NEARSHORE BEDLOAD AND SUSPENDED SEDIMENT TRANSPORT IN THE VICINITY OF THE PICKERING NUCLEAR GENERATION STATION, LAKE ONTARIO

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NWRI Contribution No. 89-17

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May 1989

MANAGEMENT PERSPECTIVE AND EXECUTIVE SUMMARY

This report was prepared at the request of the Geotechnical and Hydraulic Engineering Department of Ontario Hydro to assist Hydro in decisions regarding developments to its cooling water intake system, including possible re-location. The report addresses the question as to the amounts of sediments being transported, and the location of the most sediment-active zones. The conclusions are based on almost two years of field data collected by Hydro. This collaborative project illustrates the practical application of sediment investigation to such commercial enterprises located in the coastal zone.

The main conclusions are summarized below.

1. Sources of sediment:

   There are three important sources of sediment in the area:
   - Erosion of shoreline deposits consisting of glacial materials;
   - Subaqueous erosion of the glacial deposits exposed on the lake bottom in the nearshore zone;
   - Sediment discharge from rivers and creeks.

2. Estimates of total sediment flux:

   Bedload (including near-bed suspended load)
   Littoral zone - 1300 tonnes/yr
   Nearshore zone - 6 kg/cm/yr to 83 kg/cm/yr

   Fine suspended sediment
   Inside the intake channel - 10,000 tonnes/yr
   At the intake pumps - 18,000 tonnes/yr

3. Sediment entrainment:

   The present cooling-water-intake structure entrains approximately 108 tonnes/yr of bedload and 18,000 tonnes/yr of fine NVSS suspended load (i.e. a ratio of approximately 1:200). The intake draws bedload sediment mainly from the littoral zone (depth < 5 m), while suspended load comes from a zone which extends up to a kilometer or so offshore. The fine suspended fraction probably represents a minimum, or fair-weather value, as the storm-related data are absent from the data set. This is an important shortcoming in the study as sediment volumes entrained in either case would be strongly influenced by storm-wave resuspension and transport events, and so would be highest during the winter months.

4. Relatively sediment-free zone

The location of a relatively sediment-free zone is chosen to coincide with a minimum in the bedload flux and NVSS suspended loads, which are strongly depth-dependent. With the exception of the winter months, the offshore area (depths more than 10 m) is relatively free of strong bedload flux.

5. Depth limits to sediment transport

The particle sizes caught within the bedload traps varied considerably with both depth and time, although median diameter (D_{50}) values were usually between 0.1 and 0.5 mm. Maximum sizes reached as high as 76 mm. The measured average currents were too small to serve as the transporting agents of these large materials. The results showed that transport of bedload materials, especially in the deeper sites occurs only during storms when waves of periods greater than 6 s and significant heights of 2 m or more are active.

PERSPECTIVE - GESTION ET RÉSUMÉ

Ce rapport a été préparé à la demande du ministère de Géotechnique et de Génie hydraulique de l'Hydro Ontario afin d'éclairer les choix de cette société qui doit adopter des mesures touchant à son réseau d'alimentation en eau de refroidissement, notamment son déplacement. Le rapport porte sur les quantités de sédiments transportés et l'emplacement des zones les plus actives sur le plan sédimentaire. Les conclusions sont fondées sur l'étude de données recueillies sur le terrain pendant près de deux ans par la Société. Cette étude conjointe est la démonstration de l'application pratique de l'étude des sédiments à des entreprises commerciales situées en zone côtière.

Un aperçu des grandes conclusions est donné ci-dessous.

1. Sources de sédiments :

   Il y a trois sources importantes de sédiments dans la région :

- L'érosion des formations glaciaires en zone côtière;
- L'érosion subaquatique des formations glaciaires exposées au fond du lac près du rivage;
- Le débit sédimentaire des rivières et des ruisseaux.

2. Estimation du flux total des sédiments :

Charriage (y compris la charge en suspension près du fond)

Zone de rivage - 6 kg/cm/an à 83 kg/cm/an

Zone côtière - 1300 tonnes/an

Sédiments en suspension fine

À l'intérieur du canal d'amenée d'eau - 10 000 tonnes/an

Aux pompes de prise d'eau - 18 000 tonnes/an

3. Entraînement des sédiments

La structure d'alimentation en eau de refroidissement qui est présentement en place entraîne environ 108 tonnes/an de matériel de charriage et 18 000 tonnes/an de particules en suspension fine (NVSS), c.-à-d. un rapport d'environ 1:200. Le matériel de charriage provient principalement de la zone de rivage (profondeur inférieure à 5 m) tandis que la charge en suspension provient d'une zone qui peut s'étendre jusqu'à 1 km au large environ. La fraction en suspension fine correspond probablement à un minimum ou à une valeur par beau temps car l'ensemble des données à l'origine de l'étude ne contient aucune donnée obtenue pendant des tempêtes. Il s'agit là d'une lacune importante de l'étude puisque les volumes de sédiments entraînés dans un cas ou l'autre seraient fortement influencés par la resuspension et le transport provoqué par les ondes de tempête. Il y aurait donc davantage de sédiments durant les mois d'hiver.

4. Zone relativement libre de sédiments

Une zone relativement libre de sédiments est choisie de façon à ce qu'elle apporte un minimum de charriage et de charge en matières en suspension (NVSS), qui sont en étroite relation avec la profondeur. À l'exception des mois d'hiver, le charriage est relativement peu important au large (profondeur supérieure à 10 m).

5. Limites de profondeur au transport des sédiments

Dans les pièges pour les matériaux du lit, la granulométrie des particules captées variait considérablement selon la profondeur et le temps, bien que le diamètre médian (D_{50}) se soit habituellement tenu entre 0,1 et 0,5 mm. Au maximum, ce diamètre a atteint 76 mm. Les courants moyens mesurés n'étaient pas assez forts pour transporter ces grosses particules. Les résultats ont montré que le transport des matériaux du lit, notamment aux emplacements les plus profonds, se produit seulement durant les tempêtes alors qu'il y a des zones ayant une période supérieure à 6 s et une hauteur significative supérieure à 2 m et plus.

1.0 INTRODUCTION

Ontario Hydro has contracted the Lakes Research Branch of the National Water Research Institute (NWRI) to analyse and interpret the data of a Hydro study on sediment transport in Lake Ontario offshore from the site of the Pickering Plant (Appendix 1, Fig. 1). Study objectives are to estimate the supply of sediment to the current intake and to determine the feasibility of an alternative intake in deeper water. This note is the NWRI contribution to the final report of that study and is based on the analysis of data collected during the period March 1987 to March 1988. It includes a description of the lakebed geology and current and wave climate, and provides the required estimates of sediment entrainment at the current intake and potential entrainment offshore in the area designated for an alternative intake.

2.0 LAKEBED GEOLOGY

Side-scan sonar and diver surveys show the lakebed of the survey area to be a complex of glacial sediment, coarse lag deposits, unconsolidated lake sediments, dredge spoil, and bedrock (Fig. 2). Maps based on the five sonar surveys and two sets of diver observations agree in general on the basic pattern of bottom types but differ in detail. Although some of the inconsistency in the sonar data may be related to problems of record quality and differences in interpretation, it seems unlikely that sonar maps alone will be able to provide more than a broad-brush characterization of bottom materials even under the best of conditions. In many cases this may be sufficient, but where finer resolution is required, supplemental data from diver or underwater television surveys and bottom samples will be needed to calibrate the records and resolve the ambiguities.

The following description of bottom materials is a synthesis of the recent side-scan sonar and diver data and the results of an earlier survey of the area based on echo-sounding and grab samples (Rukavina 1969, 1980). Till and glacial-lake sediment with a thin and patchy veneer of sand- to boulder-sized lag sediment are the major bottom type. They occur through most of the eastern two-thirds of the survey area with the exception of a small bedrock exposure and thin sediment cover east and southeast of the Pickering B outfall. A large deposit of unconsolidated lake sands and silts covers the western end of the area opposite Frenchman's Bay. Sediment thickness here varies from 6 m inshore to 1.25 m offshore and the deposit likely represents littoral drift accumulated in a drowned stream valley cut through the underlying glacial sediment or bedrock. Exposed manner can be made from data available for the north shore of Lake Erie (Rukavina and Zeman, 1987) where the nearshore supply is estimated to be about 15 percent of that produced by bluff erosion. Because the Lake Erie reach is an area of higher bluffs and erosion rates than the Pickering shoreline, it is likely that local nearshore erosion will account for more than 15 percent of the local bluff supply. Another factor which should increase the nearshore contribution locally is the presence of unconsolidated sediments offshore from Frenchman's Bay which should erode more rapidly than the cohesive glacial sediments.

Stream-discharge data for the study area are available in Ongley (1973). Streams which may contribute to the local sediment budget include Duffin Creek and the Rouge River. Mean suspended-sediment discharge for the period 1965-1970 is 3487 tons (3163 tonnes)/yr for Duffin Creek and 4374 tons (3968 tonnes)/yr for the Rouge River. The total of approximately 7000 tonnes/yr is probably an overestimate of the local supply because of the possibility of discharge to the east by Duffin Creek and to the west by the Rouge River. This material is likely all fine-grained sediment (i.e. silt and clay), as Ongley does not consider the bedload fraction to be significant and presents no bedload data.

In summary, the data on sediment supply are fragmentary and insufficient to determine the sediment budget for the area. Local sources are estimated at 9,000 m^3/yr (15,000 tonnes/yr) from bluff erosion, at least 1,350 m^3/yr (2,300 tonnes/yr) from nearshore slope erosion and a maximum of about 7000 tonnes from stream discharge. No estimate is available for the supply from adjacent reaches.

4.0 BEDLOAD TRANSPORT

Two approaches were used to estimate the amount of bedload transport derived from the sources discussed above: 1) side-scan sonar surveys and 2) bedload traps.

The side-scan sonar approach was to track the movement of mobile sediments on the till surface as revealed by spatial changes in their depositional patterns on the records from successive surveys. This more broadly-based qualitative data would then be used as a supplement to the point data of the bedload traps. Unfortunately this approach proved not to be feasible for a number of reasons: poor record quality in the early surveys, poor horizontal and vertical control because the records were not corrected for slant-range distortion or differences in the position of survey lines, and gradational rather than sharp contacts. Improvements in this approach would require bottom references visible on the record to serve as a basis of comparison and tape recording of the raw sonar data followed by record enhancement to produce undistorted maps.

Direct measurements of bedload movement were made with bedload traps located at 14 sites, 10 in the lake and 4 within the intake channel (Fig. 1). Open-lake sites each had an array of 4 traps facing north, south, east and west to intercept sediment movement from these directions; intake trap arrays consisted of 3 to 5 traps all facing the incoming flow. It should be noted that the traps were not calibrated and that the results could underestimate the true transport by as much as a factor of 2, assuming a trap efficiency of 50% (P. Engel, 1987, pers. comm.). Another factor biasing the trap data occurs when the trap capacity is exceeded before recovery. This has occurred in several instances, particularly in the inshore traps. In these cases, the data have been used as is with no adjustment for the fact that they underestimate the true values.

