or that higher velocities in the central channel move and disperse the dye more rapidly.

Dye released at Old Mangere Bridge at low water (Fig. 8, Sheet 1) moved rapidly up-channel into the central Mangere Inlet forming a patch oval to circular in outline. The dye patch moved onto a central bank in the inlet (cf Figs 2 and 8 Sheet 1).

Dye released at Old Mangere Bridge at half tide showed initial rapid dispersion but then sank a short time after release.

The results of the survey are summarised in Fig. 9A and Table 2. As expected dye released from Mangere Bridge moves further and disperses more rapidly than that from Pikes Point, showing that surface current velocities and dispersion are slightly greater in the western compared to eastern Mangere Inlet. It is expected that in both areas maximum current flows (and therefore dispersion) would be achieved 4½ hours (270 mins) after low water (cf Fig. 10, Sheet 8). Subsurface dispersion is probably greatest in the eastern Mangere Inlet because the water is deeper there (cf Fig. 2). Because dye sank on the ½ tide release it is possible that this also occurred to some extent on the full tide release. Thus observed maximum dispersion rates (Table 2) are considered to be minimum possible values.

Ebb Tide Dispersion - 10 July 1979

Ebb tide dye releases made at high water from Pikes Point and Old Mangere Bridge showed similar dispersion characteristics. Both dye slugs moved seaward expanding into broad arcute patches (cf Fig. 8, Sheet 2; Pls 3-4). Both travelled along the line of the major channels in Mangere Inlet and Onehunga Bay.

Dye releases made at half tide from White Bluff, Mangere Bridge and Pikes Point were less successful. All three slugs moved westward but at certain stages of travel the dye sank below surface waters. The Mangere Bridge slug sank shortly after release when it appeared to become entrained in turbulent? waters and the silt plume in the vicinity of the Onehunga Wharves. The White Bluff and Pikes Point dye patches appeared to be cut along boundaries that notably coincided with the boundaries of silt plumes (cf Pl.5).

The results from the ebb tide dye survey are summarised in Fig 9B and Table 2. Note that dispersion data are minimum values.

The high tide dye release data shows that surficial dispersion in the Mangere Bridge area is five times that at Pikes Point (Fig. 9B).

The half tide dye release data are presented in Fig. 9B for comparison. Because turbulence and vertical shear resulted in the submergence of the dye slug the graphed data are unreliable. It is notable, however, that the maximum surficial dispersion observed at Pikes Point on the half time release (Fig. 9B) is nearly two times that observed for the high tide release (Fig. 9A). Visual observations, bathymetric information and

	Distance of Travel		Observed Dispersion	
	Total Distance Travel	Time after Release	Max. Surficial Dispersion	Time after slack water
<u>Flood Tide 4 April 1979</u>				
Tide Range 2.1 m (predicted)				
Old Mangere Bridge - LW release	1.6 km	122 min	5.9m^2/s	104-132 min.
Pikes Point - LW release	0.8 km	105 min	4.2m^2/s	104-125 min.
Old Mangere Bridge - ½ tide release		Dye sank		
<u>Ebb Tide 10 July 1979</u>				
Tide Range 3.71m (observed)				
Old Mangere Bridge - HW release	2.2 km	57 min	41.2m^2/s	62-72 min.
Pikes Point - HW release	1.3 km	61 min	8.6m^2/s	72-82 min.
White Bluff - ½ tide release	0.9 km	24 min	Dye sank	
Old Mangere Bridge - ½ tide release		Dye sank		
Pikes Point - ½ tide release	0.9	32 min	Dye sank	

Table 2. Summary of results from dye dispersion studies (cf Figs 8 and 9).

tidal velocity data suggest that dispersion at White Bluff would exceed that at Mangere Bridge.

It is expected that at both Pikes Point and Mangere Bridge maximum current flows (and therefore dispersion) would be achieved approximately 2 hours (120 minutes) after high tide (cf Fig. 10, Sheet 8). It is significant that dispersion rates observed for ebb tidal flow are larger than those for flood flow.

TIDAL GAUGING

Techniques

A tidal gauging was carried out at Old Mangere Bridge on the Mangere Inlet to determine tidal velocity distributions in the channel and to enable calculation of tidal discharge and volume for neap tide flow. Measurements were made over a full tidal cycle (Fig. 10, Sheets 1 - 9).

The channel cross section was surveyed by lead line measurements from the bridge (Fig. 10, Sheet 1).

Gauging was carried out using standard river gauging techniques and equipment employed by MWD. Current velocity measurements were made using Gurley bucket wheel meters at 32 verticals (Fig. 10, Sheet 1). Measurements were made on a large number of verticals as it is planned to analyse these data with a view to determining the minimum number of verticals and their distribution in the cross section necessary to give results of specific degrees of accuracy.

Preliminary measurements showed it was necessary to make velocity measurement at 0.1, 0.4, 0.6 and 0.9 of the total depth to obtain reliable velocity profiles.

Using 9 gauging teams a complete set of measurements was made on each of the 32 verticals within 30 minutes. Tide level observations were made throughout the gauging (at 10 minute intervals) at the Onehunga Wharf staff gauge.

Calculation

The discharge versus stage and time relationships and total flood and ebb tide volumes were computed and plotted from the stage, current velocity and channel cross section data by the following computer technique.

1. A stage/time relationship was derived (Fig. 10, Sheet 2).

2. From the channel cross section survey data (Fig. 10, Sheet 1) a stage/area relationship was calculated and from 1. an area/time curve calculated (Fig. 10, Sheet 2).

3. Mean velocities on each vertical were calculated from "at point" velocity measurements and velocity/time curves derived for each vertical (Fig. 10, Sheets 3 and 4).

4. From 3. a mean velocity/time relationship for the section was determined for 15 minute increments of time (Fig. 10, Sheet 8).

5. From the area/time (see 2.) and mean velocity/time (see 4.) data discharge values (area x time = discharge) were calculated for each 15 minute interval of time and a discharge/time curve derived (Fig. 10, Sheet 9). The area under this curve was calculated to give flood and ebb tide volumes.

Results

Physical characteristics of the site and hydrological data determined by the gauging are summarised in Table 3.

The accuracy of data from the gauging is expected to be high due to the large number of measurements made across the channel section (cf. Fig. 10, Sheet 1), however, some minor errors would be expected to be introduced on the ebb flow by turbulence generated about the New Mangere Bridge piles.

MANGERE INLET AT OLD MANGERE BRIDGE

PHYSICAL CHARACTERISTICS

Gauging Site Reference	MR N42:304505
Catchment Area	
Land Area	3446 ha
Water Area	660 ha
Total Area	4106 ha
Ratio Land/Water Area	5.2
Length of Estuary above Site	4 km
Channel Width at Site (at MSL)	234 m
Maximum Channel Depth at Site (below MSL)	8.3 m

HYDROLOGICAL DATA

Date	5 July 1978
Tide	Full Cycle, neap
Tide Range	1.07 - 3.25 - 1.20 m (Flood 1.18m; Ebb 2.05m)
Mean Spring Range	3.42 m
Mean Neap Range	1.98 m

		Flood	Ebb
Current Velocity	- maximum at point	0.53 m/s	0.633 m/s
	- maximum mean in vertical	0.47 m/s	0.49 m/s
	- maximum mean in section	0.35 m/s	0.36 m/s
Discharge	- maximum	536 m³/s	560 m³/s
Maximum Velocity and Discharge		4½ hrs after LW	2½ hours after HW
Tidal Volume		6,655,700m³	6,382,100m³

Table 3. Summary of physical characteristics of the Mangere Inlet gauging site and hydrological data determined by the tidal gauging (cf Fig. 10).

Isoline plots show tidal velocities generated at peak flood and ebb flows (cf Fig. 10, Sheets 5 and 6). The flood and ebb tide flow patterns (particularly the flood) show marked irregularities in flow near the central - bottom channel and two cores of higher velocity flow flanking the central area. Stage versus mean velocity and discharge plots (Fig. 10, Sheet 7) demonstrate that velocities and discharge are slightly greater for the ebb tide than the flood. Mean velocity and discharge versus time plots (Fig. 10, Sheets 8 and 9) show that maximum velocity and discharge on the flood tide occur $4\frac{1}{2}$ hours after low tide and $2\frac{1}{2}$ hours after high tide on the ebb tide. The period of duration of slack water (i.e. velocity less than 0.1m/sec) is 50 min at high tide and 2 hr 50 min at low tide. Maximum observed current velocities, and tidal discharge and volumes are given in Table 3. Neap tide volumes are approximately half that observed for spring tides (cf p.2).

Comparison of the flood and ebb tide volumes shows that the flood tide compartment was larger than that observed for the ebb. The difference (i.e. 273,600m^3) can in large part (90%) be attributed to the larger tidal range recorded for the flood tide (2.18m) compared to the ebb (2.04m). Interestingly predicted astronomical tides forecasted identical tidal ranges for both the ebb and flood tides. Deviations from predicted tides of this order of magnitude are not uncommon and may reflect some outer ocean disturbance. The larger flood tide compartment compared to the ebb is indicative of the large surface to depth ratio of Mangere Inlet and the strongly tidal nature of the system. It is also indicative of the small volume of freshwater entering the estuary, estimated at the time of the gauging (by measurement and calculation) as being 0.47m^3/sec. Freshwater storage over the tidal cycle therefore approximates only 0.3% of the ebb neap tide volume.

Measurements in Mangere Inlet and other tidal inlets in the Auckland area (e.g. Hume, 1979b) suggest that as a crude approximation current velocities, discharges and tidal compartments for neap tides are approximately half those for spring tides.

DISCUSSION

Combining data from field studies with existing information provides a basis for forecasting the effects of proposed power station cooling water outfall on the Mangere Inlet - Onehunga Bay area.

Morphology

The area under consideration for cooling water outfall is part of an isolated and enclosed body of water linked to the outer Manukau Harbour. The outer harbour flushes to the Tasman Sea by a narrow deep entrance channel (Fig. 1). Depth sounding surveys of the Mangere Inlet - Onehunga Bay area include detailed surveys of the Onehunga Bay area by the Auckland Harbour Board (1978) with depths shown at 0.1m intervals, more detail soundings in the vicinity of the Onehunga Wharves and Mangere Bridge (Auckland Harbour Board, 1967) and soundings of the Mangere Inlet area (Ministry of Works, 1960 and 1961) (Refer Appendix I). Using data from these surveys and correcting for subsequent reclamations a bathymetric map was drawn (Fig. 11). The figure illustrates the morphology of Mangere Inlet and Onehunga Bay and from the bathymetric data approximations of volumes at various stages of the tide were made (e.g. Table 4). No allowance was made for sedimentation or erosion subsequent to the above mentioned surveys, however, the tidal compartment for Mangere Inlet determined from these data compares favourably with that obtained by gauging. It can be seen that subtidal areas below chart datum are confined to the main channel area in Onehunga Bay and to the central western end of Mangere Inlet. Shallow intertidal creeks, usually off the mouths of inflowing streams or culverts, drain the shoal and tidal flat areas which flank the main channels.

Tidal Flows

Field surveys demonstrate that the lunar semidiurnal tide is the principle driving mechanism for waters in the area. In the absence of wind, dominant tidal motions appear to be controlled by local topography and parallel the major tidal channels and banks (Fig. 1 and Fig. 7). Hence tidal motions are predominantly back-and-forth rather than rotary in nature, particularly in deep waters in channels and at lower stages of the tide.

Wind almost certainly exerts a significant influence on any weak net circulations particularly for surface waters and in shallow intertidal areas, but data on this influence was not obtained. The prevailing southwesterly wind may play an important role in confining surface water effluent fields to the northeastern corner of the Manukau Harbour (Fig. 1).

Because of the strong tidal influence, currents measured at various locations show marked variations in speed and direction depending on tide state. At Mangere Bridge for instance the mean maximum velocity in section varies from 0.35 m/s for neap tides to 0.92 m/s for spring tides. Furthermore because of pronounced changes in bottom morphology current velocity may vary greatly across the channel section. For neap tides maximum velocities and discharge at $4\frac{1}{2}$ hours and $6\frac{1}{2}$ hours after low tide, and the period of slack water (i.e. velocities less than 0.1 m/s) ranges from 15 to 50 minutes at high tide and 1 hour to 2 hours 50 minutes at low tide (Fig. 10, Sheet 8). The shorter slack water periods occurring at spring tides. Field surveys show that dye released at slack water has a far greater tendency to remain as a coherent slug when the current begins to flow than dye released into fast flowing water, suggesting that thermal power station cooling water discharge should not be released at slack water if pooling effects are to be minimised.

These data show that spatial and time dependant variations in current velocity and discharge are very important factors in determining the location of cooling water outfall sites. Ideally sites must be chosen that make best possible use of high current flow regimes and furthermore be timed to coincide with periods of high current flow.

Salinity and Temperature

Winter (June) salinity measurements show a range of 22 to 33 ‰ between Cape Horn and Mangere Inlet and a 3 to 6 ‰ variation between high and low water at individual sites. Salinity increases seawards. The fairly high salinities encountered in upper Mangere Inlet are indicative of low fresh water drainage into the inlet and tidal exchange with outer harbour waters. Marked vertical stratification is apparent at low water and no doubt results from the longer period of slack water.

The data suggest that for neap tides mixing is poorest for one hour before and two hours after low water.

The 5 June 1979 survey showed that salinity varies at about the same period as the tides, maximum salinities coinciding with high water and minimum salinities with low water (Figs. 3 and 5). When streams discharge into the Mangere Inlet and Onehunga Bay area in full flood conditions much lower salinities would result, particularly near the stream mouths. Because of the fairly long residence time of waters in the inlet (see next section) it could take some time before ambient saline conditions are returned after excessive fresh water flow subsides.

Water temperature measurements made over a one month period in winter (May, 1979) display a large (8.4 to 20.1^{o}C) range in temperature. The record shows quasi-cyclic fluctuations in temperature of several degrees probably related to warming of inlet waters on some days and cooling at night, and exchange of Mangere Inlet and outer harbour waters over the tidal cycle. These winter observations suggest large seasonal temperature changes will occur in the inlet and marked short term variations can be expected particularly on hot summer days when the flood tide advances over the intertidal flats. A phenomenum demonstrated in part by water temperature surveys between Cape Horn and Mangere Inlet on 6 June 1979 (Fig. 6). Monitoring summer water temperature changes and their duration is important to determine the order of magnitude of natural fluctuations. Little vertical temperature stratification was apparent.

Flushing

Mangere Inlet and Onehunga Bay are estuarine areas characterised by a small total volume to tidal compartment (the difference in water volume in an inlet between low and high tide) indicating the flow is dominated by the tides (Fig. 11 and 12A, Table 4).

		Mangere Inlet	Onehunga Bay
Tide Range (m)	Mean Neap	1.4 - 3.4	
	Mean Spring	0.7 - 4.0	
Total Volume ($m^3 \times 10^6$)	MHWS	12.517	13.036
	MLWS	0.936	2.927
	MHWN	1.720	4.518
	MLWN	9.054	10.913
Tidal Compartment ($m^3 \times 10^6$)	Mean Neap	7.334	6.395
	Mean Spring	11.581	10.109

Table 4 Tidal volume data for Mangere Inlet and Onehunga Bay

The data suggest that at certain levels a straight line relationship exists between depth and the total volume of water in the inlet (Fig. 12B).

The tidal range varies from 1.98 m (neaps) to 3.42m (springs) and the surface areas at high and low spring tides are 2.7 and 5.7 km^2 respectively for Mangere Inlet and 3.1 and 3.5 km^2 respectively for Onehunga Bay. The ratio volume to tidal compartments varies from 1.05 (spring) to 1.23 (neap) for Mangere Inlet and 1.29 (spring) to 1.71 (neap) for Onehunga Bay demonstrating the hydrology of Mangere Inlet is more tide dominated than Onehunga Bay.

The residence (or flushing) time of waters in the area and the relationship between Mangere Inlet and outer harbour waters are an important consideration. The residence time of water in an inlet is the time from its initial entrance to its final exit and differs for different parcels of water depending on their relative densities and from where they enter. Because the density of water parcels change with time the residence time is difficult to measure directly. The tidal prism and the salt deficiency methods are considered here (e.g. see Bowden, 1967).

The tidal prism method is often used where tidal movements appear to be the main mixing process. Assuming water entering the inlet on an incoming tide (P) is completely mixed with that water in the inlet at low tide (V) then the residence time (t) in tidal periods is given by

$$t = \frac{V + P}{P} .$$

For Mangere Inlet this gives a residence time of 1.1 and 1.2 tidal periods (tidal period = 12.42 hours) for spring and neap tides respectively. The overall residence time for waters in the Mangere Inlet - Onehunga Bay tidal reach is 1.2 and 1.4 tidal periods for spring and neap tides respectively. This method of calculation only gives a lower limit to the flushing time because the assumption of complete mixing in each tidal period may not be justified.

An alternative method of estimating the flushing time is the salt deficiency method which considers the rate at which freshwater entering the inlet from stream inflow is flushed out and therefore its residence time (Bowden, 1967, p.19). Consider a case where the rate of influx of fresh water is R and the total volume of fresh water accumulated in the inlet is F. If So is the salinity of water outside the estuary which is available for mixing and S is the salinity at any point inside, the fresh water content at that point is given by

$$f = \frac{So - S}{So} .$$

The accumulated volume of fresh water is

$$F = \int_{vol}^{o} fd\ (vol),$$

where the integration is carried out over the total volume (V). If a steady state is assumed where R also equals the rate of removal of fresh water from the inlet, then the flushing time t to remove the accumulated fresh water present at a given instant at this rate is

$$t = \frac{F}{R}.$$

The salinity survey on the 6 June 1979 (Appendix II) showed the average salinity (mid depth data) for Mangere Inlet to be 28.0 ‰ and the salinity outside to be 29.5 ‰ . The amount of fresh water inflow determined by gauging and calculation was 0.47 m^3/s and evaporation was 0.04m^3/s (data from Mangere Sewage Purification Works). For a neap tide with high water volume of 9.40 x 10^6 m^3, the residence time is approximately 13 days. For the Mangere Inlet - Onehunga Bay system the residence time for a neap tide situation is calculated as being 33 days.

These estimates are for mean residence time for all the water in the inlet and for neap tides. The residence time would be shorter for spring tides. Compared to the tidal prism method the estimates are high and further studies would establish the ranges of residence time for a variety of tide conditions. Flushing time may also be expected to vary with rate of freshwater inflow (cf. Bowden, 1967). The flushing time calculated in this way should strictly only be applied to a pollutant if it is injected into the inlet in the same way as the freshwater. In the case of thermal power station discharge for instance the warm and therefore less dense effluent field may remain in the upper layers and be removed more quickly. The residence times should be considered to be maximum values. During the salinity survey of the 6 June it was noted that the less saline water was largely confined to the upper one metre or so of water. If this surficial salinity data is used to estimate residence time it returns values of 13 days for Mangere Inlet and 20 days for the Mangere Inlet - Onehunga Bay tidal reach. These data probably approximate more closely residence times of water in the upper layers.

The relationship between waters in Mangere Inlet and Onehunga Bay can be examined on the basis of the volumetric and field data. It is apparent that the spring and neap tide compartments for the two areas are similar (Table 4). On the ebb tide the volume of water flushed from Mangere Inlet into Onehunga Bay is approximately 1.6 x and 3.9 x the volume of water in Onehunga Bay at neap and spring low tide respectively. (Table 4). This suggests that on the ebb tide,water in Onehunga Bay is completely flushed out into the outer harbour through displacement by Mangere Inlet water. The large residence time for waters in the area demonstrates that this is not the case. Furthermore physical model tests (Hume, 1979c) show that a large amount of the tidal exchange takes place by strong tidal flushing down the central Onehunga Bay channel. This mechanism must become more important at lower stages of the tide when a larger proportion of tidal waters become confined to the channels. This demonstrates the need for cooling water discharge into main channel locations. Drogue buoy data suggest considerable exchange of water between Mangere Inlet and Wairopa Channel by means of flow in the main channel. It is apparent that while effluent released at high tide from the Mangere Bridge and central Mangere Inlet area is likely to travel well down the Wairopa Channel, ebb tide releases made at half tide from the Mangere Bridge and central Mangere Inlet are only likely to reach the vicinity of Cape Horn and White Bluff respectively, then return to Onehunga Bay on the flood tide. This situation is likely to be most pronounced for neap tides.

Proposed discharge from a combined cycle power station is likely to be in the order of 10 cumecs or 447,000 m^3 per tidal cycle. This volume is quite significant when compared to the neap and spring low water volumes in Mangere Inlet, but forms only a small proportion of the spring and ebb tidal compartments for Mangere Inlet and the Mangere Inlet - Onehunga Bay tidal reach (see below).

	Station Cooling Water Volume as a Percentage of			
	Low Tide Volume		Tidal Compartment	
	Neap	Spring	Neap	Spring
Mangere Inlet	26	48	6	4
Mangere Inlet and Onehunga Bay	7	11	3	2

REFERENCES

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Hume, T. M. 1979a : The design and construction of a surface trackable lagrangian drogue buoy. Internal Report, Water and Soil Section, MWD, Auckland. June, 1979. 11pp.

Hume, T. M. 1979b : Tidal observations in Tamaki Inlet, Waitemata Harbour. Internal Report, Water and Soil Section, MWD, Auckland. June 1979. 20pp.

Hume, T. M. 1979c : Auckland Combined Cycle Power Station Investigations - Model tests for siting marine cooling water intake and outlet structures in Onehunga Bay. Internal Report, Water and Soil Section, MWD, Auckland. July 1979. 18pp.

Hume, T. M.; Clay, M. 1979 : Notes on the use of small format camera aerial photography in marine hydrological surveys. Internal Report Water and Soil Section, MWD, Auckland. August, 1979. 12pp.

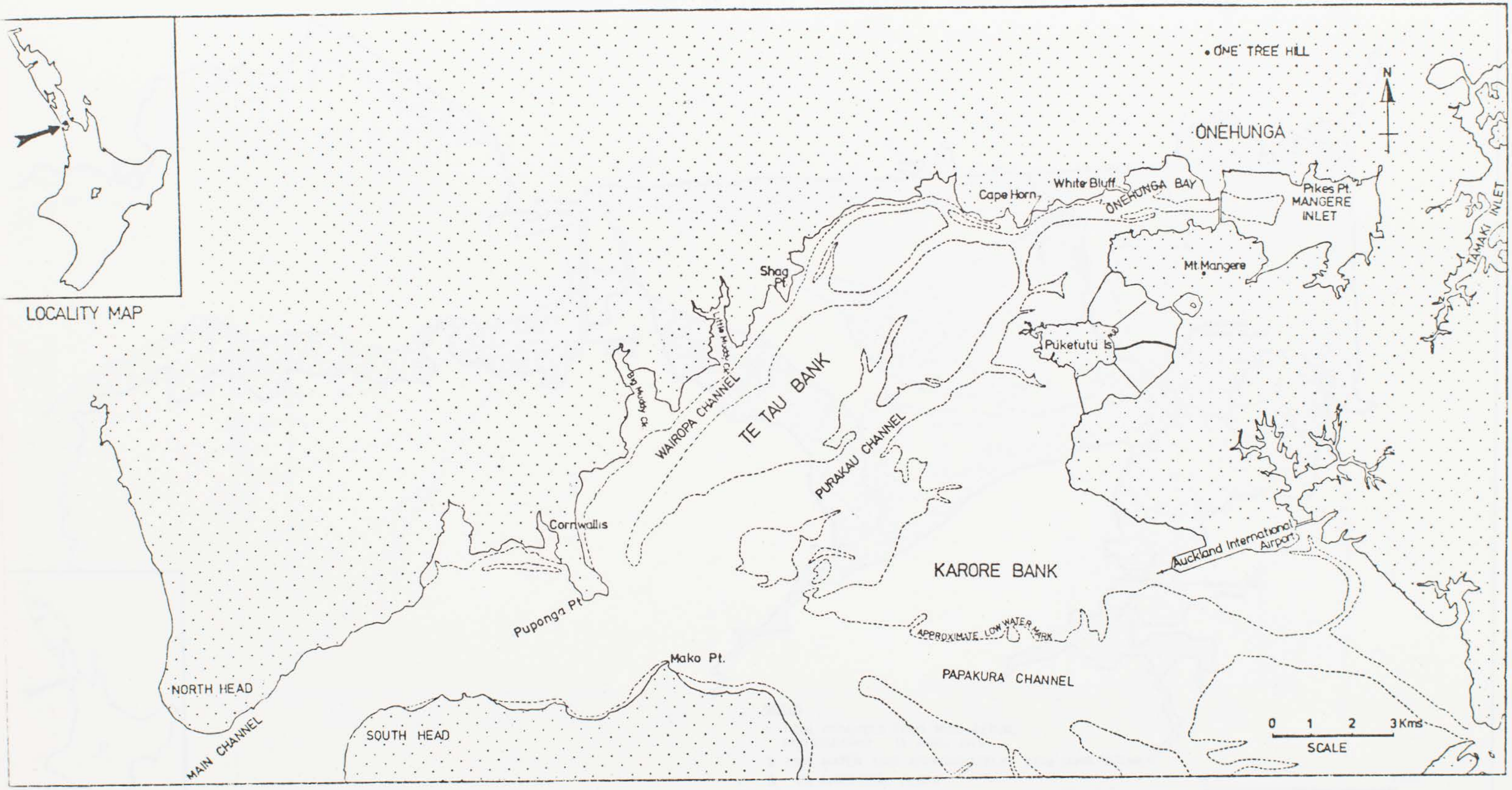

Figure 1. Locality map.

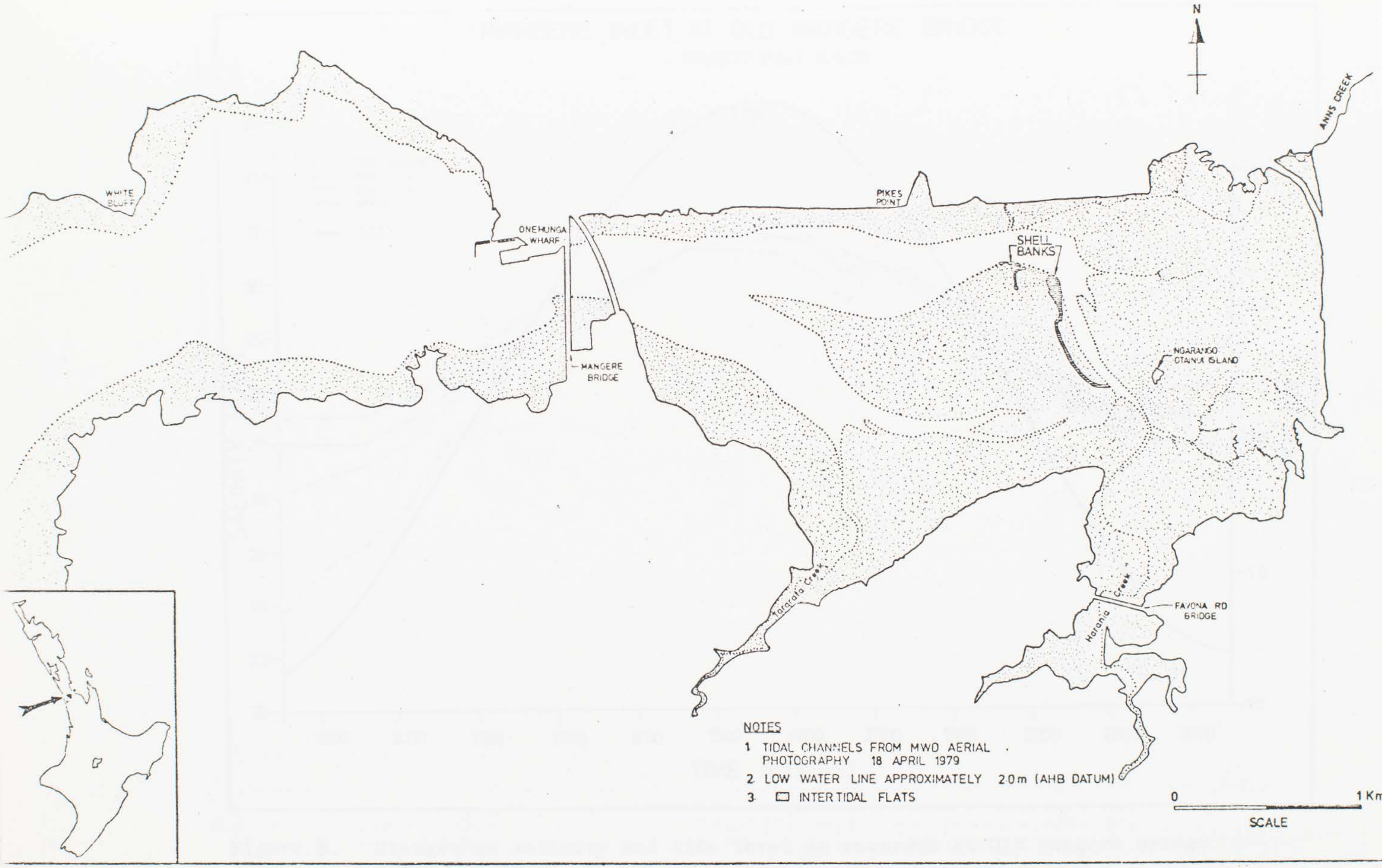

Figure 2. Distribution of tidal channels and intertidal flats in Mangere Inlet and Onehunga Bay.

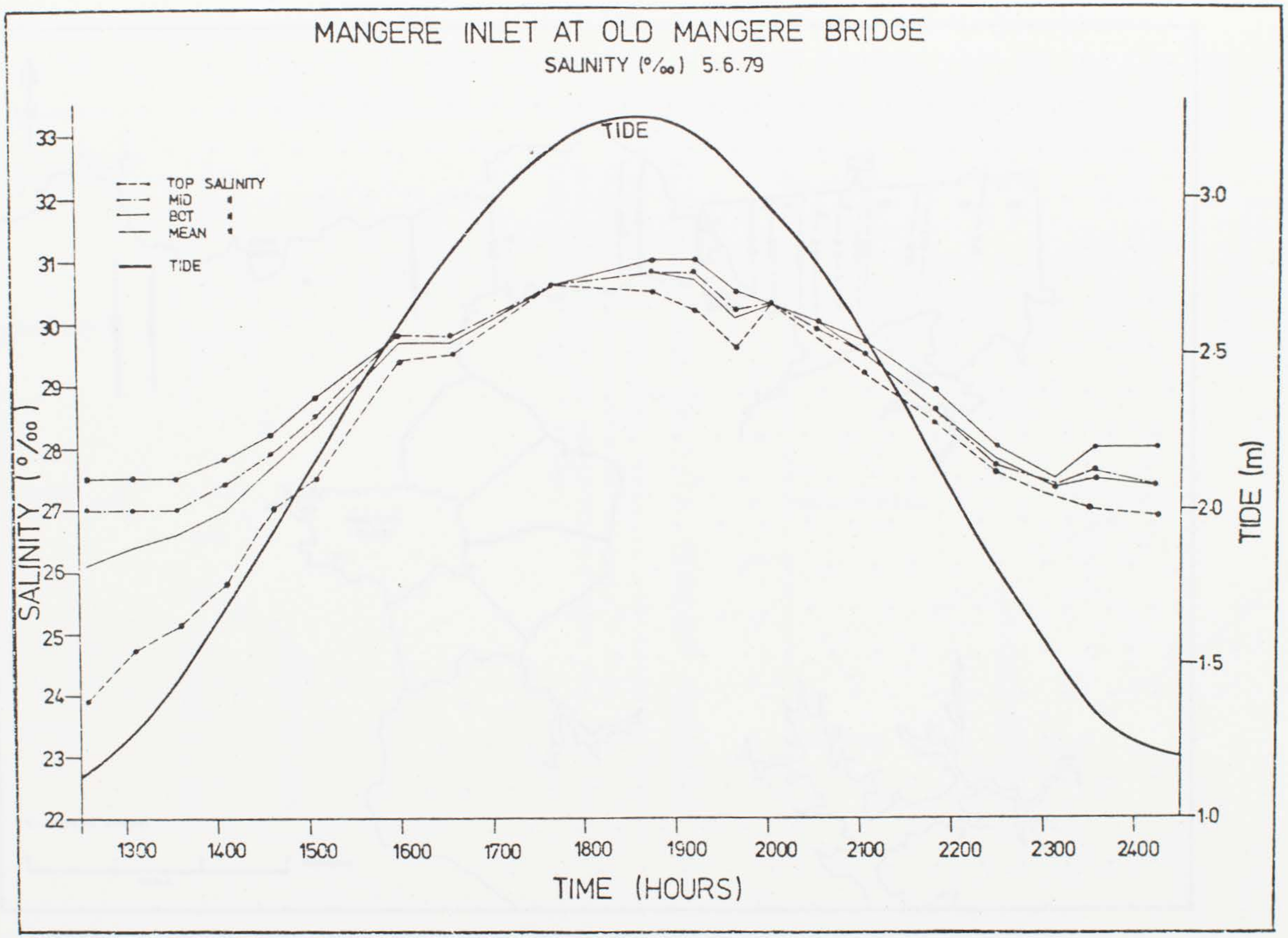

Figure 3. Changes in salinity and tide level as recorded at Old Mangere Bridge on 5 June 1979.

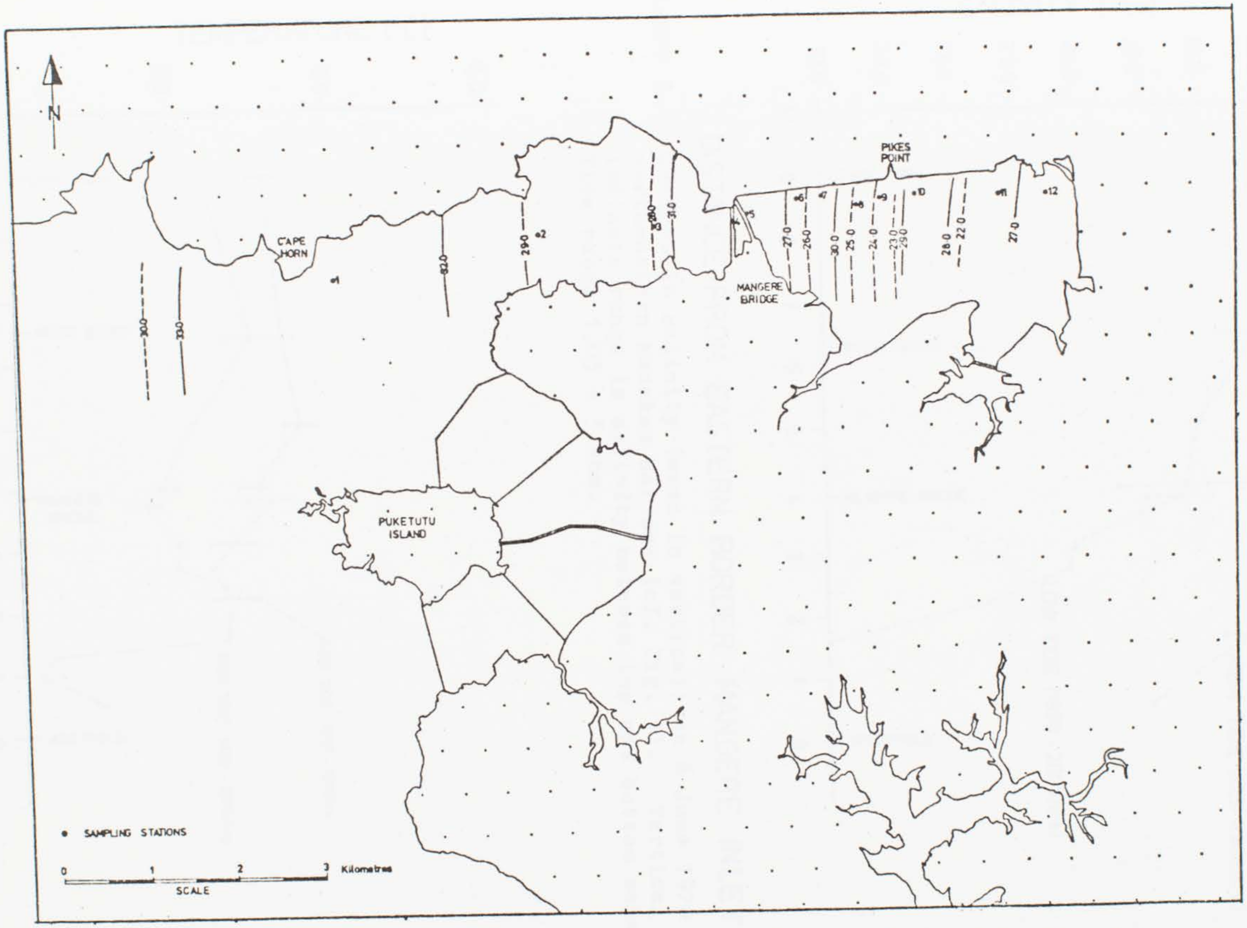

Figure 4. Isohalines (‰) (mean in vertical) near high (solid lines) and low tide (dashed lines) for northeastern Manukau Harbour.