For the open-lake sites, the weight of sediment accumulated in each trap was converted to a sediment flux in g/cm/day or kg/cm/yr. In this section and that on sediment-tube trap data, "flux" refers to mass per unit time per unit width of trap, as the trap opening has a constant area. The flux value was then summed for the four traps to determine the total flux of sediment passing the site (Appendix 3). Because the most complete data set was available along line 9-13 (sites 9,10,11,13), flux calculations along this line were used as being representative of the area at large. Appendix 4 shows the procedure used to compute fluxes. Yearly values were obtained by extending the data for each survey period halfway to the adjacent periods. The expanded periods derived in this manner were used to compute a total flux for the period and then a total annual flux for each site. The total annual flux is expressed in kg/cm/yr and represents the annual quantity of sediment bypassing the site in any direction per unit length of Line 9 - 13. Appendix 4 and Figure 3 show that flux is inversely proportional to water depth and distance from the shoreline and that it is seasonally dependent. The highest values occurred during December and were presumably related to the major winter storms noted in the meteorological records. Unlike the balance of the year when flux dropped off quickly with increasing depth, the December values were high throughout the zone and as much as 100 times higher than general at the deep-water sites. Total annual flux ranged from 40.4 kg/cm/yr inshore to 3.8 kg/cm/yr offshore.

The bedload component of littoral-sediment flux was estimated from the alongshore (east-west) trap data from the shallowest-water sites 9 and 24; site 22 was not included because its trap array was inclined to the shoreline and could not provide a clear alongshore component. Appendix 5 shows the procedure used to compute the total flux. The resultant values were then expanded by prorating the survey periods to yield an annual flux and by assuming that this flux applied to a 200-m wide littoral zone, the average width of the sand deposit mapped in the 1968 survey (Rukavina, 1969). The result was a total annual bedload flux of 637 tonnes. This figure is an estimate of the bedload sediment available for entrainment by the intake channel assuming minimal offshore - onshore sediment inputs. It includes no adjustments for trap efficiency or for cases in which trap capacity was exceeded. The data show the same seasonal dependence noted above. December-January fluxes are 2 to 3 higher than values for the balance of the year.

Fluxes within the intake channel were first averaged for each cross-section and then the total flux for the cross-section was computed as the product of the flux/cm and the active channel width. Total flux/year was then determined by prorating the survey periods as above. Appendix 6 shows the computations. Full sets of data are available only for sections 17 and 19 in the combined channel and B channel respectively. The results are anomalous in that the combined-channel fluxes are smaller than those for the B channel by a factor of about 3. Supplementary data were collected for February-March at sections 17B and 19B north and west of 17 and 19 to test for consistency, and results were again anomalous; fluxes were higher at 17B than 17 and lower at 19B than 19. The variable rates may reflect changes in the position within the channels at which sediment transport is concentrated, changes which may be related to changes in intake velocity or to changing wave and longshore-current directions. It is also possible that the high values at section 19 are the result of increased supply from erosion of channel sediment deposited during the start-up of Pickering B which would not be included in the flux at section 17. Given the uncertainly of the significance of the data, the best estimate of bedload intake flux is considered to be the average of values for sections 17 and 19, 108 tonnes/yr.

Grain-size data are available for a sub-set of the open-lake and intake samples. Appendix 7 is a listing of median size (D_{50}); Appendix 8 lists the maximum size. Median size ranged from 0.1 to 7 mm for the open-lake samples and 0.08 to 0.43 mm for intake samples; average values were 0.31 mm and 0.21 mm respectively. Maximum size ranged from 0.9 to 37.5 mm for the open-lake samples and 0.9 to 25 mm for the intake samples; average values were 8.4 mm and 6.3 mm. In general, the size distribution showed little variation with trap orientation or position. Open-lake samples showed the same seasonal effect noted for flux rates, i.e., sediments were generally coarser during the December-January storm season. Open-lake data also showed the influence of the geology of the substrate. Samples collected in the area of glacial or lag sediments were coarser than those from the inshore littoral deposit or the unconsolidated sediment deposit offshore from Frenchman's Bay.

5.0 SUSPENDED SEDIMENT DATA

An important distinction must be made in evaluating the estimates of sediment flux contained in this report. The suspended sediment fraction is divided into two components. One is the sand-sized suspended material which was sampled in the sediment tubes. This component is transported within a metre or so of the bed and therefore is included with the bedload material in later estimates of the total sediment flux close to the bed (Section 7.1 and 7.2).

The other component is the very fine suspended load (NVSS) sampled in the Van Dorn and cooling-water intake samplers. This fraction is fine enough to remain in fairly uniform suspension throughout the water column within the study area, and is entrained along with the large volumes of lake water drawn in by the plant.

5.1 Sediment-tube data

Suspended sediment tubes (2" or 5 cm in diameter and 2' or 61 cm in height) were installed on the bottom at a number of stations (Fig. 2). The tubes were emptied at intervals ranging up to 104 days, and provided a means of estimating the amount of sediment being transported in the water column above the 61 cm elevation. The raw weights of sediment collected in the tubes were reduced to provide a time-averaged value of the sediment flux (grammes per day per cm width of tube) (Appendix 9). Note that the tubes were not calibrated, so these values could differ from the true suspended sediment values, depending on trap efficiency.

The values show the expected trend, with highest values inshore and decreasing offshore. Using the shore-normal transect (Stn.9 - Stn.13) as an example, we note a ten-fold higher sediment trapping rate at Stn.9 (water depth - 3 m) than at the more offshore stations. Furthermore, with the exception of Stn. 9, there is a marked seasonal bias, with highest values noted in the Fall - Winter seasons. This probably reflects the higher intensities of wave agitation and sediment resuspension at those times.

The sediment tube data suffer from some serious shortcomings in providing an accurate estimate of the total sediment flux in an area. First, they are intended to measure vertical, not horizontal, flux, and thus cannot readily be related to longshore sediment drift. Also, each data value is integrated over a considerable length of time (in this case 64 - 104 days), and so cannot be matched with a specific time period or process event. Lastly, they give no information on the material being carried in suspension below the 61 cm elevation and above the level of the 10 cm high bedload traps.

We have attempted to address the latter deficiency, however, by combining the sediment tube data with the bedload trap data to provide a first-order estimate of the total sediment flux close to the bottom. To do this, one must first consider the tubes as traps for sediments moving laterally as well as downward above the 10 cm elevation, thus making the data compatible with those from the bedload traps. All that would then be required would be a means of covering the gap (+10 to +61 cm) related to sediments being transported between the two "traps".

One approach, shown schematically in Figure 4, consists of using the total bedload flux figure obtained above, and an analogous value obtained from the sediment tube data, as two points (SS_0, SS_1) defining an exponential curve. The exponential curve of the form :

$$SS_i = SS_o \exp^{-A(z \ \ -z \ \ )}$$

is similar to that used to define the vertical sediment concentration gradient above the bed (Vanoni, 1946). The variables (z_0 and z_1) are, respectively, the heights above the bed of the reference point SS_0 and any other point that is to be calculated on the curve. (A) is a coefficient of proportionality. Having calculated a value for (A) based on the two points, intermediate values can then be calculated at intervals of 10 cm (the height of the bedload trap opening). In other words, we assume these calculated intermediate values would correspond to values obtained if a series of 5 bedload traps were stacked up to the level of the sediment tube opening. The total flux is thus the sum of all the "traps". The bedload trap values (i.e elevation < 10 cm) is not included in this near-bed suspended sediment estimate but can later be added to complete the estimate of the total amount of sediment in motion. The approach gives, at best, a first-order estimate, but it is clearly more realistic than one based only on the two point values.

The calculated flux of suspended sediments carried close to the bed in all directions for Line 9 - 13 is presented in Appendix 9. The values range from 42.1 kg/cm/yr at Stn.9, to 2.1 kg/cm/yr at Stn.13.

Averaged median grain size for the sediment tube samples (Appendix 9) ranged from 0.1 to 0.3 mm, i.e. almost identical to that of the bedload samples at the same sites. This further supports the combining of these data into one flux value.

5.2 Van Dorn data

The Van Dorn sample bottles were used to take an instantaneous suspended sediment sample from several elevations in the water column (surface, mid-depth, and bottom). The samples were analyzed for suspended sediment concentration (mg/L or g/m^3) both in terms of total suspended solids (TSS) and non-volatile suspended sediments (NVSS). The latter consists of the inorganic or mineral fraction, which assumes considerable importance for its ability to scour, and to be deposited in and block, cooling water tubing networks. The TSS figure combines the NVSS with the organic fraction. The organic fraction is easily retained in suspension and, being less abrasive, is expected to flow through the cooling water network with little effect.

The fact that the Van Dorn bottles provide only one instantaneous sample of a highly time-dependent variable is somewhat of a disadvantage, as this makes them highly dependent on conditions at the time of the survey. In addition, the surveys are usually carried out during fairly calm weather, so the Van Dorn data would most likely be an underestimation of the actual suspended sediment flux, since a large portion of such flux is generated during stormy periods. Nevertheless they can be taken as good indicators of baseline, i.e. non-storm conditions, and may thus be useful in putting a minimum estimate on total suspended sediment loads at the sampling stations.

The Van Dorn sample data are summarized in Appendix 10 for the various survey times, corresponding roughly to Spring, Summer, Fall, and Winter. The NVSS values are also shown as depth-averages, calculated by first weighting each value according to the distance to the adjacent sample elevation in the water column. The table takes as examples only those sampling stations along the shore-normal transects (Stn.9 - Stn.13, and Stn.4 - Stn.8).

During the Summer months, average TSS and turbidity values in the open lake were very low (in fact, close to OME standards for drinking water, NTS = 1). Slightly higher values were noted in the August data, reflecting higher biologic productivity at that time of the year. NVSS values were also very low, and when combined with the measured currents, resulted in very low net NVSS fluxes.

The low, uniform level of suspended sediment in the Summer months is in contrast with the obvious high-turbidity events captured in the April aerial photographs of the area. The August suspended sediment survey was carried out the day after a heavy rainfall event (Aug. 9) and the results of this survey are appreciably higher (especially in the inshore stations) than those for March and April. It therefore appears that suspended sediment levels in the inshore areas close to the plant might be related to water depth (wave-induced resuspension) and to occasional influxes of turbid stream discharges caused by heavier-than-normal rainstorms. The suspended sediment levels at the offshore sites are apparently not connected to this inshore flux, and the data do not indicate the probable source of the material found there.

The trends in the depth-averaged data are similar to those for the sediment tube samples, and show both an offshore-decreasing trend, as well as higher Fall - Winter values. No consistent depth-related trend was noted. The stations at the mouth of, and within, the intake jetties showed the highest suspended sediment values, averaging 1.85 g/m³, while stations in water depths of 12 m or more averaged 1.17 g/m³ NVSS.

In spite of the shortcomings in the Van Dorn sample data, they can provide an estimate of normal, i.e. non-storm levels of sediment entrainment into the plant intakes. During the study period, the number of units operating in the plant fluctuated from 4 to 7, with a time-weighted average of 5.7 units. If we assume that the plant units each draw approximately 30 m³/s of water (W. Burchat, 1988, pers. comm.), then the total intake volume is generally around 171 m³/s. If the water the plant draws in has a NVSS sediment concentration equal to the average of all the 6 stations in the channel (1.85 g/m³), then a rough estimate of total sediment entrainment at the plant is approximately 316 g/s, or 1140 kg/h, or 10,000 tonnes/yr.

Median grain sizes measured on these samples were uniformly very fine, i.e. less than 0.001 mm, with maximum diameters rarely exceeding 0.050 mm, in sharp contrast with the bedload and sediment tube samples.