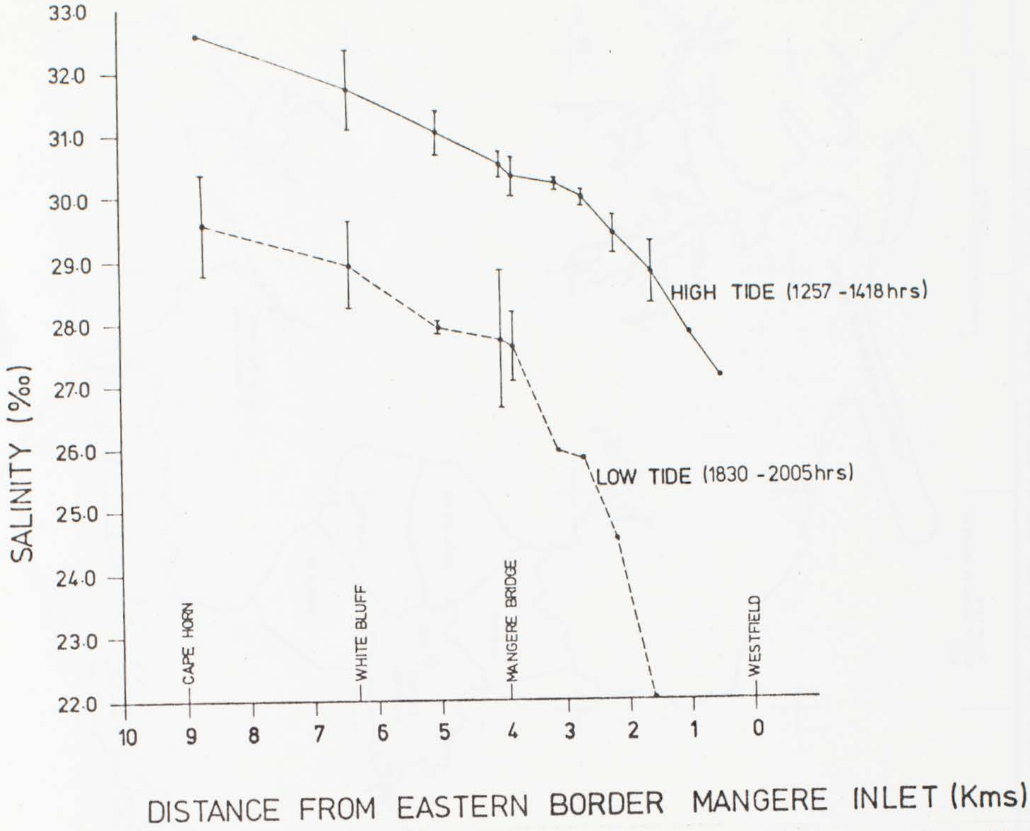

Figure 5. Changes in salinity (mean in vertical) on 6 June 1979 in the northeastern Manukau Harbour (cf. Fig. 1). Vertical bars indicate range in salinity between top and bottom waters. Tide range 1.03 - 3.46m.

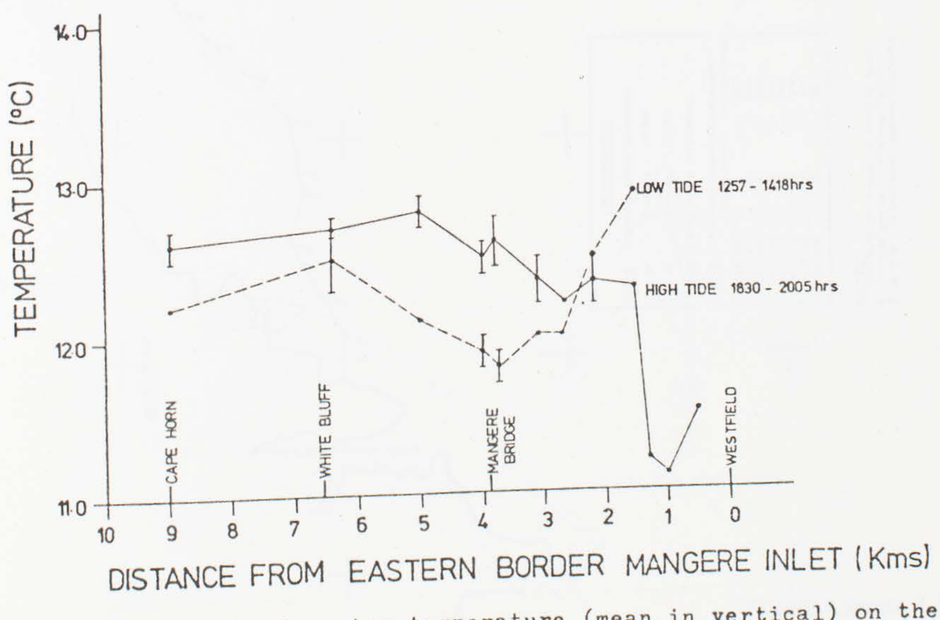

Figure 6. Changes in water temperature (mean in vertical) on the 6 June 1979 in the northeastern Manukau Harbour (cf. Fig. 1). Vertical bars indicate range in temperature between top and bottom waters. Tide range 1.03 - 3.46m.

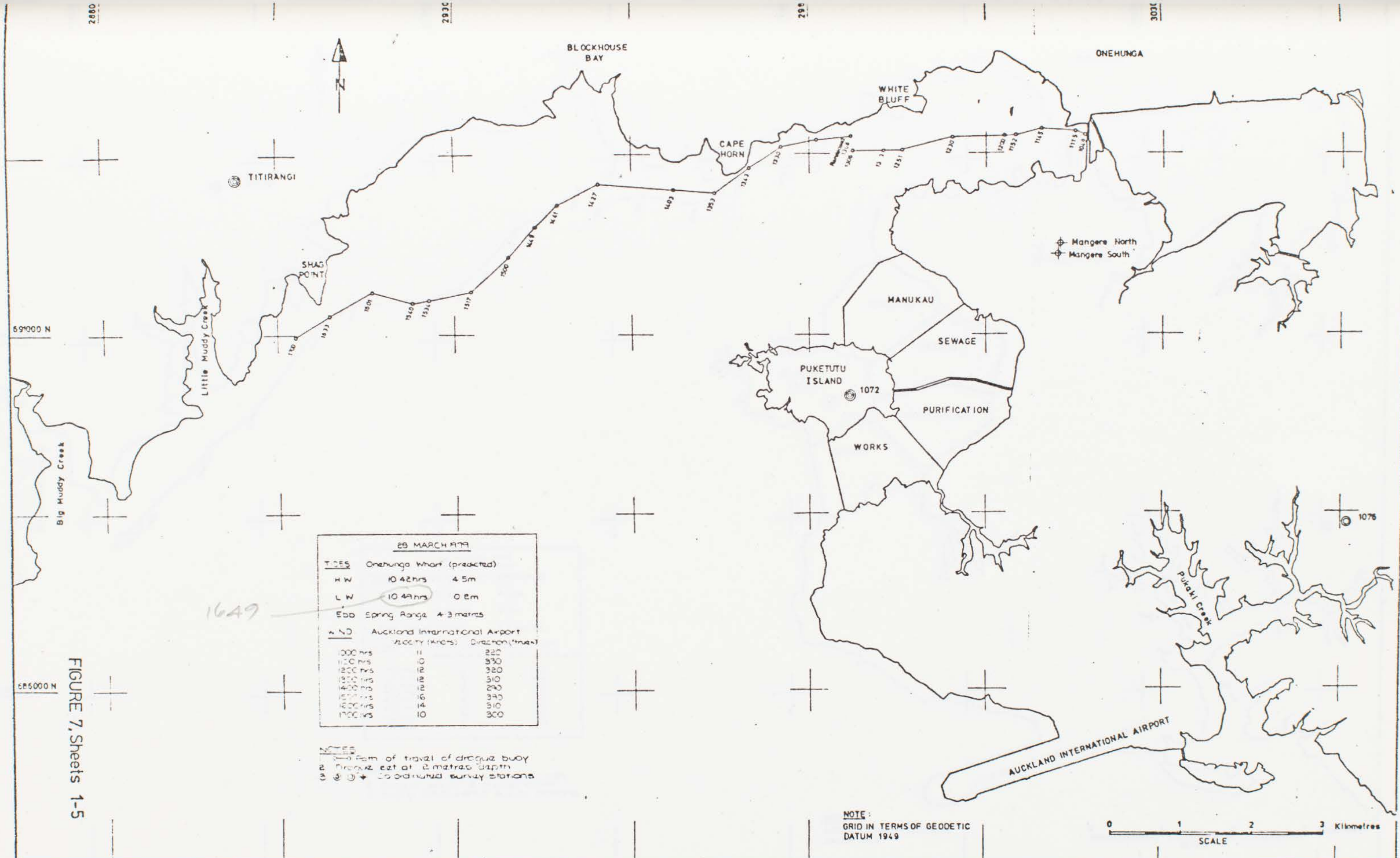

FIGURE 7, Sheets 1-5

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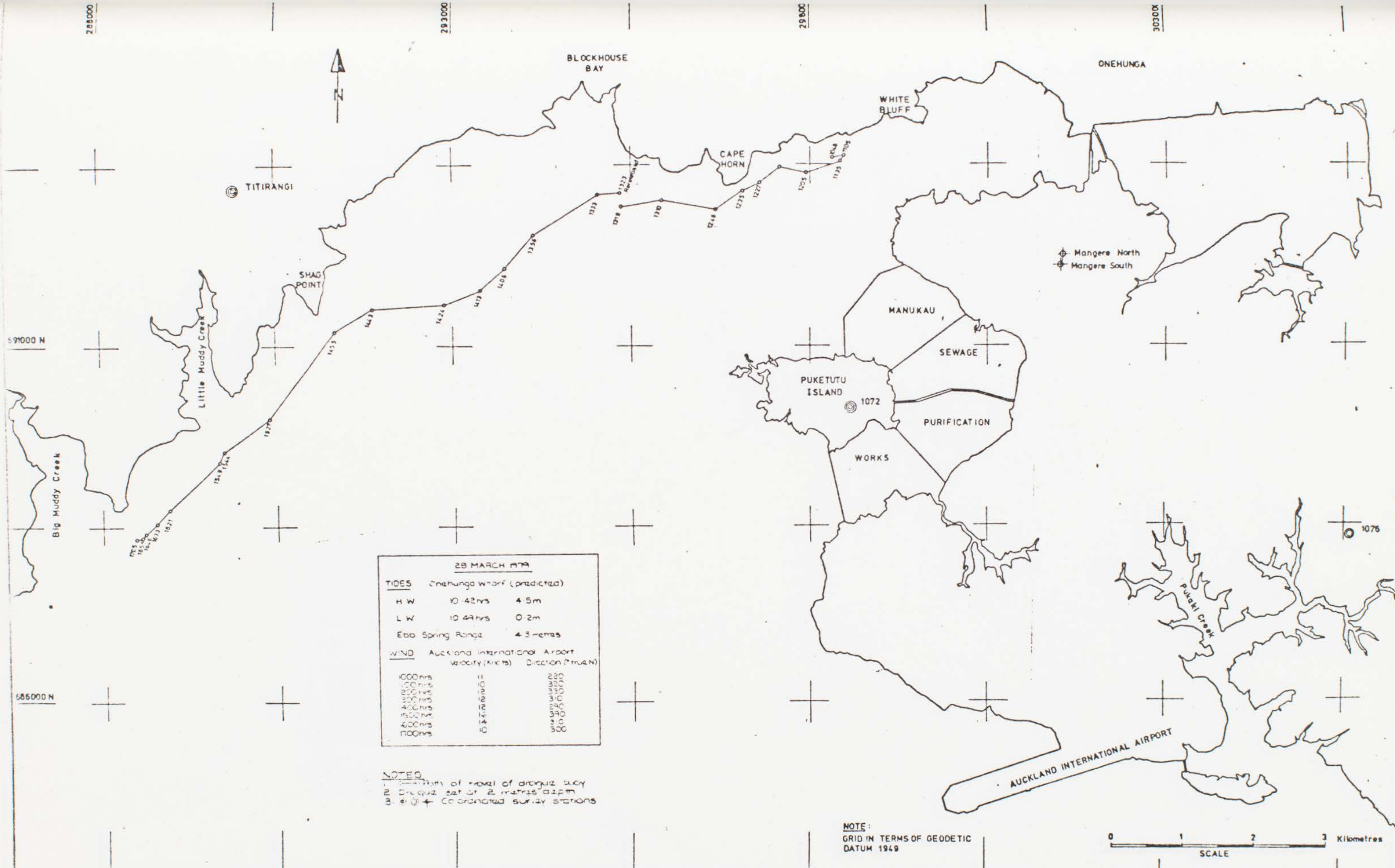
AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DROGUE BUOY OBSERVATIONS
SPRING EBB TIDE 28 MARCH 1979

ORIGINAL SCALES 1:25000
SHEET 1 of 5
FILE
JOB | CODE | SHEET | REVISION



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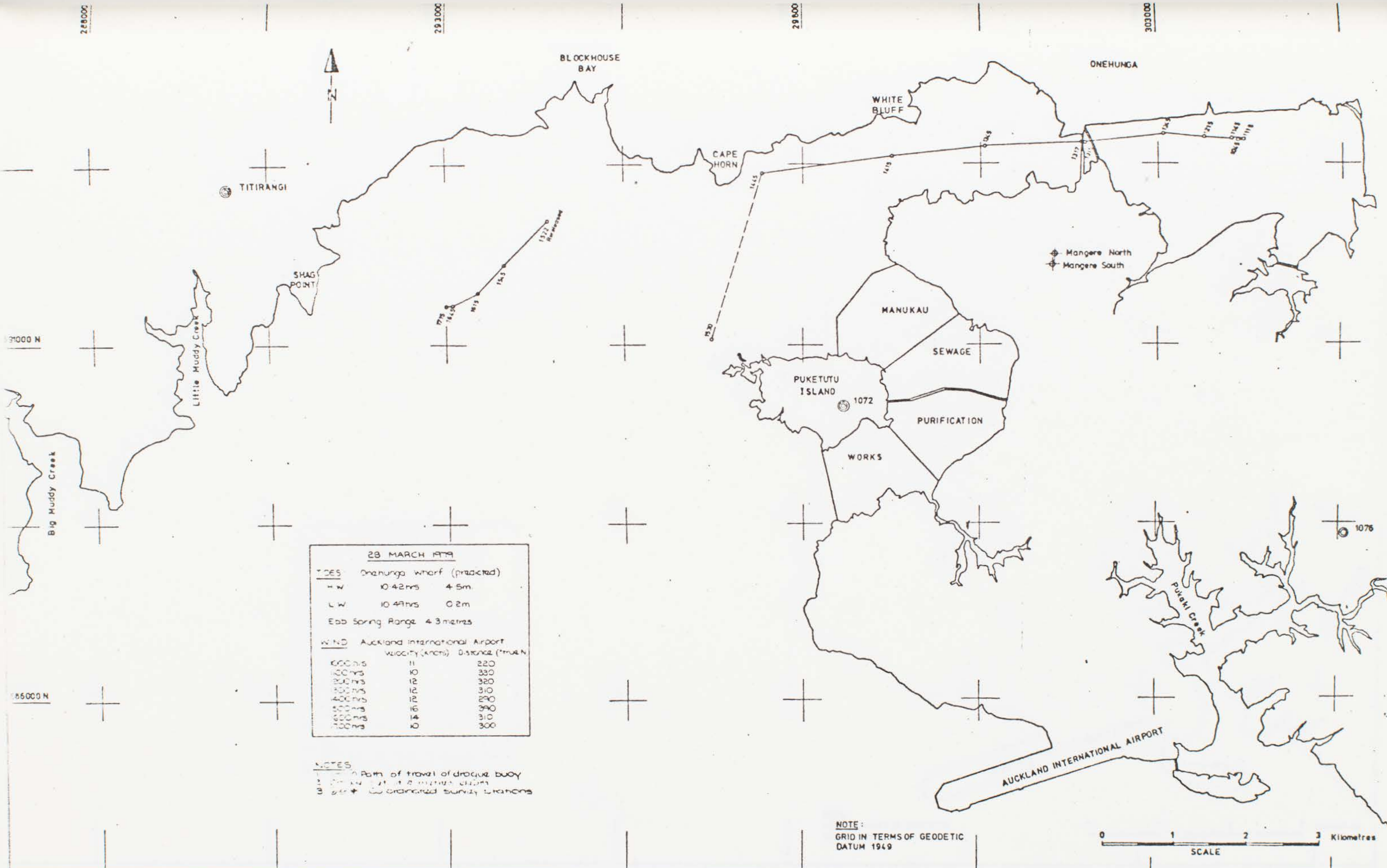
AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DROUGE BUOY OBSERVATIONS
SPRING EBB TIDE 28 MARCH 1979

ORIGINAL SCALES 1:25000
FILE
SHEET 2 of 5

JOB	CODE	SHEET	REVISION



28 MARCH 1979

TIDES Onehunga wharf (predicted)

H W	10·42 hrs	4·5m
L W	10·49 hrs	0·2m

Ebb Spring Range 4·3 metres

WIND Auckland International Airport

	Velocity (knots)	Distance (°true N)
1000 hrs	11	220
1100 hrs	10	330
1200 hrs	12	320
1300 hrs	12	310
1400 hrs	12	290
1500 hrs	16	390
1600 hrs	14	310
1700 hrs	10	300

NOTES
1. Path of travel of drogue buoy
2. [illegible]
3. Co-ordinated survey stations

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AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DROGUE BUOY OBSERVATIONS
SPRING EBB TIDE 28 MARCH 1979

ORIGINAL SCALES 1:25000
SHEET 3 of 5
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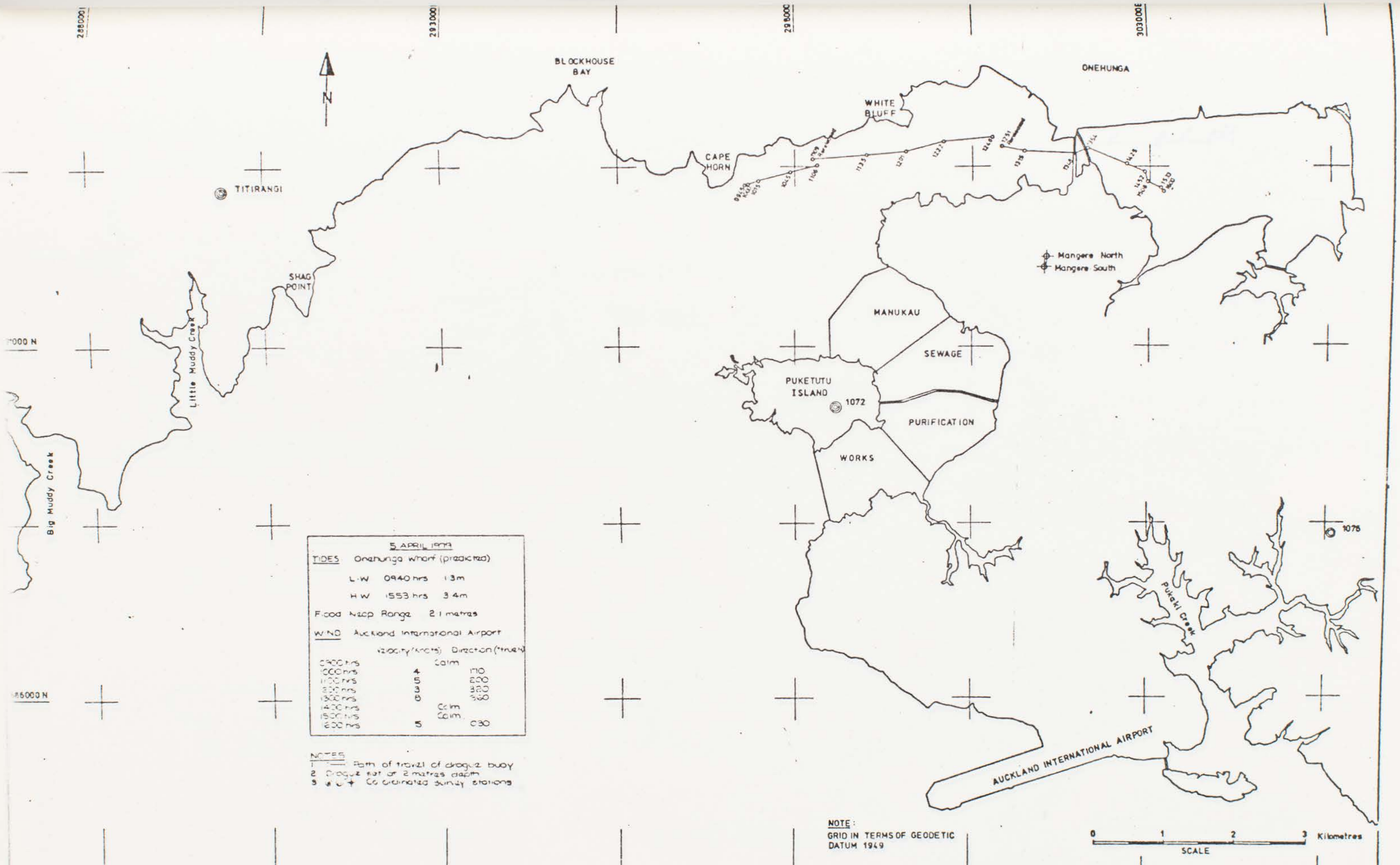

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AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DROGUE BUOY OBSERVATIONS
FLOOD NEAP TIDE 5 APRIL 1979

ORIGINAL SCALES 1:25000
SHEET 4 of 5
FILE

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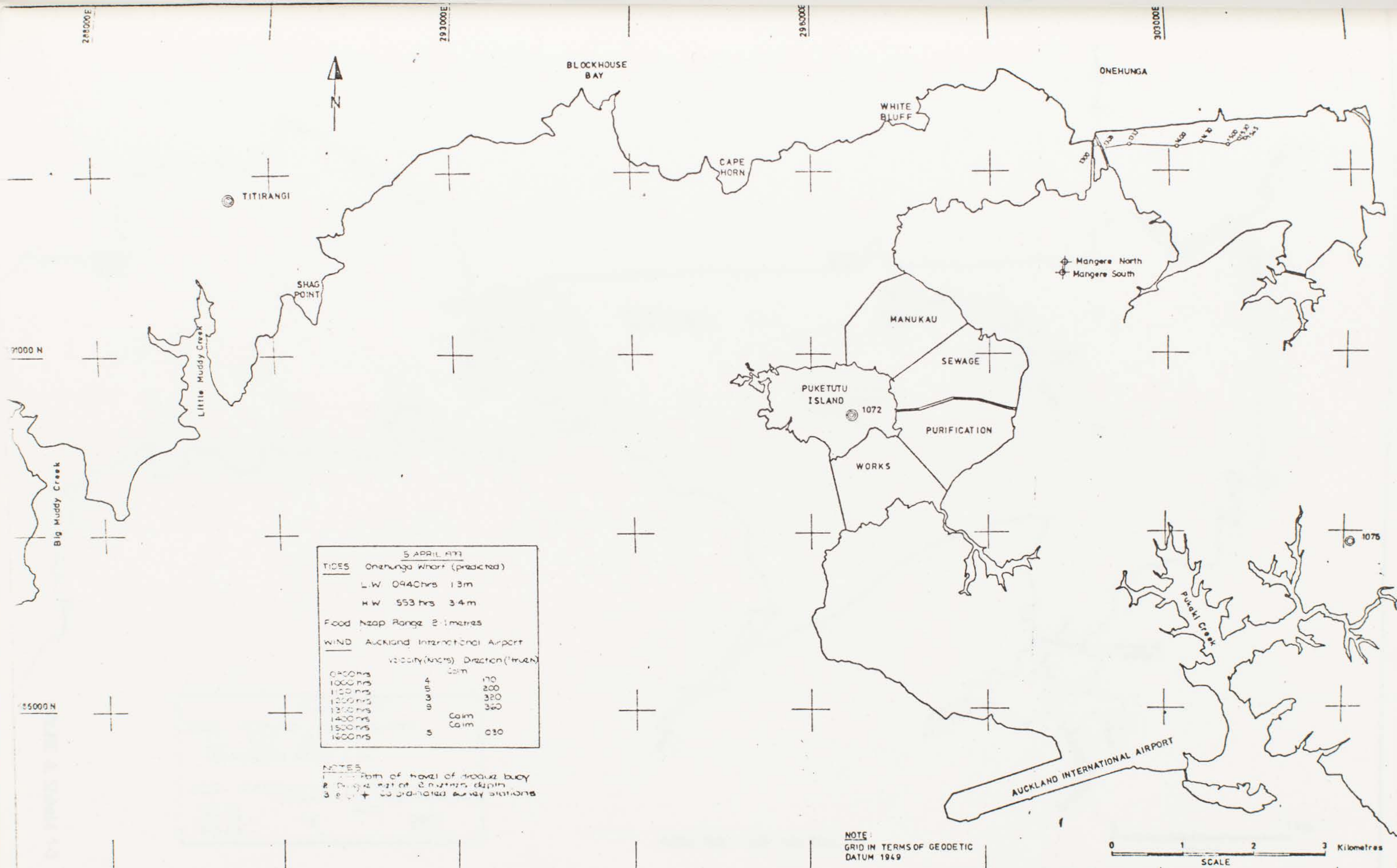

NOTE:
GRID IN TERMS OF GEODETIC DATUM 1949

0 1 2 3 Kilometres
SCALE

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AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DROGUE BUOY OBSERVATIONS
FLOOD NEAP TIDE 5 APRIL 1979

ORIGINAL SCALE 1:25000
SHEET 5 of 5

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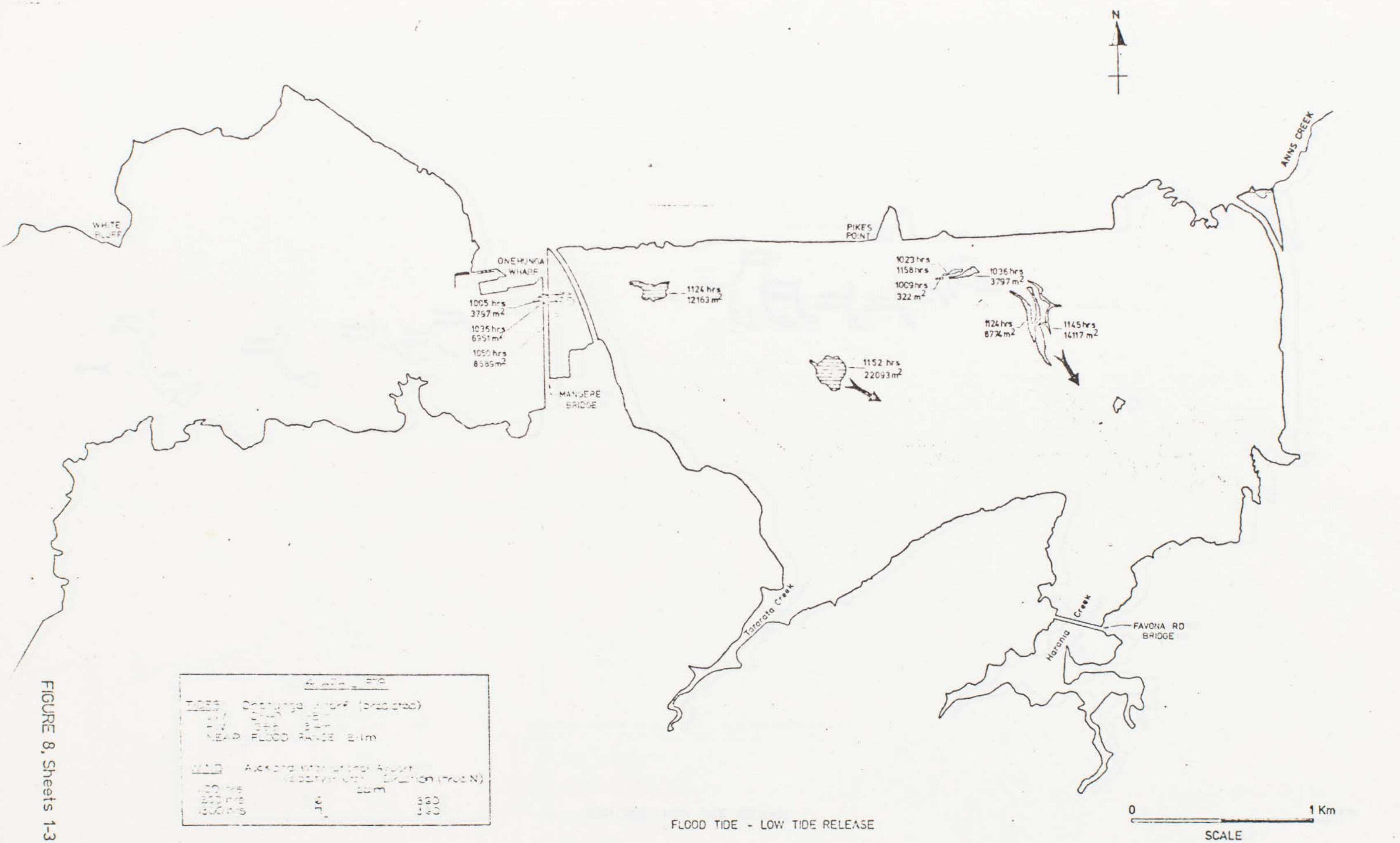

FIGURE 8, Sheets 1-3

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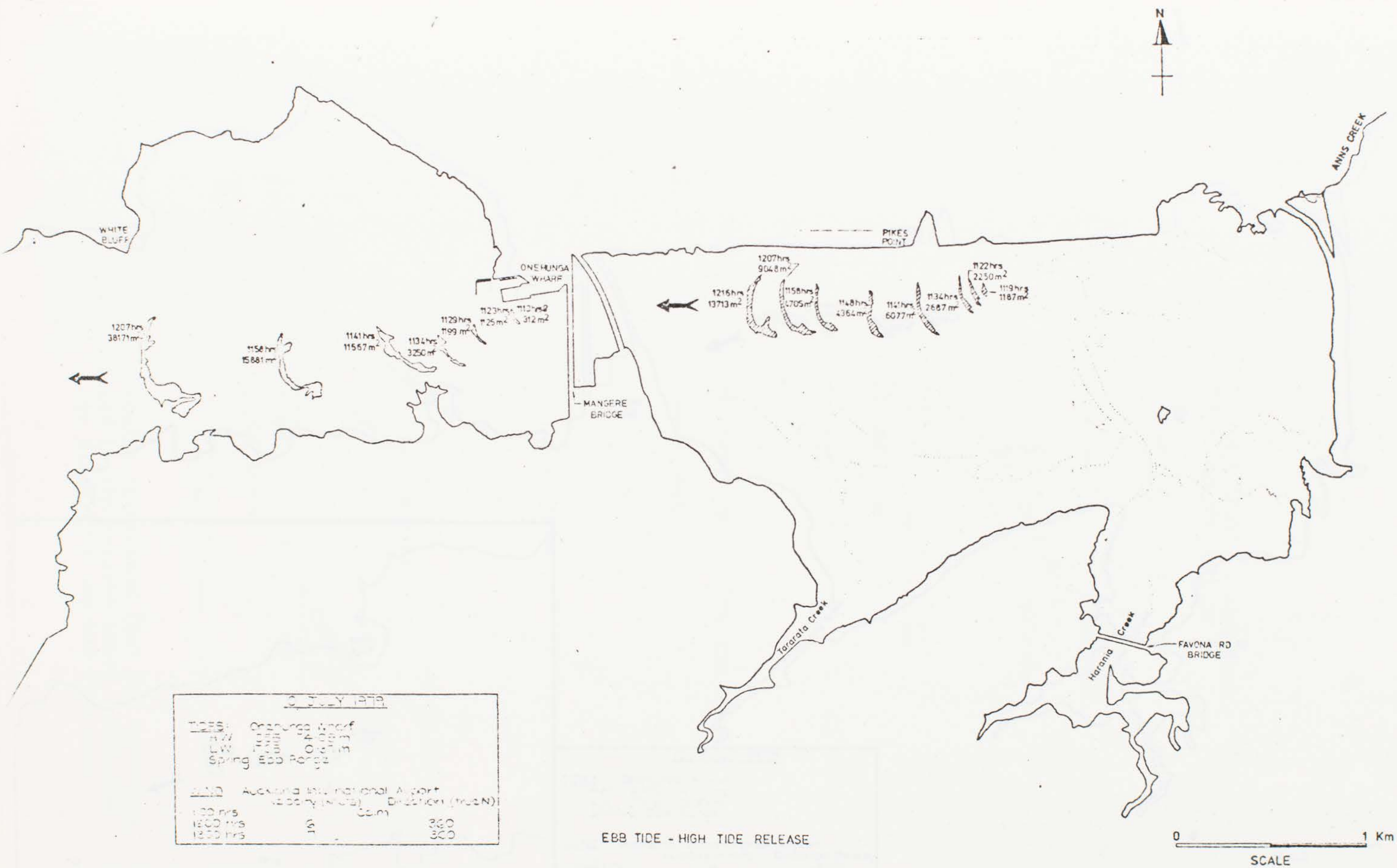
AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DYE DISPERSION STUDIES
FLOOD NEAP TIDE 4 APRIL 1979

APPROX. 1: 10000
Sheet 1 of 3



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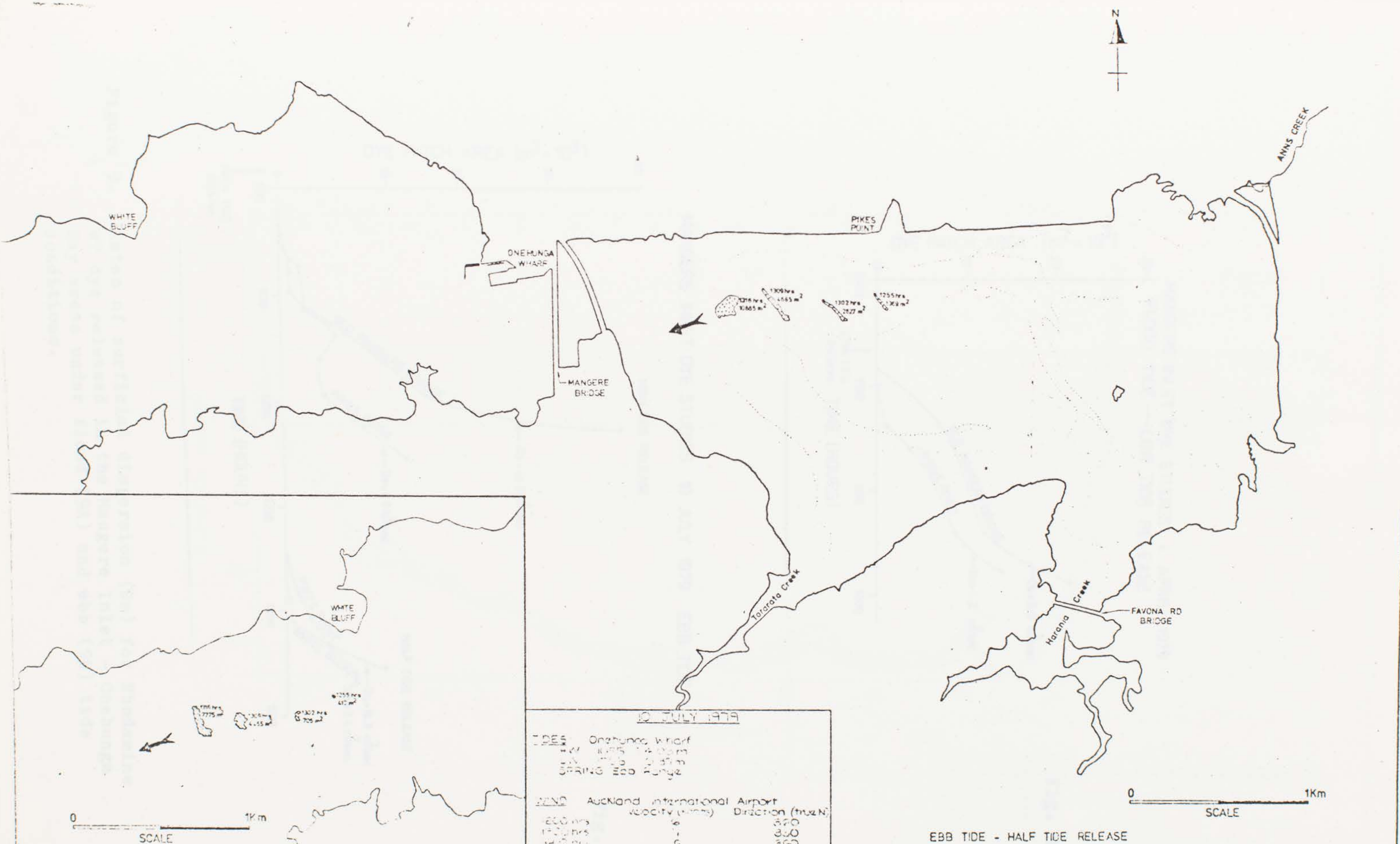
AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

DYE DISPERSION STUDIES
EBB SPRING TIDE 10 JULY 1979

APPROX. 1: 10000

Sheet 2 of 3



Ministry of Works and Development	AUCKLAND COMBINED CYCLE POWER STATIONS NORTH EASTERN MANUKAU HARBOUR
CIVIL ENGINEERING AUCKLAND	
WATER AND SOIL	DYE DISPERSION STUDIES EBB SPRING TIDE 10 JULY 1979