5.3 Cooling-water intake data

Although the intake ports of each of the 8 cooling water intake units were sampled periodically for suspended and bedload sediment content, the design of the traps suggests that this sampling was not very efficient in trapping the sediment drawn in. One advantage of these data, nevertheless, is that the the sampling is not weather-dependent as is the case with the Van Dorn surveys, so it could includes stormy conditions (and high resuspension events) as well. Unfortunately, the data presented here are for times matching those for the Van Dorn surveys so they are also non-representative of the more high-energy storm conditions.

Appendix 11 shows summaries for suspended sediment based on samples from 7 of the 8 units, averaged over several different sampling times. The NVSS values are reasonably consistent, ranging between 2.3 and 5.4 g/m^3, though higher than the Van Dorn values by a factor of 2 to 3. Anomalously high turbidity values for units 5 and 6 could be related to local turbulence because of channel geometry. Like the Van Dorn data, these sediment concentration values can also provide a crude estimate of sediment entrainment at the intakes. Assuming a constant inflow of 30 m^3/s at each intake, the concentration values convert to total NVSS sediment entrainment quantities of 250 to 580 kg/h at each intake. Summing over the intake water volume drawn in by the average of 5.7 units, we obtain an entrainment value of approximately 2100 kg/h or 18,000 tonnes/yr. The 8000 tonnes/yr difference between this figure and that obtained from the Van Dorn data could be a reflection of the inherent inaccuracies in these two estimates. It is noteworthy that no bedload-sized material was collected in the intake pump samples, even though a bedload flux of 108 tonnes/yr was measured in traps inside the intake channel. The lack of bedload material in the pump samples could reflect either prior screening of the flow, or the very low concentrations even such a flux would cause in intake volumes of 171 m^3/s or 5 x 10^9 tonnes of water per year.

The median grain size of this material was, like the Van Dorn samples, consistently less than 0.005 mm, i.e. predominantly clay-sized, compared with the bedload in the channel, which averages around 0.21 mm. No particles coarser than 0.1 mm were recorded in the size analysis of the intake pump material.

6.0 CURRENTS

Currents were measured at 2 locations in a line trending offshore from the main intake channel, using both acoustic (Neil-Brown) current meters. The meters were deployed with their sensors approximately 35 cm above the bottom. The meters were all configured to record averages of up to 600 flow measurements taken at 0.5 s intervals. As a result, the more energetic oscillatory bottom currents related to wave action (see section below on Waves) were all averaged out, leaving only the net residual currents in the record. None of the meters was configured to record the maximum instantaneous current speed nor the sample variance.

The period over which currents were measured extended from July 16 1987, to March 31, 1988. As shown in the summary of the current data in Appendix 12, greater emphasis has been placed on the measurements taken close to the bottom, as these are more useful to estimations of resuspension and sediment transport. Depths of the two current meter moorings used were 21 m for CM53 and 8 m for CM41.

Bottom currents in the area varied considerably, primarily on a seasonal basis. Some spatial and depth-related variation was noted as well, but to a much lesser degree. Bearing in mind that the values shown in Appendix 12 are averages of currents that were probably oscillatory, it is not surprising that the maximum average values were relatively low, namely 19.4 cm/s or less, and average values were all less than 7 cm/s. Currents of this magnitude are capable of initiating movement of only the finer sediments, i.e. diameters far less than the 0.2 mm D_{50} noted in the littoral sediments. The highest values occurred during the late Fall and Winter months.

Flow directions measured at all sites also showed appreciable variation, apparently depending on wind direction. Strong directional modes were noted, however, in the bottom currents at both CM53 and CM41. In the former, which was representative of offshore conditions, the dominant direction modes were NE - ENE and SW - W. Because of the local shoreline orientation, these modes probably correspond to shore-parallel flows associated with lake-wide circulation patterns. At CM41, the inshore site, the strongest mode was toward the E - ESE, with a weaker mode in the reversed direction (WNW - NW). These modes appear to correspond to longshore currents associated with waves, but the secondary mode appears to be influenced by the proximity of the intake channel and the eastern discharge outfall.

7.0 WAVES

Deep-water waves were not measured at the site directly, but had to be hindcast from local winds using a process refined by Public Works Canada (Glodowski, 1988; Baird and Glodowski, 1978). A summary of these data is presented in Appendix 13. Deepwater waves hindcast from a 15-year wind record at the Pickering site (May, 1972 - December 1986) showed a maximum period (T) of 10 s, and 4 m significant wave height (H_s). Such large storm waves occur very infrequently, however (8 out of a total record of 117,000 hours). Wave frequencies for the hindcast covering the 13-month study period were essentially similar to the 15-yr data, although the maxima for height and period were lower : T_{max} and H_{max} were 9 s and 3.5 m, respectively. Using the

15-yr data, it was noted that the largest waves were from the east, the direction of greatest fetch, followed by southwest, the secondary fetch direction. Comparing the raw frequencies of waves from the east (westward wave drift) and west (eastward drift) sectors, we note that waves from the west sector hold a slight lead for both time-periods (36,000 h vs. 30,000 h and 2550 vs. 2000 h for the 13-month period). Waves from due south were included within the west sector. Although relative wave intensities were not compared, the figures suggest a slight net littoral drift toward the east, although the dominant drift pattern at the site probably involves back-and-forth sediment movement. Such an overall drift pattern is in agreement with a slight eastward bias noted in the current directions measured at CM53 and CM41, and with the results of a littoral drift study showing eastward drift beginning around Highland Creek, near Scarborough (Greenwood and McGillivray, 1978). However, it is at odds with long-term westerly drift patterns noted at shoreline structures in this area (Rukavina 1969; Brebner and Kennedy, 1959).

A preliminary assessment was made of potential for sediment transport by wave-induced bottom currents, using the long-term hindcast data. Procedures outlined in the Shore Protection Manual (CERC, 1984) were used to calculate the bottom orbital current speed required to initiate transport of sediments of a grain diameter equal to the median (D_{50}) and maximum (D_{max}) value of the sediments collected in the bedload traps. The computer program used required that the waves used in the calculations begin in deep water (>100 m), and then be shoaled and refracted in to the desired shallow-water depth.

Initiation of transport of materials on the bottom with (D_{50} = .2 mm) corresponded to speeds of approximately 15 cm/s. For instance, in 12 m of water (the depth of the Stn. 11 trap), all waves of period T_s = 5 s and height (H_s) = 0.75 m , or greater (i.e. approximately 5% of the time) could generate bottom currents capable of transporting particles of the above diameter. In 20 m of water, i.e. near Stn. 13, such sediment would be moved only by waves of 6 s and 2 m, or equivalent period / height combination (i.e. 0.6% of the time). For Stn. 9 in 3 m of water, corresponding T_s and H_s values were calculated at 4 s and 0.4 m (10% of the time).

Appendix 8 shows that the D_{max} particle size of material caught on the bedload traps could reach as high as 76 mm, or several orders of magnitude larger than the D_{50} value. Clasts of such size could be moved only by waves with T_s > 10 s and H_s > 4 m; such waves were extremely rare in the wave hindcast. At Stn. 13 in 20 m of water, clasts up to 19 mm were noted in the traps in the January survey, and calculations of the orbital currents necessary to mobilize such materials show that speeds > 90 cm/s were required, corresponding to waves of $T_s > 9$ s and $H_s > 4$ m.

This analysis of wave-related currents cannot indicate the direction of any induced transport. Wave-orbital currents move sediments only back and forth, with little net displacement. However, although the net currents discussed in a previous section were too small to initiate much sediment transport on their own, in combination with wave-induced motion, they are capable of advecting an appreciable amount of sediment in the net current direction. For example, at Stn.4 (site of CM41), bedload material could be transported mostly in a shoreward direction, with a minor offshore trend.

8.0 TOTAL SEDIMENT FLUX

8.1 Nearshore zone (0 - 20 m)

The bedload and near-bed suspended-load fluxes for line 9-13 have been combined in Table 2 and Figure 5 to produce a profile of total sediment flux for the nearshore zone. Total flux ranges from a high of 82.5 kg/cm/yr in the littoral zone to a low of 5.9 kg/cm/yr at the 20-m contour. For most of the year, the zone lakeward of the 8-m contour is a zone of low sediment flux. It should be noted, however, that this does not apply during the winter storm season when the flux distribution across the zone is more uniform and offshore rates can approach 50 to 75 percent of the inshore rates.

Table 2: TOTAL NEARSHORE FLUX, KG/CM/YR

STN.	DEPTH M	BEDLOAD	NEAR-BED SUSPENDED LOAD	COMBINED LOAD
9	3	40.4	42.1	82.5
10	8	12.0	8.3	20.3
11	12	5.1	3.2	8.3
13	20	3.8	2.1	5.9

8.2 Littoral zone (<5 m)

Total littoral flux of material transported on or near to the bed, based on data for stations 9 and 24 is 1300 tonnes/yr of which 637 tonnes is bedload and 663 tonnes is near-bed suspended load. This represents the quantity of coarse sediment available to the present cooling-water intake as the result of alongshore transport in a littoral zone 200-m wide. The only other estimate of littoral sediment transport rates for this reach of Lake Ontario is that by Brebner and Kennedy (1959). Using long-term dredging figures for Port Whitby they calculated an annual figure of 4865 yd^3, which corresponds to 1860 tonnes/yr (including fines and assuming a sediment density of 2000 kg/m^3). Fine suspended sediment flux in this zone is harder to quantify, as it is dependent on ambient flow velocities, the width of the cross-section used, and the sediment concentration.

8.3 Cooling-water intake

The sediment flux within the cooling-water intake channel includes sediment transported as bedload and suspended load. Bedload estimates are available from the trap data but it is difficult to account for the total suspended load. Van Dorn sampler data for the intake are biased because they represent only quiet-water conditions. Material sampled at the pump intakes did not contain sand-sized material, so it is likely that bedload was not sampled. Also, the efficiency of the pump intake samplers in sampling suspended load is not known. The best estimate available is a simple combination of bedload trap and pump rates recognizing that this is likely to be low because of the reasons given above. The total flux is 18,403 tonnes/yr of which 99% is suspended load and 1% is bedload. In the intake channel, the bedload flux alone represents about 6 per cent of the coarse sediment available as littoral-sediment flux close to the bed. The fine suspended load is much larger than that available in the littoral zone and must represent mainly suspended material drawn from the open-lake zone. There is evidence from hydraulic considerations that intake velocities are high enough to influence a zone extending as much as a kilometre lakeward from the intake entrance.

9.0 SUMMARY

The key objectives of the sediment study at Pickering were to define the sedimentation processes involved, and to quantify the amount of sediment transport in the vicinity of the plant (Appendix 1). The intention was to define a relatively sediment-free zone where an alternative cooling-water intake system for the plant could be located. The study was based on more than 12 months of field data and wave hindcasts. The accuracy of the results is limited by the simplifying assumptions used, the averaging of highly time-dependent processes, and incomplete data. Although a precise error evaluation is virtually impossible, a reasonable estimate would be that the figures given are accurate to better than a factor of five. Within the limits of the data the study allowed the objectives to be met to the degree required for decision-making on the intake options. The main conclusions are summarized below.

1. Sources of sediment:

There are three important sources of sediment in the area:

- Erosion of shoreline deposits consisting of glacial materials;
- Subaqueous erosion of the glacial deposits exposed on the lake bottom in the nearshore zone;
- Sediment discharge from rivers and creeks.