DRAWN

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APPROX. 1: 10000

Sheet 3 of 3

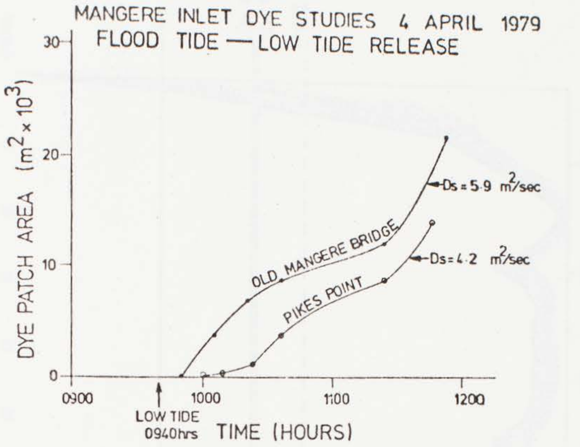


Fig. 9A

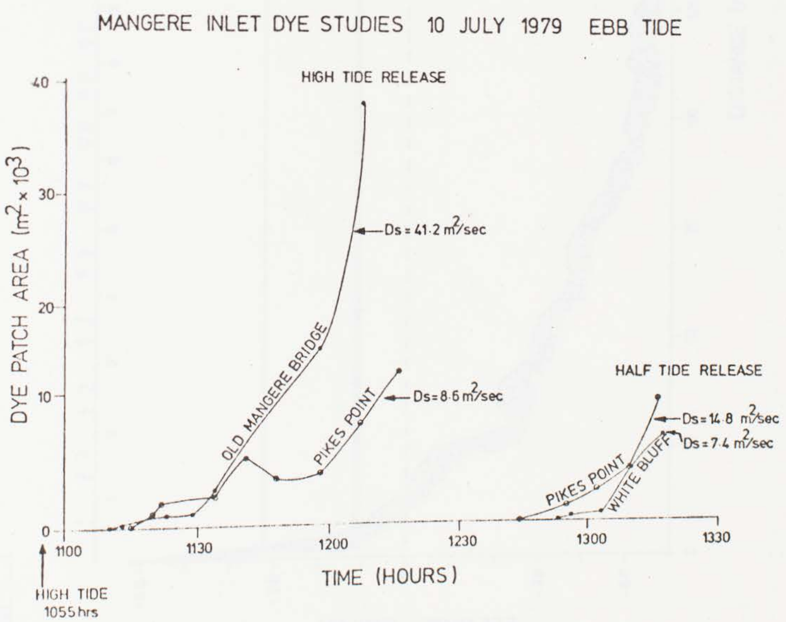
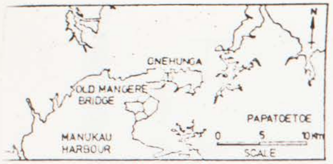
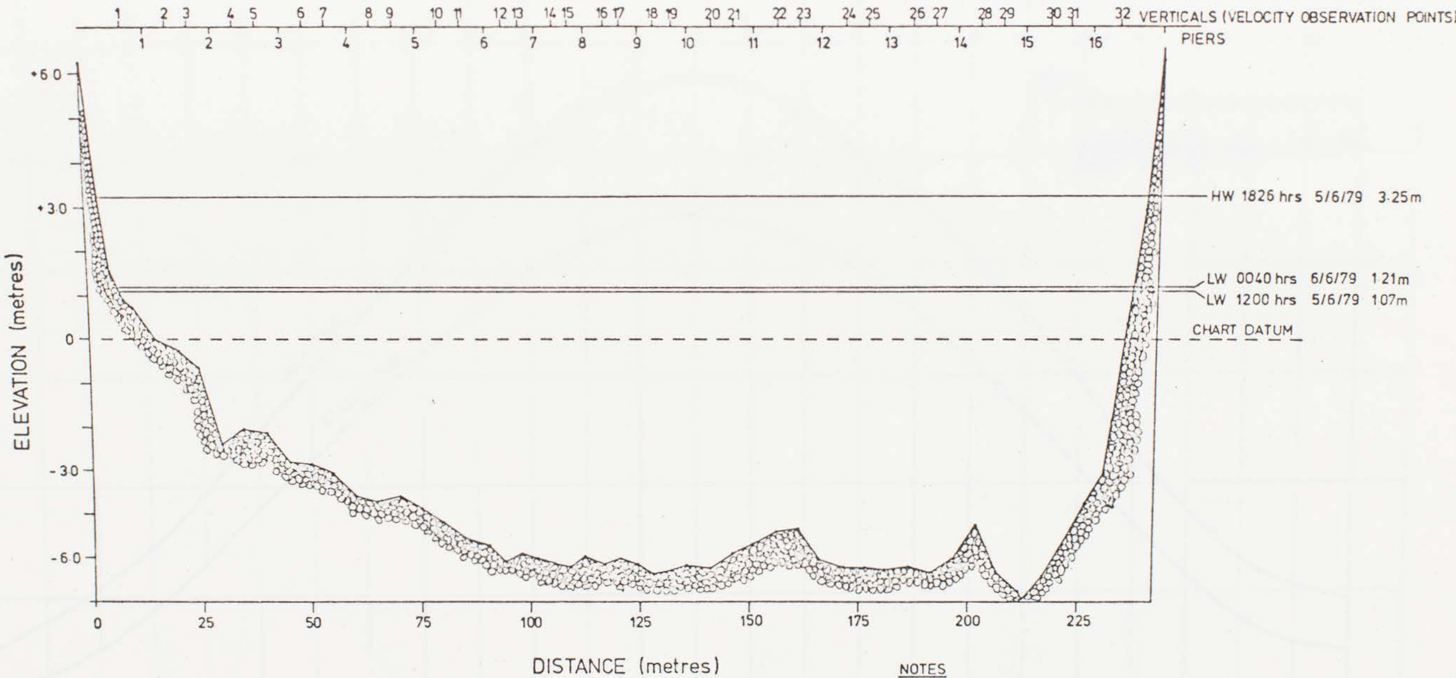


Fig. 9B

Figure 9. Rates of surficial dispersion (Ds) for Rhodamine WT dye released in the Mangere Inlet - Onehunga Bay areas under flood (9A) and ebb (9B) tide conditions.



LOCALITY PLAN



NOTES

1. ELEVATIONS IN TERMS OF AHB DATUM.
2. DEPTH MEASUREMENTS MADE BY TAKING LINE SOUNDINGS FROM BRIDGE ON 5.6.79.
3. DISTANCE 0 = CENTRE OF PILE CAP AT NORTHERN END OF OLD MANGERE BRIDGE.

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								APPROVED:		MANGERE INLET AT OLD MANGERE BRIDGE LOCALITY PLAN AND CROSS SECTION

ORIGINAL SCALES | FILE

Sheet 1 of 9

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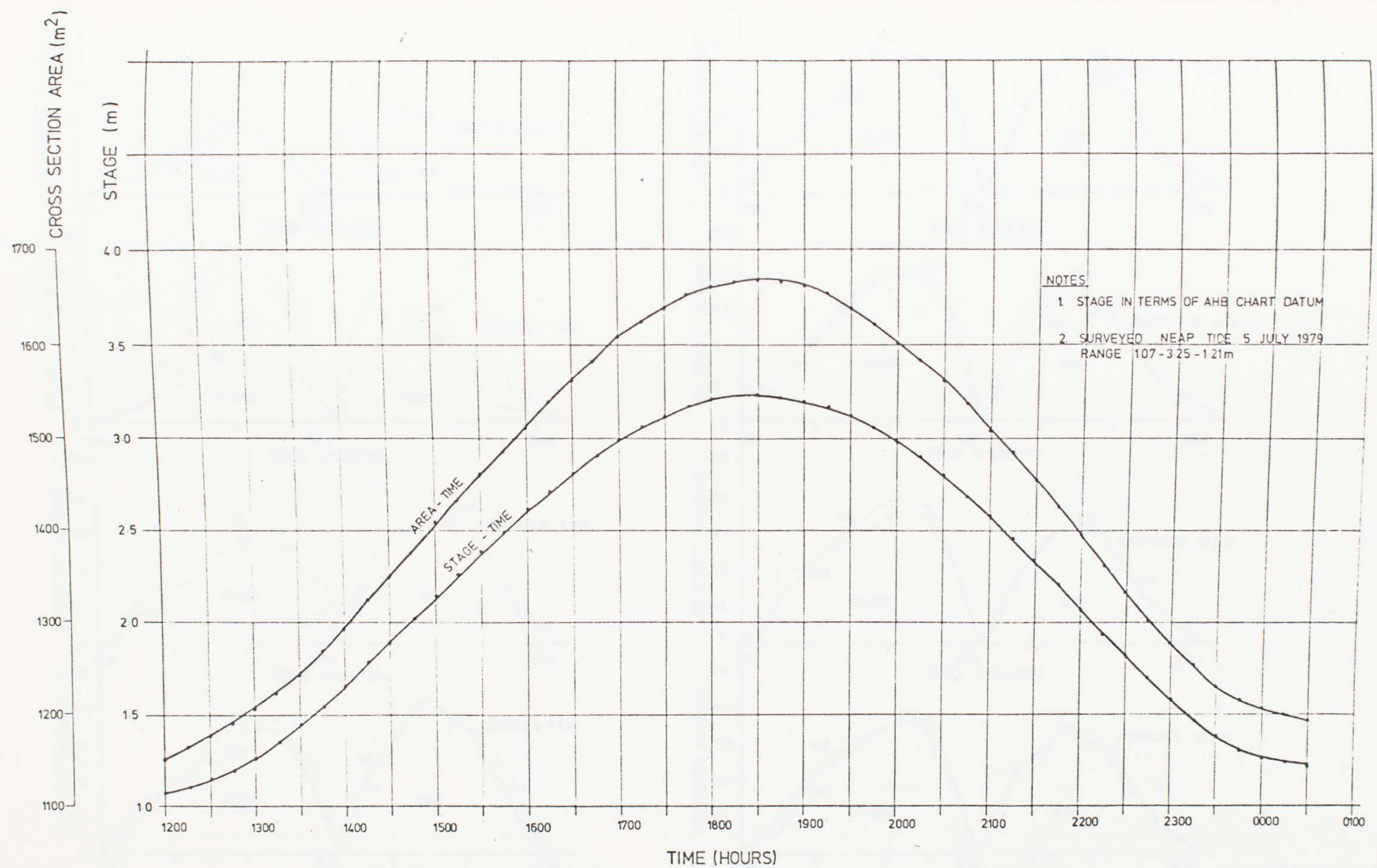

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AUCKLAND COMBINED CYCLE POWER STATIONS
TIDAL GAUGING

MANGERE INLET AT OLD MANGERE BRIDGE
STAGE, AREA VERSUS TIME PLOTS

ORIGINAL SCALES

FILE

Sheet 2 of 9

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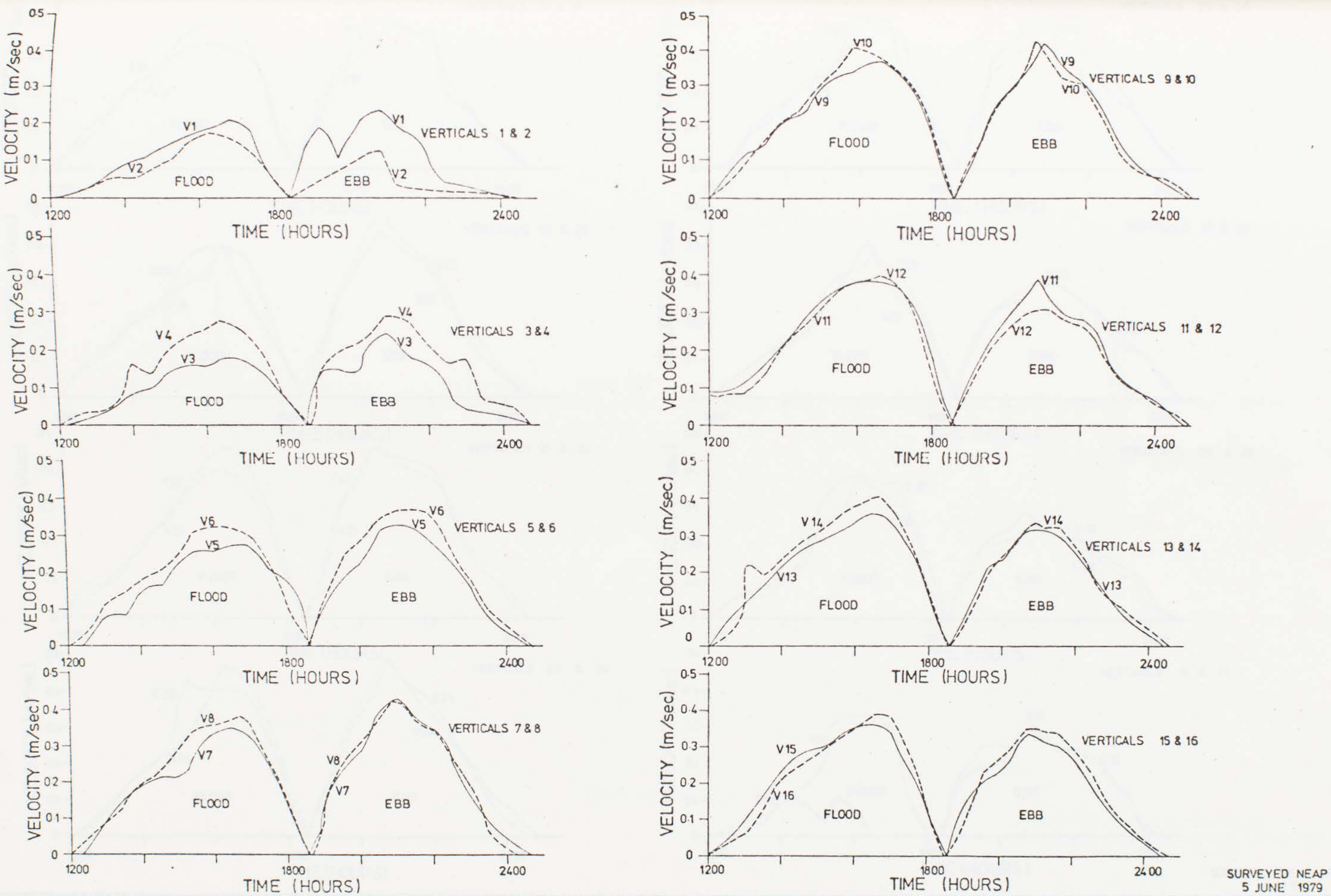

SURVEYED NEAP TIDE
5 JUNE 1979

AMENDMENTS | BY | APP'D | DATE

DRAWN J. Thompson | CHECKED | DATE 11/79

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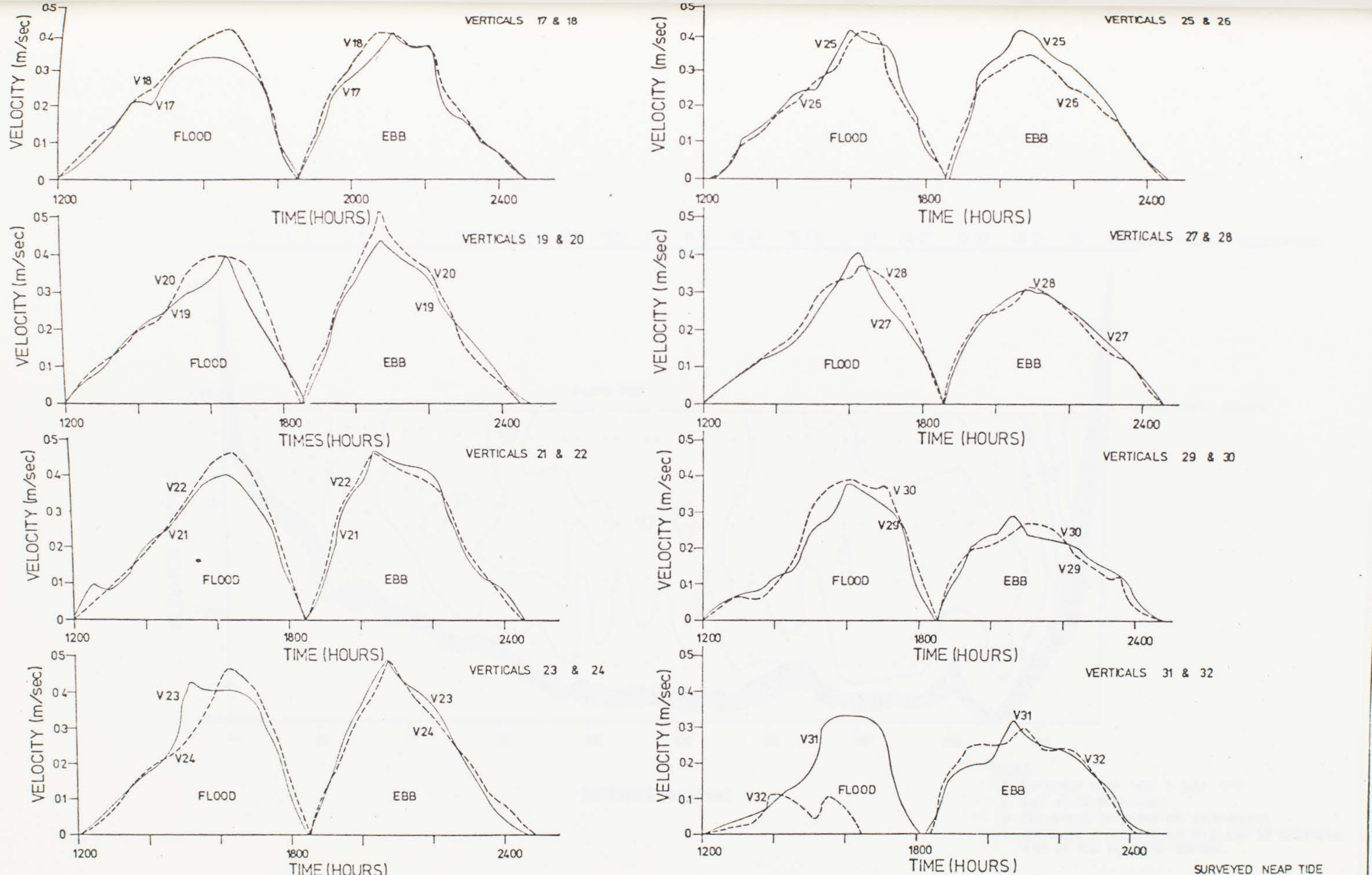
AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

MANGERE INLET AT OLD MANGERE BRIDGE
MEAN VELOCITY VERSUS TIME PLOTS

ORIGINAL SCALES | FILE
Sheet 3 of 9
JOB | CODE | SHEET | REVISION



SURVEYED NEAP TIDE
5 June 1979.

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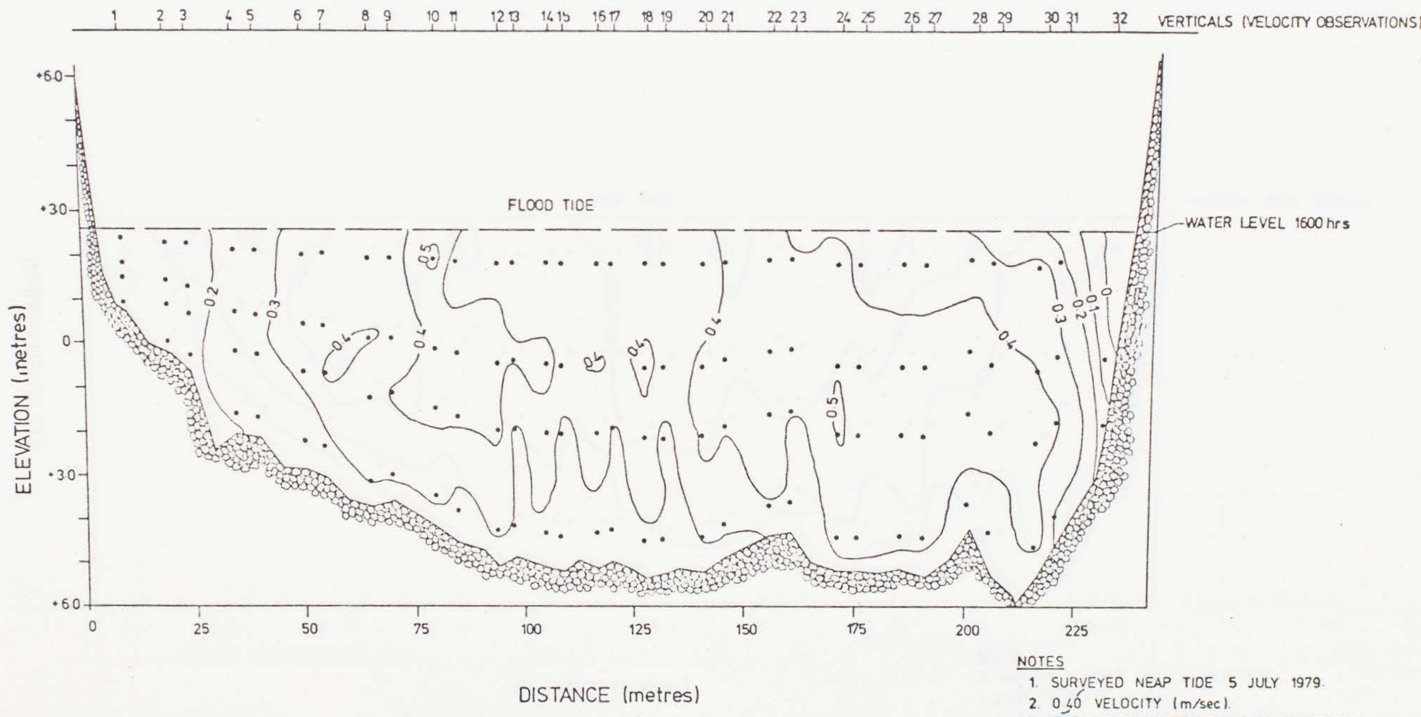
AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

MANGERE INLET AT OLD MANGERE BRIDGE
MEAN VELOCITY VERSUS TIME PLOTS

ORIGINAL SCALES | FILE
Sheet 4 of 9
JOB | CODE | SHEET | REVISION



NOTES

1. SURVEYED NEAP TIDE 5 JULY 1979.
2. 0.40 VELOCITY (m/sec).
3. ELEVATIONS IN TERMS OF AHB DATUM.
4. DISTANCE 0 = CENTRE OF PILE CAP AT NORTHERN END OF OLD MANGERE BRIDGE.