2. Estimates of total sediment flux:

Bedload (including near-bed suspended load)

Littoral zone - 1300 tonnes/yr
Nearshore zone - 6 kg/cm/yr to 83 kg/cm/yr

Fine suspended sediment

Inside the intake channel - 10,000 tonnes/yr
At the intake pumps - 18,000 tonnes/yr

3. Sediment entrainment:

The present cooling-water-intake structure entrains approximately 108 tonnes/yr of bedload and 18,000 tonnes/yr of fine NVSS suspended load (i.e. a ratio of approximately 1:200). The intake draws bedload sediment mainly from the littoral zone (depth < 5 m), while suspended load comes from a zone which extends up to a kilometer or so offshore. The fine NVSS suspended fraction probably represents a minimum, or fair-weather value, as the storm-related data are absent from the data set. Furthermore, because of its distribution throughout the inshore and offshore areas, the NVSS fraction would likely be entrained into the plant regardless of the type of cooling water structure or location.

Sediment volumes entrained in either case would be strongly influenced by storm-wave resuspension and transport events, and so would be highest during the winter months.

4. Relatively sediment-free zone

The location of a relatively sediment-free zone is chosen to coincide with a minimum in the bedload flux and NVSS suspended loads, which are strongly depth-dependent. With the exception of the winter months, the offshore area (depths more than 10 m) is relatively free of strong bedload flux. The problem of winter bedload fluxes generated by storm waves, and the higher NVSS expected during storms could probably be solved by intake structure design, rather than by intake placement.

5. Depth limits to sediment transport

The particle sizes caught within the bedload traps varied considerably with both depth and time, although D_{50} values were usually between 0.1 and 0.5 mm. Maximum sizes reached as high as 76 mm. The measured average currents were too small to serve as the transporting agents of these large materials. The current meters did not measure wave-related orbital motions, so these had to be estimated using linear wave theory. The results showed that transport of bedload materials, especially in the deeper sites occurs only during storms when waves of periods greater than 6 s and significant heights of 2 m or more are active.

9.1 FUTURE WORK

To obtain more accurate insights into the processes at work, it would be necessary to conduct more specific studies. Examples of such studies are:

- Tracer studies of bedload and suspended load sources and pathways;
- Repetitive echo-sounder surveys of the intake channel bathymetry to provide a better estimate of bedload flux;
- Tests on the function of sediment traps and means of calibration of their results;
- Longer-term studies to determine variability of processes from year to year.

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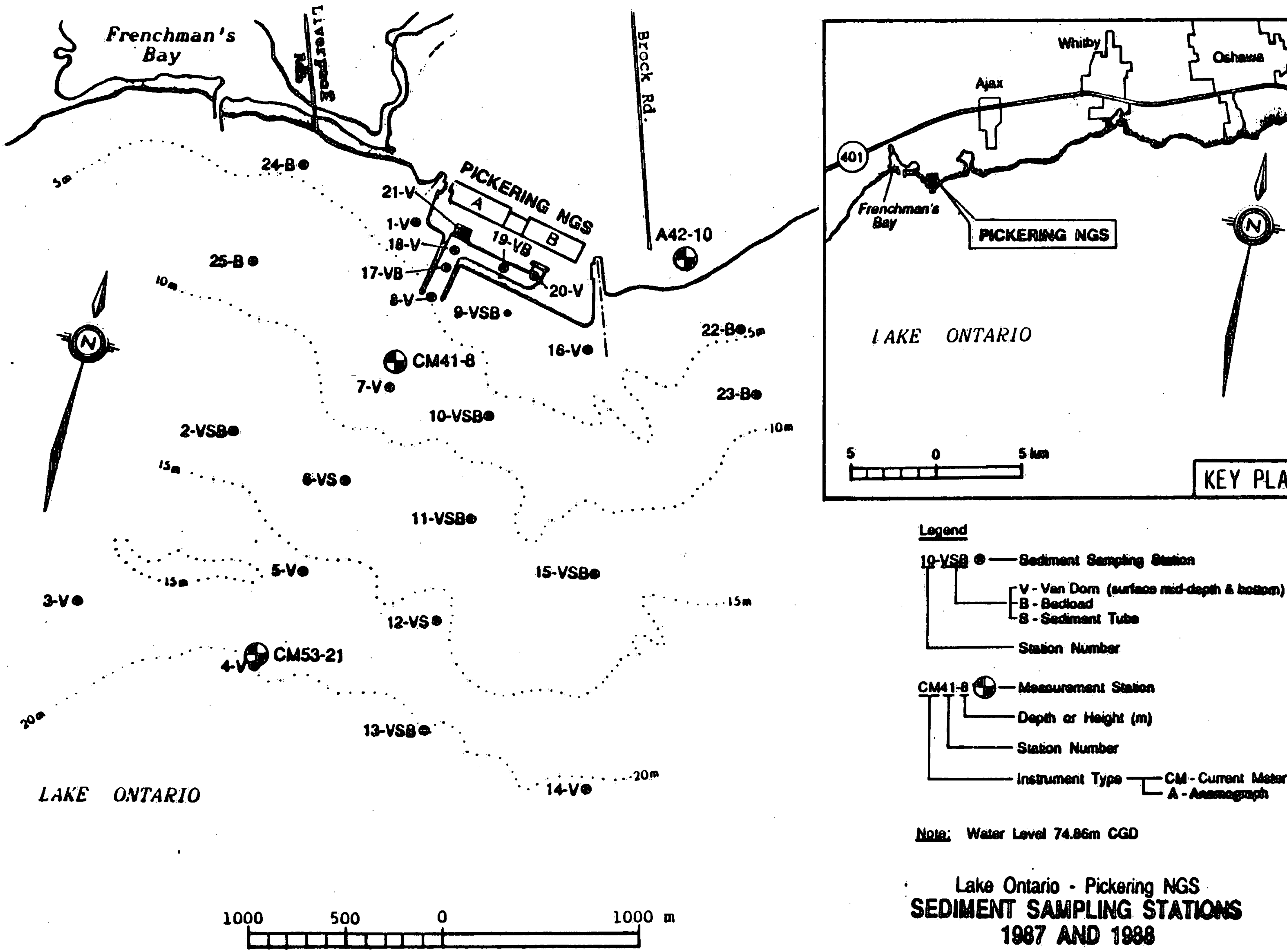
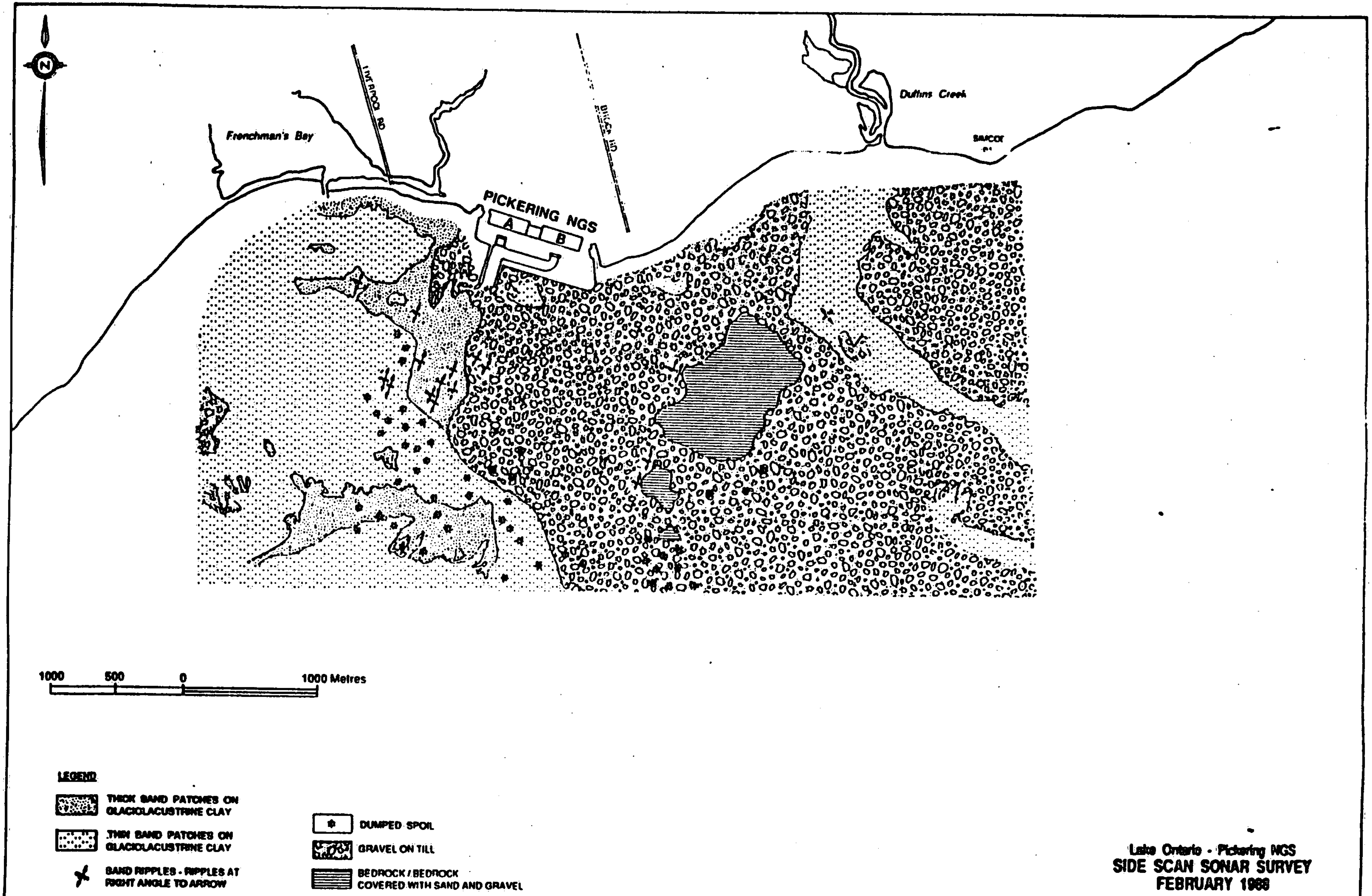


Lake Ontario - Pickering NGS
SEDIMENT SAMPLING STATIONS
1987 AND 1988

FIGURE 1



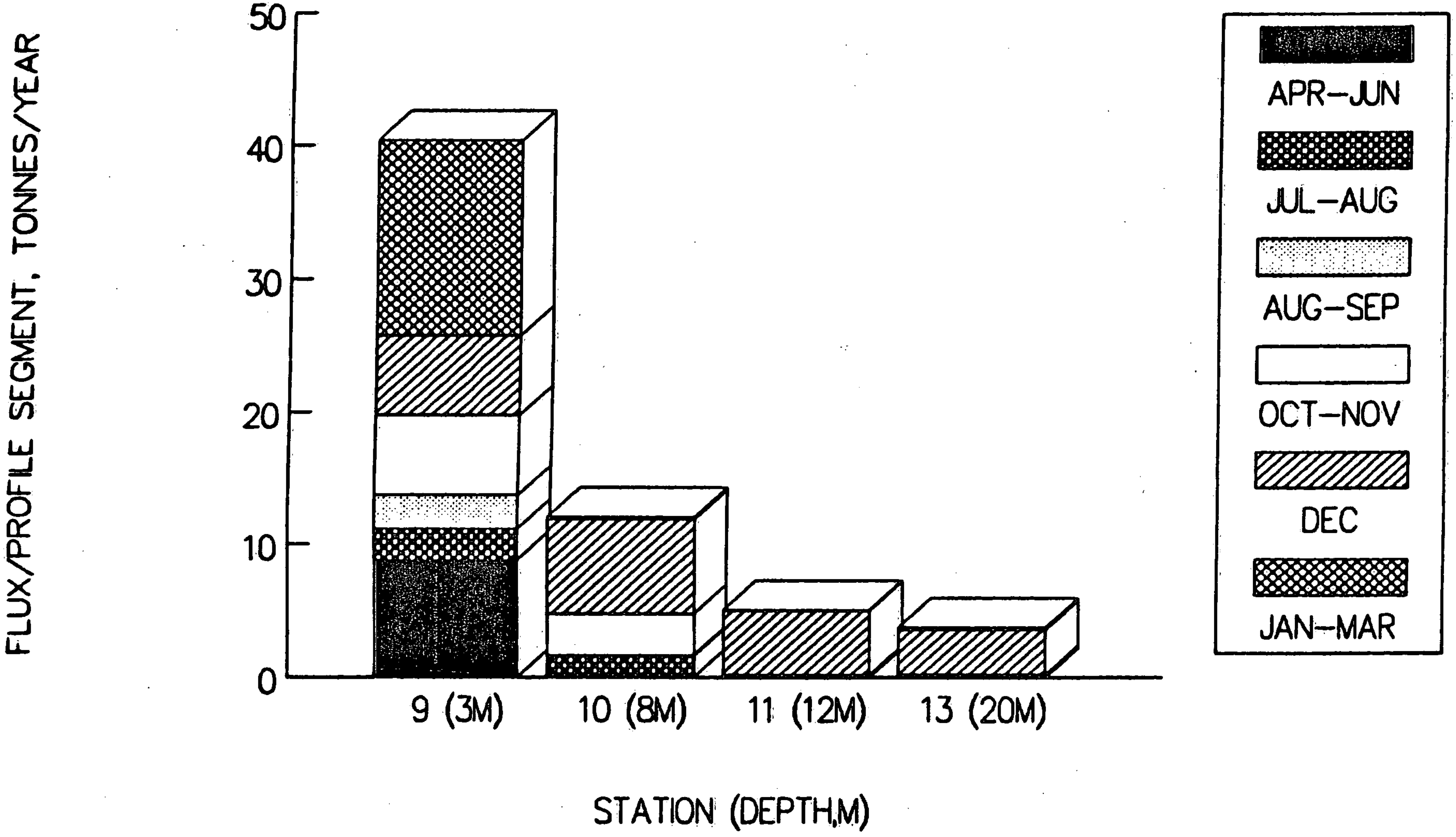
McQUEST Marine

Lake Ontario - Pickering NGS
SIDE SCAN SONAR SURVEY
FEBRUARY 1988

Figure 2

FIG. 3 TOTAL BEDLOAD FLUX, LINE 9–13

PICKERING SITE, 1987–1988



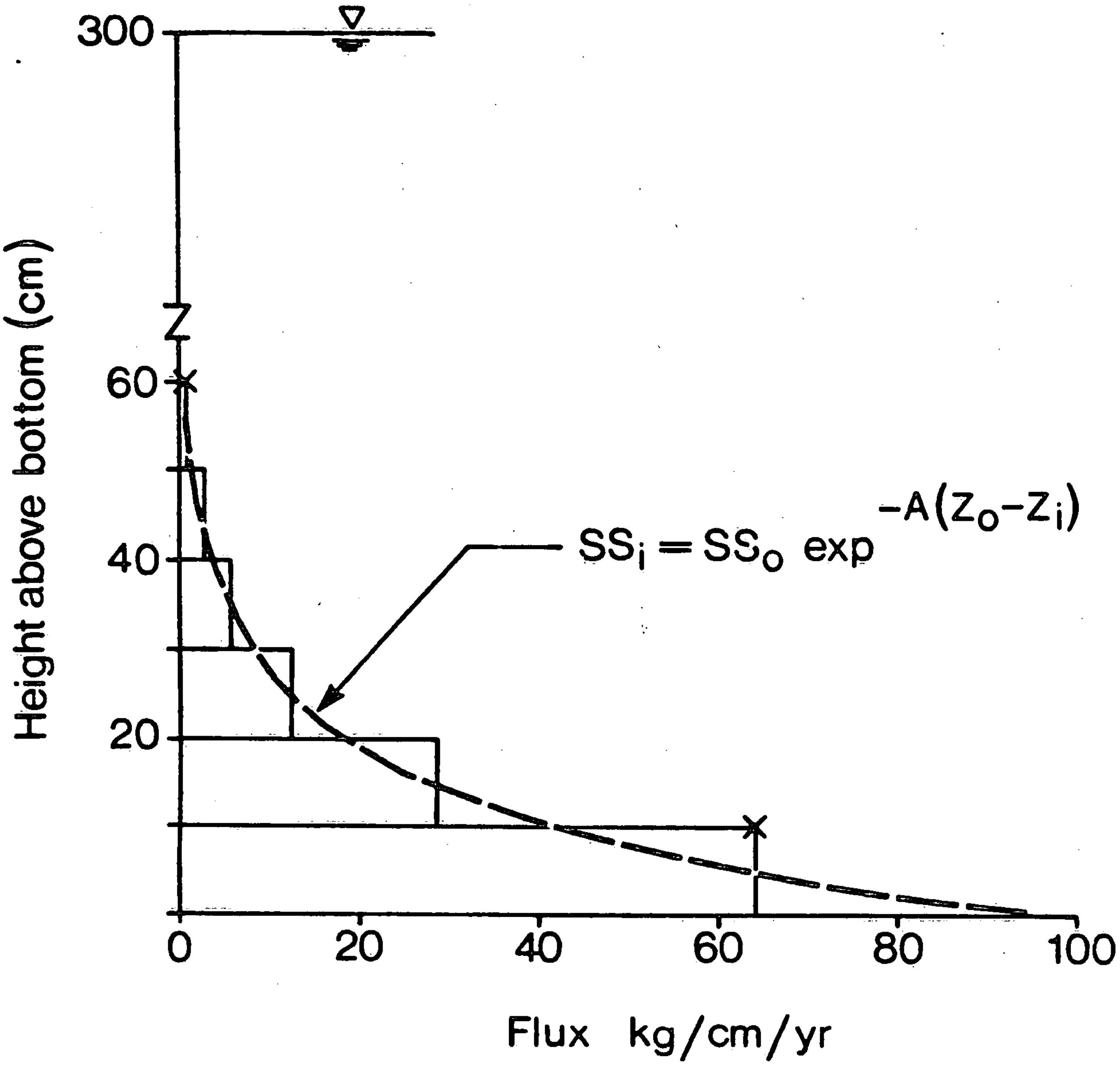
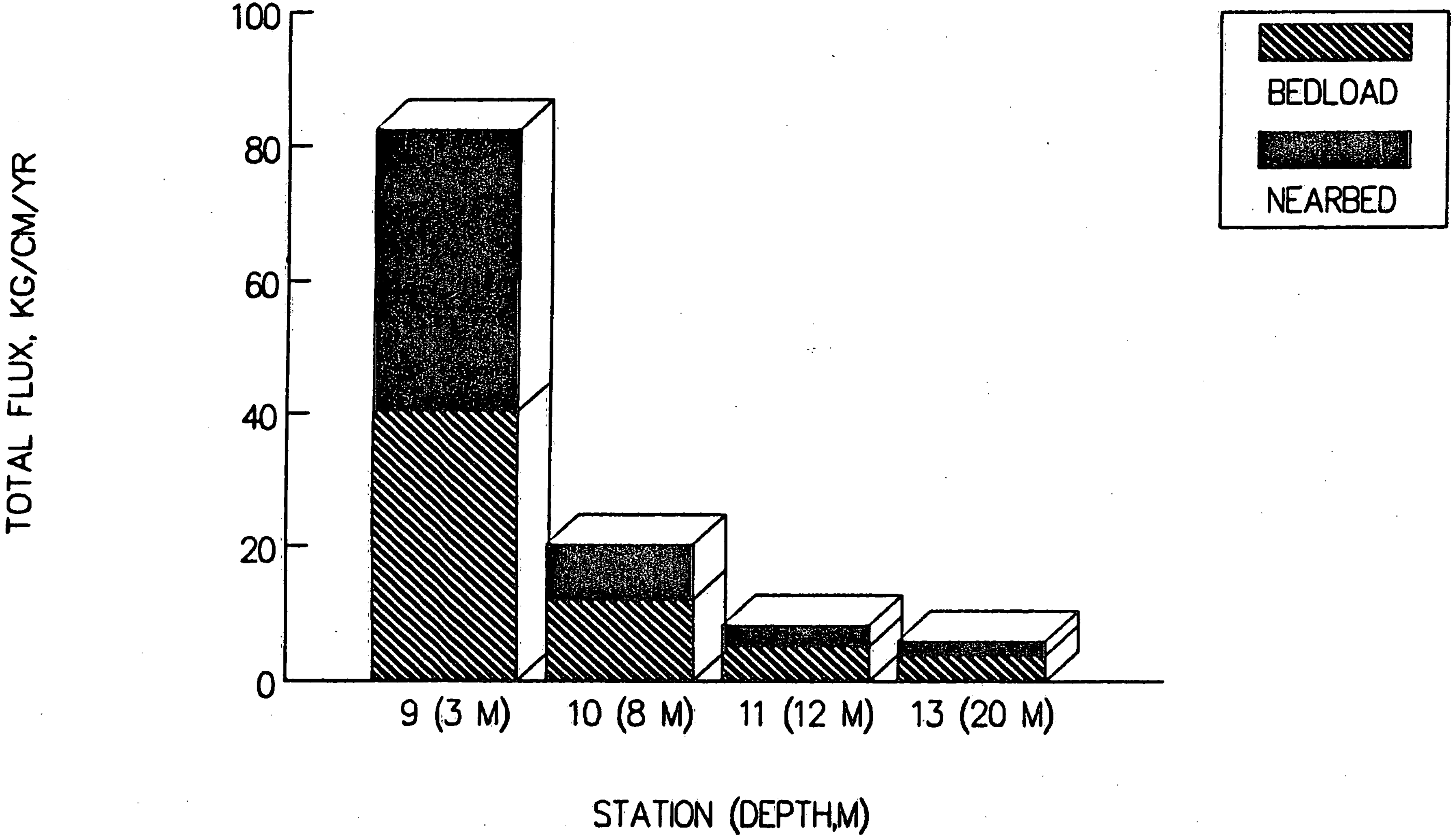


Figure 4: Schematic diagram of technique used to estimate suspended sediment flux close to the bed, above the bedload traps

FIG. 5. BEDLOAD AND NEARBED ANNUAL FLUX

LINE 9–13, PICKERING SITE, 1987–1988



Appendix 1

io hydro
700 University Avenue, Toronto, Ontario M5G 1X6

FILE NO. 12C4-1
DATE [illegible]

To	Initials	Date
[illegible]		

September 9, 1987

Dr. J.P. Coakley
Lakes Research Branch
National Water Research Institute
Canada Centre for Inland Waters
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario
L7R 4A6

Dear John:

Sedimentation Study at Pickering NGS

Following our recent meeting with you and Dr. N. Rukavina on August 25, 1987 we have prepared an outline of the terms of reference for an interim technical report on the results of the Pickering sedimentation field study. A copy is enclosed for your review.