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AUCKLAND COMBINED CYCLE POWER STATIONS
TIDAL GAUGING

MANGERE INLET AT OLD MANGERE BRIDGE
VELOCITY DISTRIBUTION IN SECTION AT 1600 hours

ORIGINAL SCALES | FILE
Sheet 5 of 9
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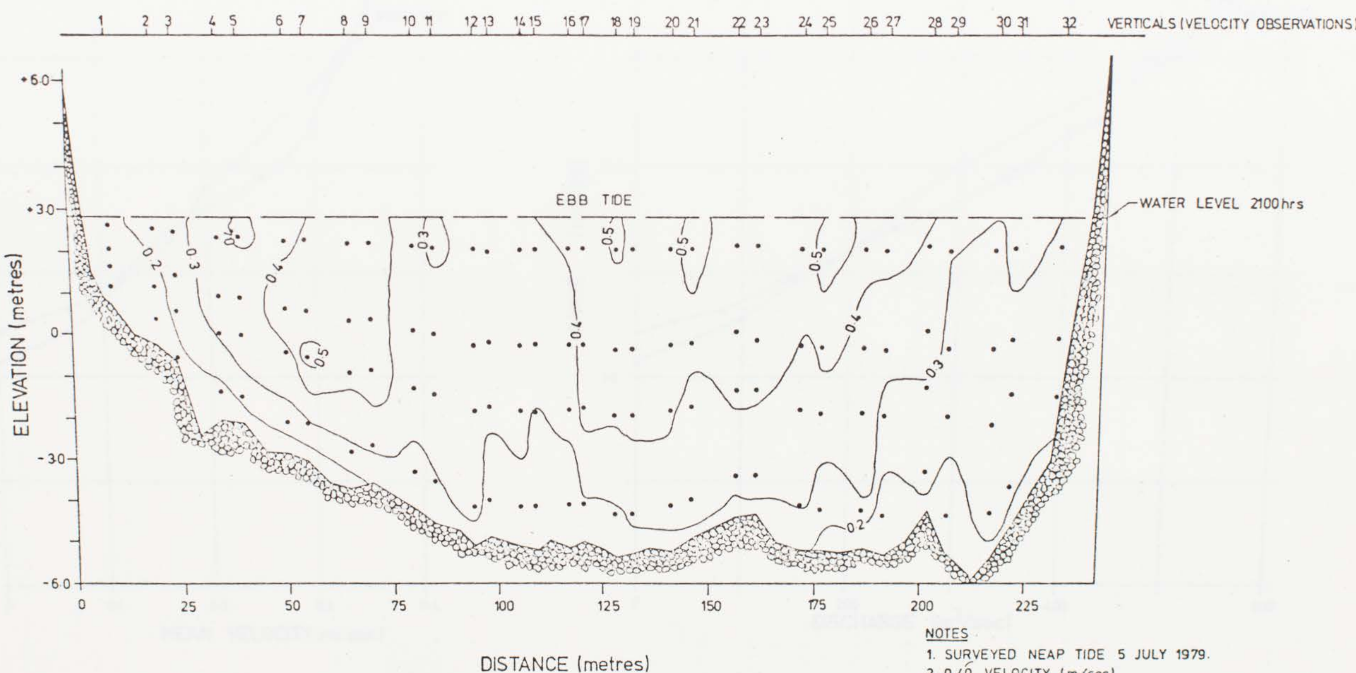

NOTES

1. SURVEYED NEAP TIDE 5 JULY 1979.
2. 0.40 VELOCITY (m/sec).
3. ELEVATIONS IN TERMS OF AHB DATUM.
4. DISTANCE 0 = CENTRE OF PILE CAP AT NORTHERN END OF OLD MANGERE BRIDGE.

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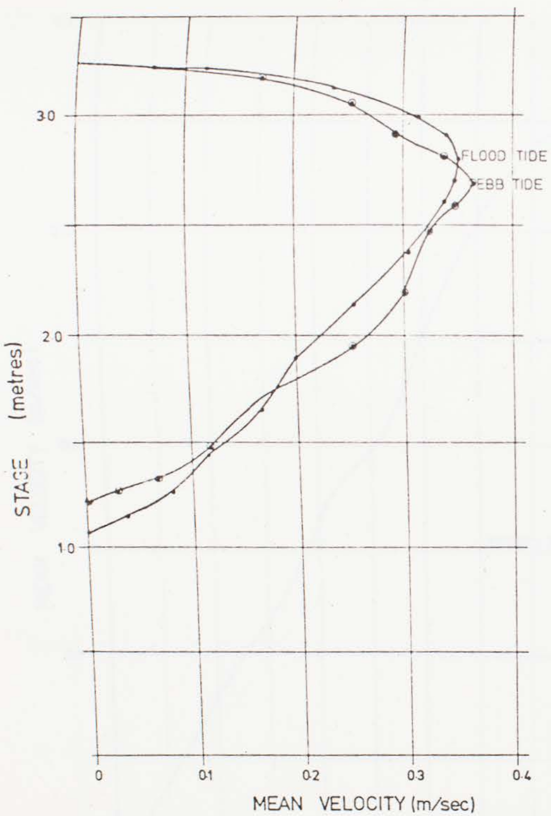
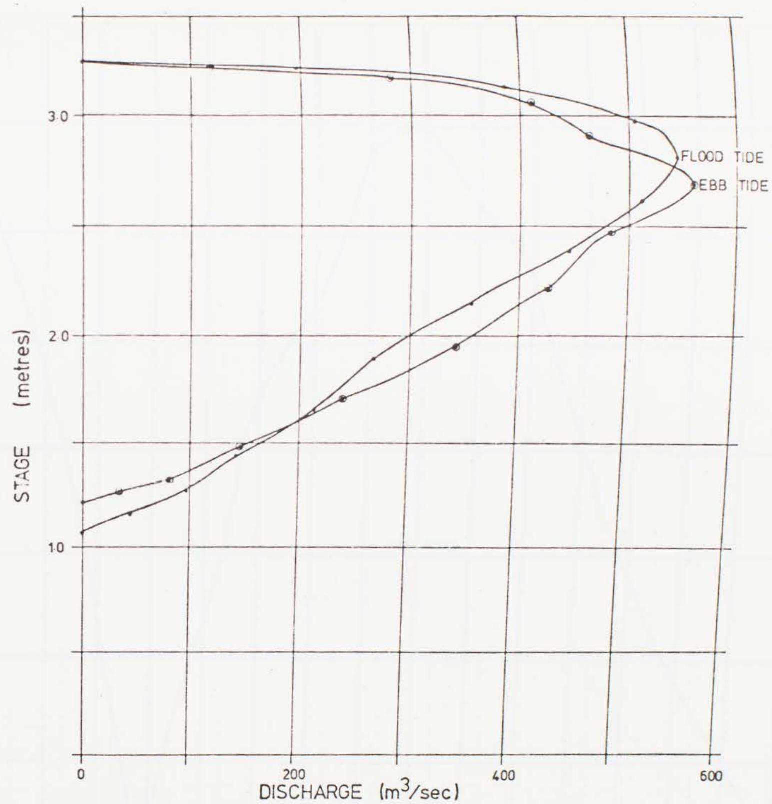
									WATER AND SOIL	MANGERE INLET AT OLD MANGERE BRIDGE VELOCITY DISTRIBUTION IN SECTION AT 2100 hours	JOB / CODE	SHEET / REVISION
									N.C. McLEOD Commissioner			





SURVEYED NEAP TIDE 5 - 6 - 79

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AUCKLAND COMBINED CYCLE POWER STATIONS
NORTH EASTERN MANUKAU HARBOUR

MANGERE INLET AT OLD MANGERE BRIDGE
STAGE VERSUS MEAN VELOCITY PLOTS

ORIGINAL SCALES

FILE

Sheet 7 of 9

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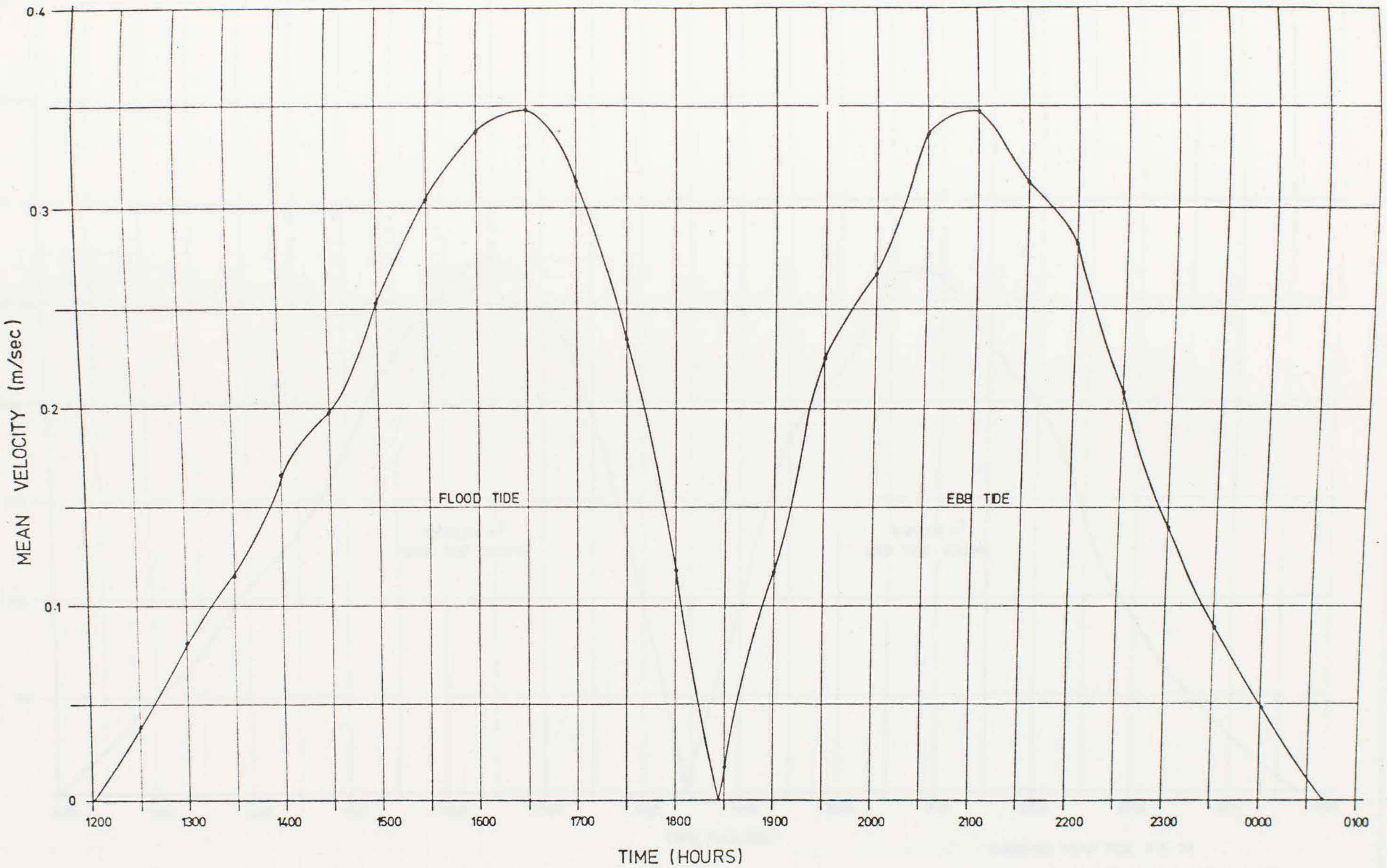

SURVEYED NEAP TIDE 5.6.79

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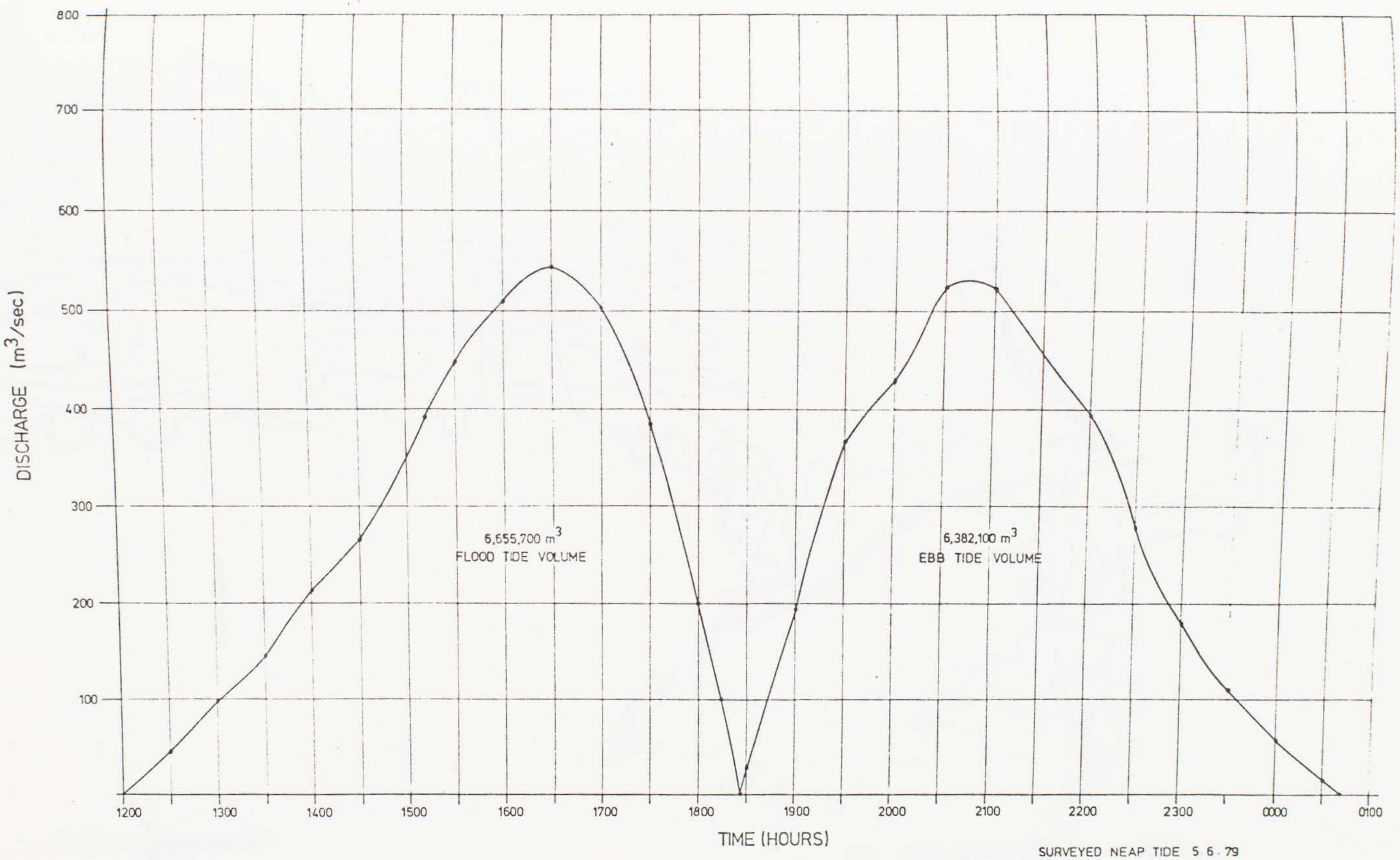
AUCKLAND COMBINED CYCLE POWER STATIONS
TIDAL GAUGING

MANGERE INLET AT OLD MANGERE BRIDGE
MEAN VELOCITY VERSUS TIME PLOT

ORIGINAL SCALES
Sheet 8 of 9
FILE
JOB | CODE | SHEET | REVISION



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								APPROVED	CIVIL ENGINEERING AUCKLAND	MANGERE INLET AT OLD MANGERE BRIDGE DISCHARGE VERSUS TIME PLOT	JOB / CODE / SHEET / REVISION
									WATER AND SOIL / N.C. McLEOD Commissioner		