I hope you will appreciate that the outline is by no means intended to limit the scope of your own input in the form of a technical note. It is merely a guideline and I would appreciate receiving your and Dr. Rukavina's comments as soon as possible.

We recognize that because of the limited data available to-date, not all the terms of reference can be addressed adequately at this time. However, they should provide you with some insight into the extent of your involvement and enable you to prepare an estimate of cost so that we may enter into a cost recovery arrangement proposed by you.

I shall be looking forward to hearing from you as soon as convenient. Perhaps we can meet again soon and try to finalize the arrangements.

A copy of our most recent side scan sonar survey carried out during the week May 5-8, 1987 is enclosed.

Yours sincerely,

R. Farooqui
Hydraulic Investigations Engineer
Geotechnical & Hydraulic Engineering

RF:PD

Enc.

cc: Dr. N.A. Rukavina
Mr. R.J. Allen Director, Lakes Research Branch

The broad objectives of the sedimentation study at Pickering NGS as outlined in the Working Proposal dated September 30, 1986 are:

1. To document the silting conditions generally in the vicinity of Pickering Generating Station.

2. To identify and establish the relative sediment free zone that would assist in locating a submerged tunnel intake in the event that a tunnel is a viable option for the solution of the sediment problems at the Pickering NGS.

Within the frame work of the above objectives the following are the terms of reference for a technical report to be prepared by Ontario Hydro's Geotechnical & Hydraulic Engineering Department with the assistance of the National Water Research Institute.

1. Prepare a synopsis of the results of the Pickering Sedimentation field program carried out to-date.

2. Estimate the total sediment flux (suspended and bed load) along shore and on/off shore in the vicinity of the station.

3. Define the relative free zone for a sediment free water supply.

4. Define the limiting depth of coarse sediment transport using wave - orbital velocities - wave climate based on a detailed hindcast using local winds.

5. What proportion of the total nearshore sediment (Littoral Drift) is being entrained in the C.W. Intake system and what is its possible source?

700 University Avenue, Toronto, Ontario M5G 1X6

April 29, 1988

Dr. J.P. Coakley
Lakes Research Branch
National Water Research Institute
Canada Centre for Inland Waters
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario
L7R 4A6

<u>Sedimentation Study at Pickering NGS</u>

Following up on our meeting on April 5, 1988 and subsequent discussions yesterday, we are forwarding to you a detailed outline of the work required to be included in your technical memorandum to address the objectives of the Pickering Sedimentation study. This outline is an expansion of the terms of reference (2 to 5) contained in our letter of September 9, 1987.

Please note that this is merely a guideline and is not intended to limit the scope of your technical memorandum.

Should you require any clarification, we will discuss it at our meeting on Wednesday May 4, 1988.

Yours sincerely,

R. Farooqui
Hydraulic Investigations Engineer
Geotechnical & Hydraulic Engineering Dept.

RF:PD

Attach.

cc: Dr. N.A. Rukavina
Lakes Research Branch

Terms of Reference

Within the frame work of the study objectives as previously outlined, the following are some suggested terms of reference to assist you in the preparation of the draft technical memorandum:

1. Prepare a synopsis of the results of the Bedload and Suspended Sediment Surveys (Van Dorn & Sediment Tubes). Provide a synopsis of the lake bottom sediment characteristics in the vicinity of Pickering NGS after reviewing the interpretation of the Side Scan Sonar Surveys.

2. Estimate on a survey basis the total sediment flux (suspended & bed load) in the littoral zone (< 5m) and the offshore zone (5 - 20 m) with appropriate units ie kg/day. Include a spatial and temporal particle size distribution assessment over the entire study area (onshore - offshore and alongshore).

3. Estimate the total sediment flux entrained by the cooling water intake system. The bed load survey results for the combined intake channel should be corrected to provide a realistic flux in relation to the 'B' channel, as indicated by the detailed intake surveys of February and March, 1988. Include a particle size distribution assessment within the intake channel. Estimate the proportion of the total nearshore sediment (littoral drift) entrained into the cooling water intake system.

4. Define a relative sediment free zone for a submerged cooling water intake taking into account the results of Bedload, Suspended Sediment (Non Dorn & Sediment Tubes), and Side Scan Sonar Surveys.

5. Determine theoretical particle size and define the potential for sediment transport (D 50 & D max) at depths of 3,8,13 and 21 m using wave-orbital velocities from the wave climate based on the long term record of winds recorded at Pickering NGS covering the period 1972-1986 and the study period March 1987 - March 1988. Comment on the uncertainty aspects of this method for a practical engineering application.

Appendix 2: Size data, bottom sediments

Size data, bottom sediments

STN.	Type	% Gravel	% Sand	% Silt	% Clay
S1 surface	lake sediment	0	74	22	4
subsurface		0	32	60	8
S2 surface	lake sediment	22	70	----8----	
subsurface		11	37	37	11
S3 surface	lag sediment	58	40	----2----	
subsurface		58	38	----4----	
S4 surface	lag sediment	70	30	0	0
subsurface	till	24	16	41	19
S5 surface	lag sediment	96	4	0	0
subsurface	bedrock				
S6 surface	lag sediment	8	90	----2----	
subsurface	till?	5	52	27	16
WL2	beach	55	45	0	0
WL3	beach	49	51	0	0
WL4	beach	81	19	0	0
WL5	beach	36	64	0	0

Appendix 3: Offshore bedload flux, g/cm/day

OFFSHORE BEDLOAD FLUX, G/CM/DAY

SITES IN ORDER OF INCREASING DEPTH   > = MISSING OR OVERLOADED TRAP(S)

STN	APPROX DEPTH	APR 29- MAY 22	JUL 17- AUG 14	AUG 14- AUG 25	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29
9	3	92	>41	50	>104	>158	221
24	4	NA	NA	NA	>196	>443	581
22	5	NA	NA	NA	14	65	22
10	8	NA	28	0	53	>187	>2
23	8	NA	NA	0	9	>36	2
25	8	NA	NA	1	80	>168	29
11	12	0	1	0	1	129	1
15	12	0	>1	0	1	140	2
2	14	1	18	2	5	>231	11
13	20	0	>1	>1	0	>90	2

Appendix 4: Calculation of offshore bedload flux for line 9-13

CALCULATION OF OFFSHORE BEDLOAD FLUX FOR LINE 9-13

STA	DEPTH M	APR 29- MAY 22	JUL 17- AUG 14	AUG 14- AUG 25	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29

TOTAL FLUX/SITE = SUM OF FLUX FOR 4 TRAPS, GM/CM/DAY

9	3	92	41	50	104	158	221
10	8	NA	28	1	53	187	2
11	12	0	1	0	1	129	1
13	20	1	1	1	0	90	2

EXTENDED DAYS FOR EACH SURVEY PERIOD

		96	57	50	59	38	66

TOTAL FLUX/SITE/EXPANDED SURVEY PERIOD, KG/CM/PERIOD

9	3	8.8	2.3	2.5	6.1	6.0	14.6
10	8	NA	1.6	0.1	3.1	7.1	0.1
11	12	0.0	0.1	0.0	0.1	4.9	0.1
13	20	0.1	0.1	0.1	0.0	3.4	0.1

TOTAL ANNUAL BEDLOAD FLUX/SITE, KG/CM/YEAR

SITE	DEPTH M	YEARLY TOTAL
9	3	40.4
10	8	12.0
11	12	5.1
13	20	3.8

Appendix 5: Calculation of littoral bedload flux

CALCULATION OF LITTORAL BEDLOAD FLUX

CALCULATION OF LITTORAL BEDLOAD FLUX

STA	DEPTH M	APR 29- MAY 22	JUL 17- AUG 14	AUG 14- AUG 25	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29
	FLUX/SITE = SUM OF EAST/WEST FLUXES, GM/CM/DAY						
9	2	45	26	30	74	>92	124
24	4	NA	NA	NA	>77	>202	313
AVERAGE	3	45	26	30	>76	>147	219
	EXPANDED DAYS FOR EACH SURVEY PERIOD						
		96	57	50	59	38	66
	TOTAL FLUX/EXPANDED SURVEY PERIOD, TONNES/PERIOD						
200-M LITTORAL ZONE	3	86	30	30	90	112	289

TOTAL LITTORAL BEDLOAD FLUX/YEAR 637 TONNES

Appendix 6: Calculation of intake-channel bedload flux

CALCULATION OF INTAKE-CHANNEL BEDLOAD FLUX

STATION	AP-MY	JY-AU	AUG	NOV	DEC	JAN	FEB	MAR	
G/CM/DAY									
B-E								0.82	
-W								3.17	
-C								2.55	
-26E								1.68	
-26W								0.92	
AVERAGE								1.83	
17-E	1.75	16.72	8.58	72.24	26.91	2.08	1.77	3.18	
-W	0.76	5.84	6.39	51.95	12.80	6.97	8.31	7.69	
-C	0.97	2.50	1.13	24.12	3.43	3.04	3.50	1.29	
-26E						3.59	8.27	14.20	
-26W						41.83	49.73	343.42	
AVERAGE	1.16	8.35	5.37	49.44	14.38	11.50	14.32	73.96	
17B-E							19.50	5.68	
-W							206.70	132.46	
-C							100.19	144.26	
-26E							33.82	25.38	
-26W							33.98	46.19	
AVERAGE							78.84	70.79	
19-N		30.56	30.44	7.93	19.46	95.85	52.59	18.71	
-S		27.91	59.08	258.59	105.42	25.74	101.81	135.51	
-C		29.70	16.39	163.27	867.90	151.84	175.51	147.11	
AVERAGE		29.39	35.30	143.26	330.93	91.14	109.97	100.44	
19B-N							72.98	7.32	
-S							46.81	43.12	
-C							116.20	14.36	
AVERAGE							78.66	21.60	
KG/DAY									
STN. B								12.61	
STN. 17	8.00	57.64	37.03	341.11	99.22	79.36	98.78	510.30	
STN. 17B							543.98	488.48	
STN. 19		146.95	176.52	716.32	1654.63	455.72	549.85	502.22	
STN. 19B							393.32	108.00	
TONNES/SURVEY PERIOD									
DAYS->	76	57	50	59	38	33	20	33	YEAR
STN. B								0.42	0.42
STN. 17	0.61	3.29	1.85	20.13	3.77	2.62	1.98	16.84	51.08
STN. 17B							10.88	16.12	27.00
STN. 19		8.38	8.83	42.26	62.88	15.04	11.00	16.57	164.95
STN. 19B							7.87	3.56	11.43