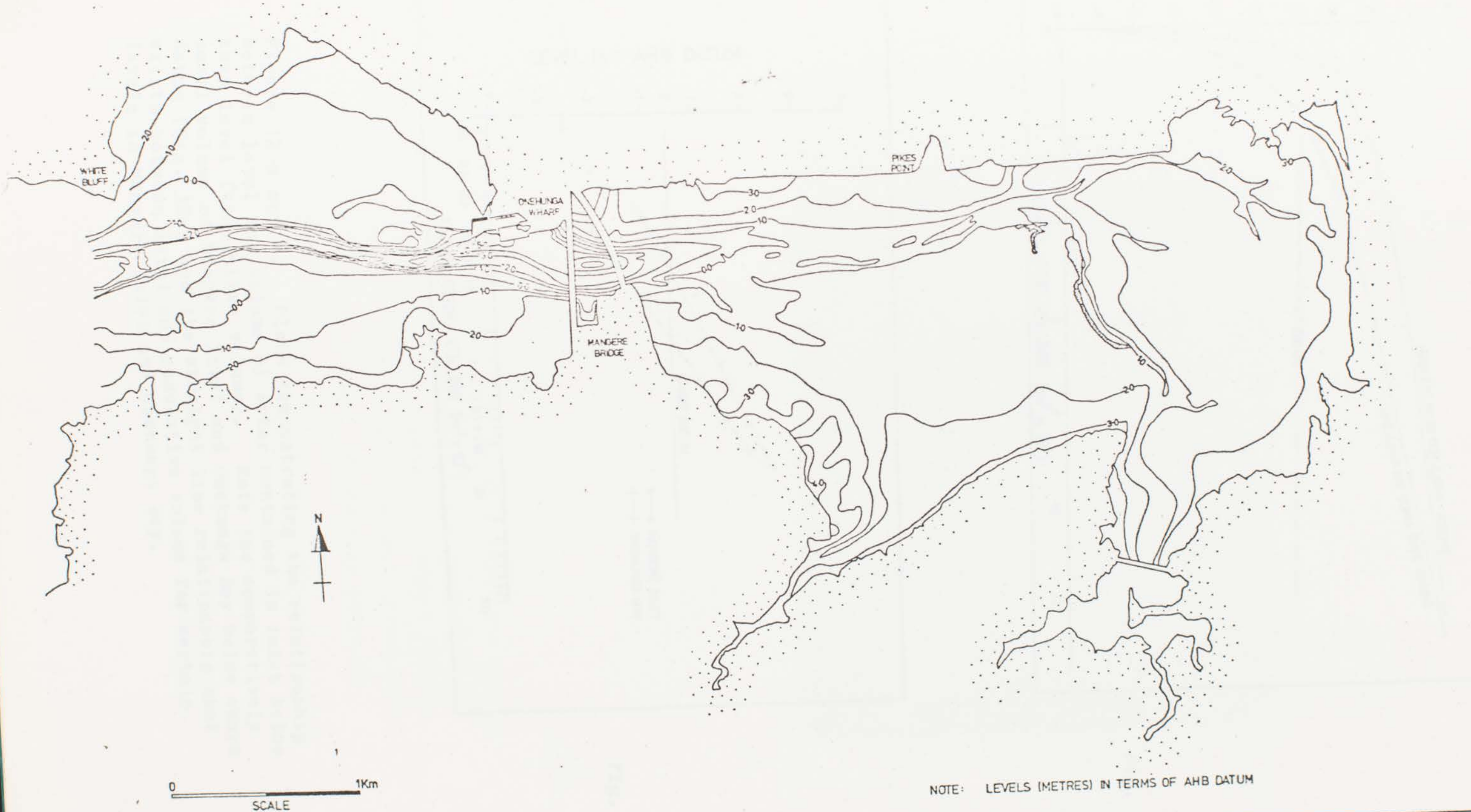


Figure 11 Bathymetry of Mangere Inlet and Onehunga Bay

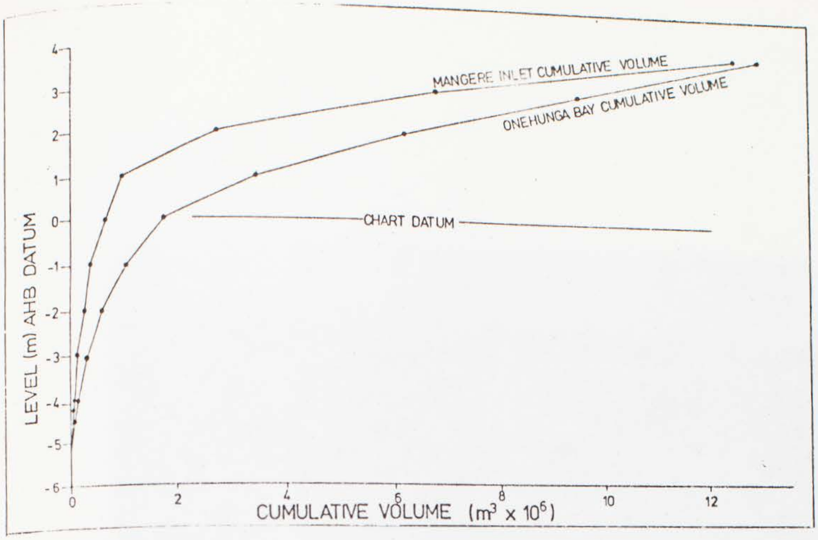


Fig. 12a

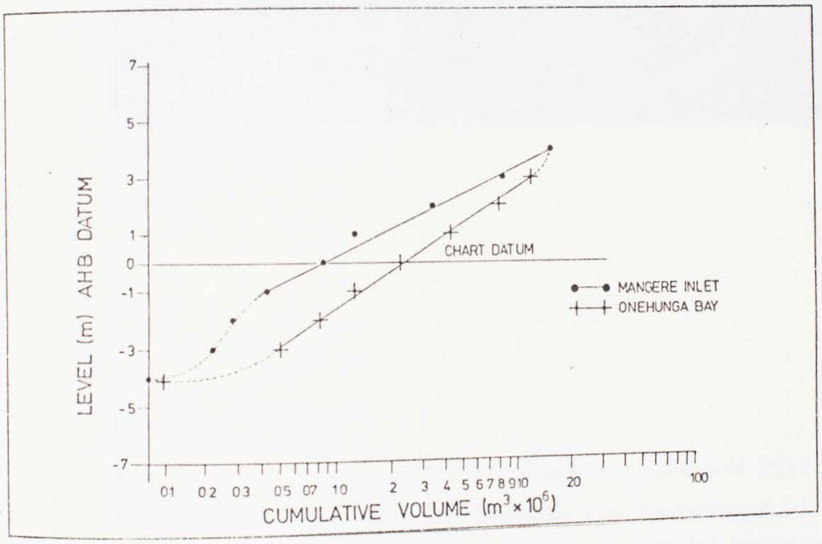


Fig. 12b

Figure 12 a and b. Plots demonstrating the relationship between level and volume of water contained in inlet below that level (cumulative volume). Note the comparatively small volume of Mangere Inlet and Onehunga Bay below chart datum (Fig. 12a) and the straight line relationship that exists between level and cumulative volume for certain levels in Mangere Inlet and Onehunga Bay.

Plate 1

View looking northwest down Mangere Inlet and Wairopa Channel. Mangere Inlet lies in the foreground, Onehunga Bay is the area immediately beyond Mangere Bridge (centre) and the Wairopa Channel curves left towards the Manukau Heads. Photograph taken at highwater on 10 July 1979.

Plate 2

Neap flood tide dispersion of dye (4 April 1979, 1224 hrs) released in tidal channel adjacent to Pikes Point (cf. Fig. 2 and Fig. 8,Sheet 1).

Note how the dye patch has split into two ribbons that flank the channel borders. Arrows show inferred direction of current movements.

The white shape is a shell bank (Fig. 2) and the brown material is algae growing on the intertidal mud flats.

Plate 3A
1144 hrs

Plate 3B
1212 hrs

Plate 3
Photographic sequence from 10 April 1979 showing spring ebb tide dispersion of dye released from Mangere Bridge area (approximately extreme left centre of Pl.3A).
Note the arcuate shape that the dye patch assumes as it travels westwards (to right of photograph) down Onehunga Bay (cf Fig. 8, Sheet 2).

Plate 4

Spring ebb tide dispersion of dye released from Pikes Point area (bottom left of photograph). Note that the dye patch assumes an arcuate shape similar to that released in Onehunga Bay (cf Pl. 2). Photograph taken on 10 April 1979 at 1210 hrs (cf. Fig. 8, Sheet 2).

Plate 5
Dye patch at 1316 hours released from Pikes Point area under spring ebb tide conditions. The top border of the print parallels the northern boundary of the Mangere Inlet (cf. Fig. 8, Sheet 3). Note the dense silt plumes streaming right to left (east to west) across the area and how the lower part of the dye patch is cut by one such plume.

MANUKAU HARBOUR - GENERAL

Published Papers, Reports and Charts

Hydrographic Branch, Navy Department 1969 : Chart NZ 4315, Approaches to Onehunga 1 : 18,000

____________ 1973 : Chart NZ 4314, Manukau Harbour, 1 : 48,000

Auckland Harbour Board 1974 a : Comparison of levelling and sounding datums for Onehunga, Manukau Harbour Drawing S90/26 of 18.10.74.

____________ 1974b : Chart of abnormal high tides recorded at Onehunga, Manukau Harbour, during the period 1926 - 1973. Drawing S90/25 of 25.1.74.

Anderson, P.W., Grange, K. R. 1976a : Bibliography of scientific studies of Manukau Harbour, Auckland. Miscellaneous Publication N.Z. Oceanographic Institute 74.

Henriques, P. R. 1976 : Manukau Harbour Ecology : preliminary investigations. Report to the Works Division, Auckland Regional Authority, Auckland

Auckland Regional Water Board 1976 : Baseline data on water quality in the Auckland water region obtained in 1975 and 1976. Report prepared for the ARWB by the Works Division, Auckland Regional Authority, Auckland. 84 p.

____________ 1977 : Baseline data on water quality in the Auckland water region obtained in 1976 and 1977. Volume II. Report prepared for the ARWB by the Works Division, Auckland Regional Authority, Auckland. 65 p.

Hendriques, P. R. 1977 : Selected ecological aspects of the Manukau Harbour. Unpublished Ph.D. thesis in Botany, University of Auckland, Auckland.

Heath, R. A., Greig, M. J. N., Shakespear, B. S. 1978 : Circulation and hydrology of Manukau Harbour. N.Z. Journal of Marine and Freshwater Research 11 (3) : 589 - 608.

Other Data

Auckland Harbour Board : Tide gauge records from Onehunga Wharf, Manukau Harbour for the period 1926 - present. Data held by AHB.

Appendix I. Summary of published and unpublished hydrological data available on the study area.

MANGERE INLET - WAIROPA CHANNEL

Published Papers, Reports and Charts

Auckland Harbour Board, 1967 : Onehunga east of Mangere Bridge. O.B.C. Reclamation : siltation survey. Drawing H5/6a of October 1967. Scale 100 feet:1 inch.

____________ 1970a : Tidal stream observations in the vicinity of Puketutu Island, Manukau Harbour. Drawings HT 5/1/1 - HT 5/1/7 of December 1970. Scale 1 : 18,000.

____________ 1970b : Manukau Harbour Puketutu Island area. Estimated tidal stream pattern at half flood tide. Drawing HT 5/1/9 of 14 December 1970. Scale 1 : 18,000.

____________ 1970c : Manukau Harbour Puketutu Island area. Estimated tidal stream pattern at half ebb tide. Drawing HT 5/1/8 of 14 December 1970. Scale 1 : 18,000.

____________ 1978 : Bathymetry of Mangere Bridge to White Bluffs. Drawing H5/15/1 of 19 September 1974. Scale 1 : 5,000.

Auckland Regional Authority 1972 : Investigation of dispersion of effluent from Manukau Treatment Works. Internal report, Works Division, ARA, Auckland 20 March 1972.

Hume, T. M. 1979 : Auckland Combined Cycle Power Station Investigations - Model Tests for Siting Marine Cooling Water Intake and Outlet Structures in Onehunga Bay. Internal Report, Water and Soil Section, M.W.D., Auckland. July, 1979. 18pp.

Hutchinson, E. G. 1978 : Manukau Harbour Surveys. Internal Report, Works Division, Auckland Regional Authority, Auckland. 10 February 1978.

Ministry of Works, 1960 : Manukau Mudflats - Reclamation Survey. Comparison survey datum : with datums of : AHB, L & S Dept., AMDB and NZR. Drawing ADO 29395 of 20 May 1960. Scale 2 feet = 1 inch.

Ministry of Works, 1961 : Manukau Harbour Mudflat Reclamation Contour Survey. Drawing ADO 29817 of February 1961. Scale 400 feet = 1 inch.

Mortimer, D. H. 1972 : Manukau Harbour investigations - Isotope and other harbour tests. 1971 - 1972. Internal report, Works Division, Auckland Regional Authority, Auckland.

Wells-Green, P. 1979 : Port of Onehunga - Tidal Model. Internal Report, Auckland Harbour Board. July 1979. 139pp.

Other Data

Auckland Harbour Board : Tidal volumetric gauging at Mangere Bridge - Spring ebb flow 19 June 1978. Data held by AHB.

____________________ : Current velocity and water slope measurements made in the vicinity of Mangere Bridge and White Bluffs in 1978. Data held by AHB.

Auckland Regional Authority : Daily water temperature records from Mangere Bridge 1960 - 78. Data held by Works Division, ARA, Auckland.

Station	Time	Water Depth (m)	Observation Depth	Temperature (°C)	Salinity (‰)
1. Cape Horn	1257	7.1	T	13.7	28.4
			M	12.2	29.6
			B	12.5	30.0
2. White Bluff	1308	5.2	T	12.4	28.2
			M	12.5	29.0
			B	12.8	29.6
3.	1317	2.4	T	12.1	27.8
			M	12.1	28.0
			B	12.1	28.0
4. Old Mangere Bridge	1323	5.9	T	11.8	26.8
			M	11.9	27.8
			B	12.0	29.0
5.	1330	7.5	T	11.8	26.6
			M	11.8	27.7
			B	12.0	27.7
6.	1340	1.3	T	12.0	26.0
			B	12.0	26.0
7.	1355	0.4	T	12.0	25.9
8.	1405	0.8	T	12.5	24.6
9. Pikes Point	1418	0.6	T	12.9	22.0

Appendix IIA. Temperature and salinity data from northeastern Manukau Harbour at low tide on 6 June 1979; station positions are shown in Fig. 3 (T = top, M = middle, B = bottom). All measurements made with Yellowsprings SCT meter.

Station	Time	Water Depth (m)	Observation Depth	Temperature (°C)	Salinity
1. Cape Horn	2005	9.5	T	12.8	32.4
			M	12.6	32.6
			B	12.6	32.6
2. White Bluff	1952	7.5	T	12.7	30.4
			M	12.7	31.8
			B	12.8	31.8
3.	1941	6.4	T	12.8	30.4
			M	12.8	31.1
			B	12.6	31.1
4. Old Mangere Bridge	1935	7.9	T	12.7	30.2
			M	12.5	30.6
			B	12.5	30.6
5.	1930	10.4	T	12.6	30.0
			M	12.6	30.4
			B	12.3	30.6
6.	1924	2.5	T	12.5	30.2
			B	12.2	30.4
7.	1918	2.8	T	12.2	30.2
			B	12.2	30.0
8.	1910	2.5	T	12.5	29.2
			B	12.2	29.8
9. Pikes Point	1904	2.8	T	12.3	28.4
			B	12.3	29.4
10.	1855	1.1	M	11.2	30.0
11.	1843	1.2	M	11.1	27.9
12.	1830	0.7	M	11.5	27.2

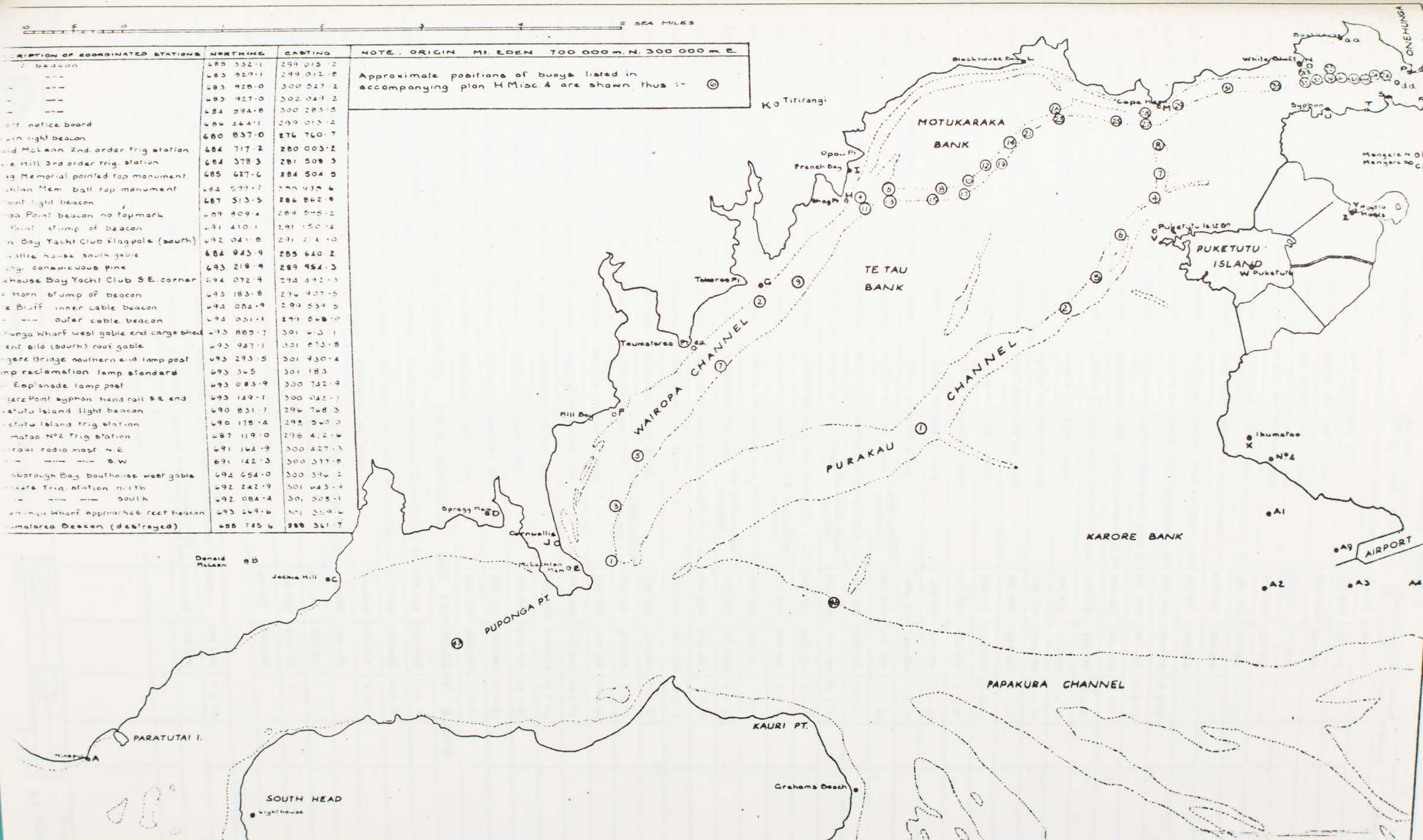
Appendix IIB. Temperature and Salinity data from northeastern Manukau Harbour at high tide on 6 June 1979; station positions are shown in Fig. 3 (T = top, M = middle, B = bottom). All measurements made with Yellowsprings SCT meter.

CO-ORDINATED STATIONS	NORTHING	EASTING
One Tree Hill Obelisk	697 552.4	301 662.8
Pylon 32	693 951.5	301 913.9
Pylon 33	694 082.0	301 759.6
Pylon 34	694 501.8	301 292.2
Pylon 35	694 698.1	300 206.3
Cement Silo North	693 960.2	301 878.3
Cement Silo South	693 950.9	301 875.1

Note : Origin Mt Eden 700 000 m.N. 300 000 m.E.

Appendix III.

Co-ordinated survey control marks in the Mangere Inlet - Wairopa Channel area. Additional data given in Auckland Harbour Board plans H MISC 3 and H MISC 4.



NOTE. ORIGIN Mt. EDEN 700 000 m. N. 300 000 m. E.