Appendix 7: Median grain-size (MD50) of bedload samples

MEDIAN GRAIN-SIZE (MD50) OF BEDLOAD SAMPLES

STN	APR 21- MAY 22	JUL 17- AUG 26	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29	FEB 23- FEB 24	MAR 8- MAR 9	AVERAGE
OFFSHORE			GRAIN SIZE, MM					
2N	0.13	0.12	0.02	0.24	0.15			0.13
2S	0.11	0.14	0.10	0.22	0.05			0.12
2E	0.14	0.12	0.04	0.23	0.14			0.13
2W	0.09	0.10	0.04	0.23	0.30			0.15
AVERAGE	0.12	0.12	0.05	0.23	0.16			0.14
9N	0.17	0.15	0.21	0.22	0.20			0.19
9S	0.15	0.16		0.22	0.19			0.18
9E	0.17	0.18	0.24	0.40	0.20			0.24
9W	0.18	0.19	0.23	0.25	0.20			0.21
AVERAGE	0.17	0.17	0.23	0.27	0.20			0.21
10N		0.44	0.60	0.70	0.21			0.49
10S		0.12	0.15	0.40	0.24			0.23
10E		0.08	0.24	0.84	0.32			0.37
10W		0.06	0.22	0.70	0.23			0.30
AVERAGE		0.17	0.30	0.66	0.25			0.35
11N	0.13		0.22	0.42				0.26
11S	0.13	0.20	0.24	0.42	0.60			0.32
11E	0.01		0.30	0.44	0.50			0.31
11W	0.18	0.18	0.36		0.27			0.25
AVERAGE	0.11	0.19	0.28	0.43	0.46			0.29
13N	0.20	0.22	0.16					0.19
13S	0.17	0.17	0.23	0.24	0.34			0.23
13E	0.20	0.22	0.20	0.24				0.21
13W	0.25		0.23	0.24	0.24			0.24
AVERAGE	0.20	0.20	0.21	0.24	0.29			0.23
15N	0.13			0.32	0.45			0.30
15S	0.09			0.41	0.46			0.32
15E	0.09	0.26		0.36	1.00			0.43
15W	0.15	0.23		0.42	0.80			0.40
AVERAGE	0.12	0.25		0.38	0.68			0.35
22N			0.08	0.30	0.13			0.17
22S			0.09	0.30	0.15			0.18
22E			0.09	0.26	0.19			0.18
22W			0.07	0.21				0.14
AVERAGE			0.08	0.27	0.16			0.17

STA #	APR 21- MAY 22	JUL 17- AUG 26	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29	FEB 23- FEB 24	MAR 8- MAR 9	AVERAGE
<u>OFFSHORE CONT'D</u>								
23N			0.07	0.44	0.07			0.19
23S			0.08	0.46	0.05			0.20
23E			0.07	0.46	0.05			0.19
23W			0.08		0.05			0.06
AVERAGE			0.08	0.45	0.06			0.19
24N			0.14	1.70				0.92
24S			0.14	0.42	0.11			0.22
24E			0.20	7.00	0.11			2.44
24W			0.14	0.30	0.12			0.19
AVERAGE			0.16	2.36	0.11			0.87
25N		0.12	0.15	0.54	0.19			0.25
25S		0.13	0.18	0.34	0.18			0.21
25E			0.15	1.00	0.18			0.44
25W		0.11	0.20	0.44	0.22			0.24
AVERAGE		0.12	0.17	0.58	0.19			0.27
OVERALL AVERAGE	0.14	0.17	0.17	0.60	0.25			0.31

STA #	APR 21- MAY 22	JUL 17- AUG 26	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29	FEB 23- FEB 24	MAR 8- MAR 9	AVERAGE
<u>INTAKE</u>			GRAIN SIZE, MM					
8C							0.08	0.08
8E							0.14	0.14
8E26							0.08	0.08
8W							0.30	0.30
8W26							0.32	0.32
AVERAGE							0.18	0.18
17C	0.20	0.12	0.29	0.26	0.29	0.30	0.10	0.22
17E	0.23	0.16	0.28	0.40	0.30	0.27	0.10	0.25
17E26					0.31	0.33	0.10	0.25
17W	0.19	0.27	0.28	0.23	0.33	0.20	0.30	0.26
17W26					0.21		0.36	0.29
AVERAGE	0.20	0.18	0.28	0.30	0.29	0.28	0.19	0.25
17BC						0.26	0.28	0.27
17BE						0.43	0.14	0.29
17BE26						0.32	0.22	0.27
17BW						0.30	0.21	0.26
17BW26							0.12	0.12
AVERAGE						0.33	0.19	0.26
19C		0.13	0.20	0.21	0.21	0.21	0.22	0.20
19N		0.21	0.16	0.25	0.17	0.17	0.15	0.18
19S		0.13	0.17	0.13	0.13	0.12	0.13	0.13
AVERAGE		0.16	0.17	0.20	0.17	0.17	0.17	0.17
19BC						0.30	0.16	0.23
19BN						0.23	0.13	0.18
19BS						0.19	0.19	0.19
AVERAGE						0.24	0.16	0.20
OVERALL AVERAGE	0.20	0.17	0.23	0.25	0.24	0.26	0.18	0.21

Appendix 8: Maximum grain-size of bedload samples

MAXIMUM GRAIN-SIZE OF BEDLOAD SAMPLES

STA #	APR 21- MAY 22	JUL 17- AUG 26	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29	FEB 23- FEB 24	MAR 8- MAR 9	AVERAGE
OFFSHORE			GRAIN SIZE, MM					
2N	2.0	3.4	2.0	4.8	9.5			4.3
2S	2.0	2.0	2.0	9.8	9.5			5.1
2E	2.0	7.5	2.0	4.8	19.0			7.1
2W	2.0	2.0	2.0	9.5	19.0			6.9
AVERAGE	2.0	3.7	2.0	7.2	14.3			5.8
9N	3.4	4.8	9.5	19.0	4.8			8.3
9S	3.4	11.9		25.0	4.8			11.3
9E	4.8	3.4	25.0	25.0	4.8			12.6
9W	3.4	3.4	19.0	37.5	19.0			16.5
AVERAGE	3.8	5.9	17.8	26.6	8.3			12.5
10N		19.0	9.5	19.0	4.8			13.1
10S		9.5	2.0	9.5	9.5			7.6
10E		2.8	9.5	19.0	9.5			10.2
10W		3.4	5.8	25.0	2.0			9.0
AVERAGE		8.7	6.7	18.1	6.4			10.0
11N	2.0		2.0	19.0				7.7
11S	2.0	2.0	2.0	19.0	19.0			8.8
11E	4.8		2.0	37.5	4.8			12.3
11W	2.0	2.0	2.0	37.5	4.8			9.7
AVERAGE	2.7	2.0	2.0	28.3	9.5			8.9
13N	2.0	5.8	2.0	2.0				3.0
13S	4.8	7.2	2.0	2.0	19.0			7.0
13E	2.0	9.5	2.0	2.0				3.9
13W	2.0		0.9	4.8	9.5			4.3
AVERAGE	2.7	7.5	1.7	2.7	14.3			5.8
15N	2.0		4.8	4.8	2.0			3.4
15S	2.0		2.0	4.8	2.0			2.7
15E	2.0	2.0	0.9	4.8	19.0			5.7
15W	2.0	2.0	2.0	19.0	9.5			6.9
AVERAGE	2.0	2.0	2.4	8.3	8.1			4.6
22N			9.5	9.5	4.8			7.9
22S			4.8	37.5	9.5			17.3
22E			4.8	25.0	9.5			13.1
22W			2.0	2.0	2.0			2.0
AVERAGE			5.3	18.5	6.4			10.1

STA #	APR 21- MAY 22	JUL 17- AUG 26	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29	FEB 23- FEB 24	MAR 8- MAR 9	AVERAGE
<u>OFFSHORE CONT'D</u>								
23N			19.0	19.0	4.8			14.3
23S			2.0	25.0	9.5			12.2
23E			2.0	25.0	9.5			12.2
23W			2.0		9.5			5.8
AVERAGE			6.3	23.0	8.3			12.5
24N			2.0	25.0	4.8			10.6
24S			19.0	37.5	2.0			19.5
24E			25.0	76.0	4.8			35.3
24W			19.0	25.0	4.8			16.3
AVERAGE			16.3	40.9	4.1			20.4
25N		0.9	2.0	25.0	4.8			8.2
25S		4.8	4.8	25.0	9.5			11.0
25E			4.8	19.0	4.8			9.5
25W		0.9	4.8	19.0	19.0			10.9
AVERAGE		2.2	4.1	22.0	9.5			9.4
OVERALL AVERAGE	2.6	5.0	6.2	19.5	8.6			8.4

STA #	APR 21- MAY 22	JUL 17- AUG 26	NOV 12- NOV 23	DEC 10- DEC 23	JAN 25- JAN 29	FEB 23- FEB 24	MAR 8- MAR 9	AVERAGE
INTAKE				GRAIN SIZE, MM				
8C							19.0	19.0
8E							9.5	9.5
8E26							4.8	4.8
8W							4.8	4.8
8W26							4.8	4.8
AVERAGE							8.6	8.6
17C	2.0	2.0	17.3	9.5	7.2	4.8	4.8	6.8
17E	2.0	5.8	7.1	4.8	4.8	2.0	2.0	4.1
17E26					9.5	9.5	0.9	6.6
17W	2.0	10.5	11.9	2.0	9.5	4.8	4.8	6.5
17W26					4.8		9.5	7.2
AVERAGE	2.0	6.1	12.1	5.4	7.2	5.3	4.4	6.1
17BC						4.8	2.0	3.4
17BE						25.0	19.0	22.0
17BE26						25.0	25.0	25.0
17BW						4.8	2.0	3.4
17BW26							2.0	2.0
AVERAGE						14.9	10.0	12.5
19C		3.9	4.8	3.4	2.0	2.0	0.9	2.8
19N		9.5	11.9	10.5	14.3	19.0	19.0	14.0
19S		1.3	3.4	1.2	0.9	0.9	0.9	1.4
AVERAGE		4.9	6.7	5.0	5.7	7.3	6.9	6.1
19BC						9.5	4.8	7.2
19BN						4.8	4.8	4.8
19BS						2.0	4.8	3.4
AVERAGE						5.4	4.8	5.1
OVERALL AVERAGE	2.0	5.5	9.4	5.2	6.6	8.5	7.1	6.3

Appendix 9: Suspended sediment data: Sediment tubes

SEDIMENT TUBE DATA

STA NO.	SEAS.	DEPTH (M)	FLUX MG/CM^2/DY	NO.DAYS	TOTAL WT, G	D-50 (MM)	TRAP RATE G/CM/DY	ANNUAL AVG. G/CM/DY	SED.TUBE FLUX KG/CM/Y
9	SUMM	3	588.6	104	1240.2		2.347		
	FALL		641.9	94	1222.5		2.560		
	WINTER		900.4	84	1532.3		3.591	2.833	1.037
10	SPRING	8	3.7	62	4.6	0.22	0.015		
	SUMMER		27.4	104	57.7	0.1	0.109		
	FALL		122.2	94	232.7		0.487		
	WINTER		71.5	84	121.7	0.2	0.285	0.224	0.082
11	SPRING	11	1	62	1.3	0.22	0.004		
	SUMMER		15.5	104	32.7	0.13	0.062		
	FALL		27.3	94	52.0		0.109		
	WINTER		23.2	84	39.5	0.3	0.093	0.067	0.024
13	SPRING	21	0.8	62	1.0	0.23	0.003		
	SUMMER		4.2	104	8.8		0.017		
	FALL		18.4	94	35.0		0.073		
	WINTER		8.3	84	14.1		0.033	0.032	0.012

CALCULATION OF NEAR-BED FLUX (10-60 CM)