Approximate positions of buoys listed in accompanying plan H Misc. 4 are shown thus :- ⓪

...RIPTION OF COORDINATED STATIONS	NORTHING	EASTING
: beacon	685 332·1	299 015·2
—"—	683 929·1	299 012·8
— —"—	683 928·0	300 527·2
— —"—	683 927·0	302 049·2
— —"—	684 594·8	300 283·5
...t notice board	686 364·1	299 013·4
...in light beacon	680 837·0	276 760·7
...ald McLean 2nd. order trig station	684 717·2	280 003·2
...e Hill 3rd order trig. station	684 378·3	281 508·3
...g Memorial pointed top monument	685 627·6	284 504·5
...chlan Mem. ball top monument	684 599·7	285 475·6
...oint light beacon	687 513·5	286 862·9
...oa Point beacon no topmark	689 809·4	289 545·2
... Point stump of beacon	691 410·1	291 150·4
...n Bay Yacht Club flagpole (south)	692 041·8	291 [illegible]
...attie house south gable	684 943·9	285 640·2
...ng. conspicuous pine	693 218·9	289 954·3
...khouse Bay Yacht Club S.E. corner	694 072·9	294 442·3
...e Horn stump of beacon	693 183·8	296 407·5
...e Bluff inner cable beacon	694 084·9	299 539·5
— —"— outer cable beacon	694 031·1	299 648·0
...hunga Wharf west gable end cargo shed	693 885·7	301 [illegible]
...ent silo (south) roof gable	693 947·1	301 673·8
...gere Bridge southern end lamp post	693 293·5	301 930·4
...mp reclamation lamp standard	693 365	301 183
... Esplanade lamp post	693 083·9	300 712·9
...gere Point syphon hand rail S.E. end	693 149·1	300 042·1
...etutu Island light beacon	690 831·7	296 768·3
...etutu Island trig station	690 178·4	298 560·0
...matao No2 trig station	687 119·0	298 412·6
...raki radio mast N.E.	691 164·9	300 427·3
— —"— —"— S.W.	691 142·3	300 377·8
...sborough Bay boathouse west gable	694 654·0	300 396·2
...re Trig. station north	692 242·9	301 643·4
— —"— —"— south	692 084·4	301 505·1
...hunga Wharf approaches reef beacon	693 669·6	301 359·6
...matarea Beacon (destroyed)	688 725·6	288 361·7

MANUKAU HARBOUR - BUOYAGE

SCALE 1:48 000

H MISC 3

LOCATION PLAN TO ACCOMPANY LIST ON PLAN H MISC 4

MAIN CHANNEL (WAIROPA) BUOYS.

No	DESCRIPTION	MOORINGS	BEARING & DIST FROM REFERENCE POINT	COORDINATES N	COORDINATES E	CHANGE DUE	OVERDUE	REMARKS	No
1	BLACK CONICAL, BIRD SPIKE	18.3 m 1" CHAIN 15 CWT WT	201° 4298 TAUMATAREA B"	684 713	284 821	[illegible]			
2	RED CAN	18.3 m 1" CHAIN 1300 lb WT	058° 1521 " "	689 532	289 652				
3	BLACK CONICAL, CONICAL SURMOUNT	15.2 m 1" CHAIN 1300 lb WT	205°15' 3287 " "	685 753	286 960	[illegible]			
4	RED CAN	18.3 m 1" CHAIN 1300 lb WT	047°30' 3902 " "	691 362	291 239	[illegible]			
5	BLACK CONICAL, BIRDSPIKE	18.3 m 1" CHAIN 15 CWT WT	207°30' 2230 " "	686 748	287 332	[illegible]			
6	RED CAN	13.7 m 1⅛" CHAIN 1300 lb WT	279°15', 4964 PUKETUTU I. LT.	691 630	291 869	[illegible]			
7	BLACK CONICAL, BIRDSPIKE	20.1 m 1⅛" CHAIN 1300 lb WT	120°15', 614 TAUMATAREA B"	688 416	288 892	[illegible]			
8	RED CAN	13.7 m 1" CHAIN ½ TON WT	281°30', 3960 PUKETUTU I. LT.	691 621	292 888	[illegible]			
9	BLACK CONICAL, BIRDSPIKE	18.3 m 1" CHAIN 1300 lb WT	057°15', 2363 TAUMATAREA B"	690 004	290 349	28 6 82			
10	RED CAN	13.7 m 1⅛" CHAIN 1300 lb WT	285°45', 3532 PUKETUTU I. LT.	691 790	293 369	21 8 82			
11	BLACK CONICAL, BIRDSPIKE	21.9 m 1" CHAIN 1300 lb WT	050°, 3895 TAUMATAREA B"	691 229	291 345	[illegible]			
12	RED CAN	13.7 m 1" CHAIN 1300 lb WT	293°, 3294 PUKETUTU I. LT.	692 119	293 736	28 6 82			
13	BLACK CONICAL, CONICAL SURMOUNT	13.7 m 1" CHAIN 1300 lb WT	278°, 4936 "	691 518	291 880	[illegible]			
14	RED CAN	13.7 m 1" CHAIN ½ TON WT	303°15', 3145 "	692 556	294 138	[illegible]			
15	BLACK CONICAL BIRD SPIKE	16.5 m 1⅛" CHAIN 1300 lb WT	279°45', 4165 "	691 537	292 663	[illegible]			
16	RED CAN	13.7 m 1⅛" CHAIN ½ TON WT	323°, 2860 "	693 116	295 047	21 8 82			
17	BLACK CONICAL, CONICAL SURMOUNT	13.7 m 1⅛" CHAIN 15 CWT WT	281°15', 3640 "	691 542	293 198	4 11 80			
18	RED CAN	15.2 m 1" CHAIN ½ TON WT	358°15', 2219 "	693 050	296 701	[illegible]			
19	BLACK CONICAL BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	298°, 3040 "	692 259	294 084	[illegible]			
20	RED CAN	13.7 m 1" CHAIN ½ TON WT	267°, 2016 F.R. ONEHUNGA WHARF	693 780	299 600	16 6 80			
21	BLACK CONICAL BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	309°30', 2950 PUKETUTU I. LT.	692 708	294 492	9 2 79			
22	RED CAN	13.7 m 1⅛" CHAIN ½ TON WT	271°15', 1483 F.R. ONEHUNGA WHARF	693 918	300 130	24 2 79			
23	BLACK CONICAL, CONICAL SURMOUNT	13.7 m 1" CHAIN 15 CWT WT	322°, 2779 PUKETUTU I. LT.	693 022	295 057	9 2 79			
24	RED CAN	13.7 m 1" CHAIN ½ TON WT	263°, 671 F.R. ONEHUNGA WHARF	693 804	300 947	2 12 79			
25	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	342°45', 2214 PUKETUTU I. LT.	692 946	296 112	17 11 79			
26	RED CAN	13.7 m 1" CHAIN ½ TON WT	252°, 382 F.R. ONEHUNGA WHARF	693 768	301 250	4 11 80			
27	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	358°, 2038 PUKETUTU I. LT.	692 868	296 697	17 11 79			
29	BLACK CONICAL, BIRDSPIKE	18.8 m 1" CHAIN 1300 lb WT	012°, 2534 "	693 310	297 295	17 11 79			
31	BLACK CONICAL, BIRDSPIKE	12.8 m 1" CHAIN 1300 lb WT	029°, 3130 "	690 984	296 853	9 6 80			
33	BLACK CONICAL, BIRDSPIKE	12.8 m 1" CHAIN 1300 lb WT	264°, 2560 F.R. ONEHUNGA WHARF	693 618	299 067	9 6 80			
35	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	264°45', 2007 "	693 702	299 615	28 6 82			
37	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	265°45', 1778 "	693 754	299 840	24 7 82			
39	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	267°30', 1516 "	693 820	300 099	24 7 82			
41	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	268°, 1183 "	693 844	300 431	22 9 80			
43	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	263°30', 956 "	693 777	300 663	22 9 80			
45	BLACK CONICAL, BIRDSPIKE	13.7 m 1" CHAIN 1300 lb WT	258°30', 758 "	693 735	300 870	22 9 80			

PURAKAU (SOUTH) CHANNEL, SPOIL GROUND and TEMPORARY BUOYS.

No	DESCRIPTION	MOORINGS	BEARING & DIST FROM REFERENCE POINT	COORDINATES N	COORDINATES E	CHANGE DUE	OVERDUE	REMARKS	No
1	DOUBLE ENDED STEEL CONICAL BUOY, BALL SURMOUNT.	22.9 m 1" CHAIN 1300 lb WT	110°, 4388 TAUMATAREA B"	687 225	292 485	23 4 79			
2	RED WOODEN BARREL	12.2 m 1" CHAIN 700 lb WT	229°, 2070 PUKETUTU I. LT.	690 756	296 682	23 4 79			
4	RED WOODEN BARREL	13.7 m 1" CHAIN 700 lb WT	001° 630 "	690 867	296 769	3 5 79			
5	SPOIL GROUND BUOY YELLOW & BLACK		267°15', 622 PUKETUTU I. LT.	690 806	296 145				
6	SPOIL GROUND BUOY YELLOW & BLACK		233°30', 1169 "	690 143	295 827				
7	TEMP CHANNEL MARKER RED CAN		005°, 1665 "	692 490	296 913				
8	TEMP CHANNEL MARKER RED CAN		007°, 1128 "	691 951	296 906				
46	SWATCHWAY BUOY RED & WHITE SPHERICAL	13.7 m 1⅛" CHAIN 1300 lb WT	151°45', 5415 TAUMATAREA B"	683 912	290 948	[illegible]			
47	HUIA BANK BUOY RED BARREL	27.4 m 1⅛" CHAIN 1300 lb WT	234°30', 970 PUPONGA PT. McLACHLAN MEM.	684 037	285 206	[illegible]			

MANUKAU HARBOUR BUOYAGE

DESIGNED		DRAWN		DRAWING	SHEET
CHECKED		PASSED		H MISC 4	
APPROVED		REVISION			

NORTHEAST MANUKAU HARBOUR :

SITE: Mangere Bridge Release

TIDE: SPRING EBB 4·3M. RANGE 28-3-79 DROGUE DEPTH: 2·0m

METHOD OF OBS' DROGUE BUOY OBSERVER: M.J.M. WATER & SOIL

TIME	GRID REFERENCE		VELOCITIES m/sec.		
	LONGITUDE	LATITUDE	OBS'	EST'D SPRING	EST'D NEAP
1049	174° 47' 09"	36° 56' 10"			
1115	174° 47' 03"	36° 56' 08"	0·10	0·08	0·05
1145	174° 46' 44"	36° 56' 07"	0·26	0·21	0·10
1152	174° 46' 29"	36° 56' 09"	0·92	0·74	0·42
1200	174° 46' 23"	36° 56' 10"	0·32	0·26	0·15
1230	174° 45' 54"	36° 56' 10"	0·41	0·33	0·19
1251	174° 45' 26"	36° 56' 15"	0·58	0·46	0·27
1300	174° 45' 14"	36° 56' 15"	0·50	0·40	0·23
1306	174° 44' 57"	36° 56' 16"	1·20	0·96	0·55
RERELEASED 1308	174° 44' 55"	36° 56' 09"			
1319	174° 44' 36"	36° 56' 10"	1·03	0·82	0·47
1330	174° 44' 16"	36° 56' 14"	0·75	0·60	0·35
1343	174° 43' 57"	36° 56' 23"	0·70	0·56	0·32
1353	174° 43' 38"	36° 56' 34"	1·01	0·81	0·46
1403	174° 43' 14"	36° 56' 33"	0·97	0·78	0·45
1427	174° 42' 32"	36° 56' 30"	0·73	0·58	0·34
1441	174° 42' 09"	36° 56' 39"	0·75	0·60	0·35
1449	174° 41' 56"	36° 56' 49"	0·92	0·74	0·42
1500	174° 41' 40"	36° 57' 03"	0·87	0·70	0·40
1517	174° 41' 19"	36° 57' 19"	0·71	0·57	0·33
1534	174° 40' 54"	36° 57' 23"	0·60	0·48	0·28
1540	174° 40' 44"	36° 57' 24"	0·68	0·54	0·31
1601	174° 40' 22"	36° 57' 19"	0·47	0·38	0·22
1633	174° 39' 57"	36° 57' 29"	0·36	0·29	0·17
1700	174° 39' 38"	36° 57' 45"	0·35	0·28	0·16

APPENDIX IV Drogue buoy data

SITE: NORTHEAST MA'IKAU HARBOUR: White Bluff Release

TIDE: EBB SPRING 4.3 m RANGE 28-3-79 DROGUE DEPTH: 2.0 m

METHOD OF OBS' DROGUE BUOY OBSERVER: LSR WATER & SOIL

TIME	GRID REFERENCE		VELOCITIES m/sec.		
	LONGITUDE	LATITUDE	OBS'	EST'D SPRING	EST'D NEAP
1048	174° 44' 44"	36° 59' 03"			
1105	174° 44' 51"	36° 56' 13"	0.18	0.14	0.08
1135	174° 44' 49"	36° 56' 15"	0.05	0.04	0.02
1205	174° 44' 29"	36° 56' 20"	0.29	0.23	0.13
1213	174° 44' 15"	36° 56' 18"	0.76	0.61	0.35
1227	174° 44' 03"	36° 56' 25"	0.44	0.35	0.20
1235	174° 43' 53"	36° 56' 29"	0.55	0.44	0.25
1246	174° 43' 38"	36° 56' 37"	0.68	0.54	0.31
1310	174° 43' 07"	36° 56' 33"	0.33	0.26	0.15
1319	174° 42' 45"	36° 56' 35"	1.05	0.84	0.48
REFRELEASED 1323	174° 42' 45"	36° 56' 29"			
1333	174° 42' 32"	36° 56' 31"	0.55	0.44	0.25
1356	174° 41' 55"	36° 56' 48"	0.76	0.61	0.35
1406	174° 41' 45"	36° 57' 02"	1.02	0.82	0.47
1413	174° 41' 25"	36° 57' 13"	1.11	0.89	0.51
1424	174° 41' 03"	36° 57' 19"	0.87	0.70	0.40
1443	174° 40' 23"	36° 57' 21"	0.89	0.71	0.41
1455	174° 40' 01"	36° 57' 32"	0.87	0.70	0.40
1527	174° 39' 22"	36° 58' 10"	0.80	0.64	0.37
1544	174° 38' 55"	36° 58' 26"	0.80	0.64	0.37
1549	174° 38' 53"	36° 58' 31"	0.55	0.44	0.25
1621	174° 38' 23"	36° 58' 51"	0.51	0.41	0.23
1633	174° 38' 16"	36° 58' 58"	0.36	0.29	0.17
1646	174° 38' 09"	36° 59' 03"	0.29	0.23	0.13
1655	174° 38' 08"	36° 59' 04"	0.15	0.12	0.07
1705	174° 38' 06"	36° 59' 05"	0.05	0.04	0.02

NORTHEAST MANUKAU HARBOUR :

SITE: Mangere Inlet Release

TIDE: EBB SPRING 4.3m RANGE 28-3-79 DROGUE DEPTH: 2.0m

METHOD OF OBS' DROGUE BUOY OBSERVER: BIORESEARCHES.

TIME	GRID REFERENCE		VELOCITIES m/sec.		
	LONGITUDE	LATITUDE	OBS'	EST'D SPRING	EST'D NEAP
1045	174° 48' 39"	36° 56' 08"			
1115	174° 48' 42"	36° 56' 08"	0.03	0.02	0.01
1145	174° 48' 36"	36° 56' 08"	0.09	0.07	0.04
1215	174° 48' 20"	36° 56' 07"	0.19	0.15	0.09
1245	174° 47' 57'	36° 56' 05"	0.33	0.26	0.15
1315	174° 47' 12"	36° 56' 08"	0.60	0.48	0.28
1317	174° 47' 10"	36° 56' 08"	1.04	0.84	0.48
1345	174° 46' 15"	36° 56' 09"	0.67	0.54	0.31
1415	174° 45' 23"	36° 56' 13"	0.72	0.58	0.33
1445	174° 44' 09"	36° 56' 21"	1.02	0.82	0.47
RERELEASED 1522	174° 42' 07"	36° 56' 41"			
1545	174° 41' 42"	36° 57' 02"	0.64	0.51	0.29
1615	174° 41' 47"	36° 57' 14"	0.30	0.24	0.14
1645	174° 41' 12"	36° 57' 20"	0.23	0.18	0.11
1715	174° 41' 09"	36° 57' 21"	0.05	0.04	0.02

NORTHEAST MANUKAU HARBOUR :

SITE: Cape Horn Release

TIDE: NEAP FLOOD 1·8 m RANGE 4-5-79 DROGUE DEPTH: 2·0 m

METHOD OF OBS' DROGUE BUOY OBSERVER: MJM. WATER & SOIL

TIME	GRID REFERENCE		VELOCITIES m/sec.		
	LONGITUDE	LATITUDE	OBS'	EST'D SPRING	EST'D NEAP
0945	174° 44' 03"	36° 56' 26"			
1000	174° 44' 05"	36° 56' 25"	0·06	0·11	0·07
1015	174° 44' 10"	36° 56' 23"	0·16	0·30	0·18
1045	174° 44' 30"	36° 56' 20"	0·27	0·51	0·30
1106	174° 44' 44"	36° 56' 16"	0·30	0·57	0·33
RERELEASE 1109	174° 44' 42"	36° 56' 13"			
1135	174° 45' 13"	36° 56' 11"	0·48	0·91	0·53
1201	174° 45' 41"	36° 56' 10"	0·36	0·68	0·40
1222	174° 45' 56"	36° 56' 05"	0·43	0·82	0·47
1248	174° 46' 24"	36° 56' 04"	0·44	0·84	0·48
RERELEASED 1251	174° 46' 30"	36° 56' 08"			
1315	174° 46' 43"	36° 56' 10"	0·22	0·42	0·24
1348	174° 47' 09"	36° 56' 11"	0·34	0·65	0·37
1354	174° 47' 19"	36° 56' 09"	0·63	1·20	0·69
1425	174° 47' 41"	36° 56' 16"	0·31	0·59	0·34
1452	174° 47' 51"	36° 56' 19"	0·17	0·32	0·19
1508	174° 47' 52"	36° 56' 24"	0·16	0·30	0·18
1533	174° 48' 02"	36° 56' 27"	0·15	0·29	0·17
1600	174° 48' 03"	36° 56' 28"	0·03	0·06	0·03

NORTHEAST MÀNUKAU HARBOUR:

SITE: Mangere Bridge Release

TIDE: NEAP FLOOD 1·8m RANGE 4·5·79 | DROGUE DEPTH: 2·0 m.

METHOD OF OBS' DROGUE BUOY | OBSERVER: BIORESEARCHES

TIME	GRID REFERENCE		VELOCITIES m/sec.		
	LONGITUDE	LATITUDE	OBS'	EST'D SPRING	EST'D NEAP
1300	174° 47' 12"	36° 56' 06"			
1308	174° 47' 17"	36° 56' 07"	0·29	0·55	0·32
1333	174° 47' 33"	36° 56' 06"	0·25	0·48	0·28
1400	174° 47' 57"	36° 56' 08"	0·38	0·72	0·42
1430	174° 48' 14"	36° 56' 07"	0·22	0·42	0·24
1500	174° 48' 27"	36° 56' 07"	0·18	0·34	0·20
1530	174° 48' 34"	36° 56' 06"	0·10	0·19	0·11
1545	174° 48' 36"	36° 56' 06"	0·04	0·08	0·04