STA NO.	SED.TUBE FLUX KG/CM/Y	BEDLOAD FLUX KG/CM/Y	COEFF A	ZO	ZI	NEARBED FLUX SEGMENT KG/CM/Y	TOTAL KG/CM/Y
9	1.037	40.4	0.0654	5	15	21.0	
				5	25	10.9	
				5	35	5.7	
				5	45	3.0	
				5	55	1.5	42.1
10	0.082	12.0	0.0890	5	15	4.9	
				5	25	2.0	
				5	35	0.8	
				5	45	0.3	
				5	55	0.1	8.3
11	0.024	5.1	0.0953	5	15	2.0	
				5	25	0.8	
				5	35	0.3	
				5	45	0.1	
				5	55	0.0	3.2
13	0.012	3.8	0.1033	5	15	1.3	
				5	25	0.5	
				5	35	0.2	
				5	45	0.1	
				5	55	0.0	2.1

Appendix 10: Suspended sediment data: Van Dorn

SUSPENDED SEDIMENT SAMPLES (TSS AND NVSS IN MG/L OR G/M³)

STN	WATER DEPTH	DATE	SURFACE		MID-DEPTH		BOTTOM		TOTAL		TIME AVG.	DEP.AVG
			TSS	NVSS	TSS	NVSS	TSS	NVSS	TSS	NVSS	NVSS	NVSS
4	20	04/21/87	2.3	0.6	2.6	1.0	2.7	1.1	51.0	18.5		
	20	07/10/87	3.4	1.4	3.5	1.8	3.3	1.5	69.0	32.0		
	20	11/11/87	1.7	0.6	1.4	0.6	1.4	0.8	29.5	13.0		
	20	12/23/87	2.2	0.6	2.3	0.8	2.9	0.7	48.5	14.5		
	20	02/01/88	1.3	0.7	2.4	1.0	2.9	1.0	45.0	18.5		
	20	03/31/88	12.0	2.9	4.4	1.7	4.8	1.9	128.0	41.0		
										137.5	22.9	1.1
5	15	04/21/87	2.2	1.0	2.8	1.3	2.4	1.2	38.3	18.0		
	15	07/10/87	6.0	2.1	3.8	1.1	4.6	1.8	68.3	22.9		
	15	11/11/87	1.7	0.7	1.6	0.5	1.5	0.6	24.0	8.6		
	15	12/23/87	2.4	0.7	2.3	0.7	2.9	1.0	37.1	11.6		
	15	02/01/88	1.8	0.5	2.3	0.9	3.2	1.0	36.0	12.4		
	15	03/31/88	10.5	2.4	11.8	2.1	4.8	1.5	145.9	30.4		
										103.9	17.3	1.2
6	12	04/21/87	3.2	1.2	2.7	1.1	2.6	1.3	33.6	14.1		
	12	07/10/87	6.7	2.3	4.0	1.6	4.4	1.8	57.3	21.9		
	12	11/11/87	2.1	0.9	2.2	0.9	2.0	0.8	25.5	10.5		
	12	12/23/87	2.9	0.6	3.0	0.7	3.4	1.0	36.9	9.0		
	12	02/01/88	2.6	0.8	2.9	0.8	2.6	0.8	33.0	9.6		
	12	03/31/88	9.2	2.0	6.1	1.8	5.9	1.7	81.9	21.9		
										87.0	14.5	1.2
7	8	04/21/87	2.4	0.7	2.8	1.0	2.7	1.3	21.4	8.0		
	8	07/10/87	7.2	2.2	5.5	1.8	12.2	3.0	60.7	17.5		
	8	11/11/87	1.6	0.7	1.9	0.7	1.8	0.8	14.4	5.8		
	8	12/23/87	4.3	0.9	4.6	1.0	4.4	0.9	35.8	7.6		
	8	02/01/88	3.4	1.2	3.0	0.8	3.6	1.2	26.0	8.0		
	8	03/31/88	9.2	1.7	9.1	2.2	7.7	2.0	70.2	16.2		
										63.1	10.5	1.3
8	5	04/21/87	2.6	0.9	3.0	1.2	3.3	1.3	14.9	5.8		
	5	07/10/87	7.3	2.3	7.0	2.2	10.1	3.0	39.3	12.1		
	5	11/11/87	2.0	1.0	2.0	0.6	2.0	0.7	10.0	3.6		
	5	12/23/87	38.0	4.2	30.2	3.6	27.2	3.0	157.0	18.0		
	5	02/01/88	11.0	2.0	11.9	2.3	10.5	2.1	56.6	10.9		
	5	03/31/88	8.4	2.1	8.8	2.4	8.7	2.1	43.4	11.3		
										61.6	10.3	2.1
9	2	04/21/87	2.8	1.3	2.7	1.0	2.9	1.0	5.5	2.1		
	2	07/10/87	10.8	3.3	11.0	3.3	13.0	3.6	22.9	6.7		
	2	11/11/87	3.7	1.0	4.9	1.3	7.2	1.4	10.3	2.5		
	2	02/01/88	6.9	1.6	7.2	1.4	7.9	2.0	14.6	3.2		
										14.6	3.7	1.8
10	7	04/21/87	2.7	1.1	3.8	1.4	4.1	1.5	25.2	9.4		
	7	07/10/87	7.2	2.3	5.8	2.2	4.9	1.9	41.5	15.1		
	7	11/11/87	2.5	0.9	2.7	1.0	1.8	0.8	17.0	6.5		
	7	02/01/88	4.0	1.1	4.4	1.3	3.3	0.8	28.2	7.9		
										38.9	9.7	1.4

STN	WATER DEPTH	DATE	SURFACE		MID-DEPTH		BOTTOM		TOTAL		TIME AVG.	DEP.AVG
			TSS	NVSS	TSS	NVSS	TSS	NVSS	TSS	NVSS	NVSS	NVSS
11	12	04/21/87	2.3	0.9	3.3	1.4	4.0	1.6	38.7	15.9		
	12	07/10/87	7.0	2.3	3.1	1.5	3.6	1.6	50.3	20.7		
	12	11/11/87	2.5	0.9	1.9	0.9	2.0	1.0	24.9	11.1		
	12	02/01/88	5.3	1.1	5.2	1.0	5.0	1.0	62.0	12.2		
										59.8	15.0	1.2
12	15	04/21/87	2.2	0.9	3.7	1.7	3.2	1.2	48.0	20.6		
	15	07/10/87	6.1	2.1	3.4	1.1	3.5	1.3	61.5	21.0		
	15	11/11/87	2.3	0.9	2.2	1.3	1.8	0.9	31.9	16.5		
	15	02/01/88	4.1	1.2	3.0	0.6	3.5	1.1	51.0	13.1		
										71.3	17.8	1.2
13	20	04/21/87	2.5	1.1	3.0	1.0	2.3	1.1	54.0	21.0		
	20	07/10/87	5.5	2.1	2.9	1.6	2.2	1.4	67.5	33.5		
	20	11/11/87	1.1	0.6	1.4	0.8	1.4	0.8	26.5	15.0		
	20	02/01/88	1.7	0.8	1.7	0.9	1.7	0.8	34.0	17.5		
										87.0	21.8	1.1
17	6	04/21/87	3.2	1.2	3.3	1.2	3.1	1		8.4		
	6	07/10/87	5.6	1.9	3.7	1.4	4.7	1.6		9.4		
	6	11/11/87	2.1	0.7	2.7	1.3	2.6	0.8		6.2		
	6	02/01/88	10.5	1.8	10.4	2.1	9.9	1.8		11.7		
	6	03/31/88	8.6	2.3	8.7	1.6	9	1.9		11.1		
										46.8	9.4	1.6
18	6	04/21/87	3.2	1.1	3.5	1.2	3.4	1.4		7.3		
	6	07/10/87	3	1.1	1.3	0.7	5.9	1.4		5.8		
	6	11/11/87	2	0.7	2.3	1	2.5	1		5.5		
	6	02/01/88	10.1	1.7	10.1	1.8	10.6	1.9		10.8		
	6	03/31/88	8.9	2.2	8.7	2	11.2	2		12.3		
										41.9	8.4	1.4
19	4	04/21/87	3.8	1.1	3.7	1	4	1.4		4.5		
	4	07/10/87	6.2	2.1	7.3	2.2	4	1.4		7.9		
	4	11/11/87	2	0.8	2.2	0.7	2.6	1.4		3.6		
	4	02/01/88	14.3	4.8	17.0	6.7	15.9	5.6		23.8		
	4	03/31/88	8.7	2.1	9.7	2.3	9.5	2.1		8.8		
										48.6	9.7	2.4
20	9	04/21/87	7.3	1.7	3.5	1.3	4.9	1.4		12.8		
	9	07/10/87	6.7	2.0	7.8	2.3	13.2	3.3		22.3		
	9	11/11/87	2.9	1.3	2.6	1.1	2.8	1.4		11.0		
	9	02/01/88	11.7	2.2	11.4	2.4	12.9	2.9		22.3		
	9	03/31/88	9.9	2.0	9.7	2.1	9.6	2.2		18.9		
										87.3	17.5	1.9
21	9	04/21/87	3.4	1.3	2.9	1.2	3.2	1.3		11.3		
	9	07/10/87	7	2.7	6.8	2.1	7.2	1.9		19.8		
	9	11/11/87	2.4	1.0	2.5	1.2	2.6	0.9		9.7		
	9	02/01/88	9.8	1.8	10.6	1.9	10.7	2		17.1		
	9	03/31/88	10.8	2.3	9.9	2.2	10.2	2.3		20.3		
										78.1	15.6	1.7

Appendix 11: Suspended sediment data: Intake pumps

SUSPENDED SEDIMENT SAMPLES FROM INTAKE PUMPS MG/L OR G/M-3

STN.	DATE	TSS	NVSS	TOTAL ENTRAINED
UNIT 1	02/01/88	16.0	3.0	
	03/31/88	11.8	2.6	
			2.8	302.4 KG/H
UNIT 3	04/21/87	8.8	2.0	
	11/11/87	11.4	2.4	
	02/01/88	22.4	4.0	
			2.8	302.4
UNIT 4	04/21/87	7.1	2.0	
	11/11/87	20.4	3.4	
	02/01/88	20.6	3.7	
	03/31/88	11.3	1.8	
			2.7	294.3
UNIT 5	04/21/87	15.4	2.2	
	11/11/87	21.4	3.4	
	02/01/88	432.0	5.9	
	03/31/88	151.2	10.0	
			5.4	580.5
UNIT 6	11/11/87	17.6	4.2	
	02/01/88	34.2	6.5	
	03/31/88	36.7	3.0	
			4.6	493.2
UNIT 7	04/21/87	7.1	1.7	
	11/11/87	2.4	1.0	
	02/01/88	11.9	2.4	
	03/31/88	60.6	4.3	
			2.3	253.8
UNIT 8	04/21/87	7.3	1.8	
	11/11/87	4.5	1.7	
	03/31/88	101.0	5.7	
			3.1	331.2

TOTAL FOR 7 UNITS 2557.8 KG/H
TOTAL FOR 5.7 UNITS 2082.8 KG/H

OR 18295.14 TONNES/Y

Appendix 12: Current meter data summary

FREQUENCY DISTRIBUTION OF CURRENT BY DIRECTION

LAKE ONTARIO - PICKERING NGS

CM41 - 8M

PERIOD FROM JUL ~~01~~ 16/87 TO MAR 31/88

DIRECTION TO	NUMBER OF READINGS	% OF TOTAL	AVERAGE SPEED CM/S	TOTAL TRANSPORT METRES	% OF TOTAL	MAXIMUM SPEED CM/S	DATE OF MAXIMUM DAY/HOUR
N	221	3.6	2.3	17963	1.9	9.2	SEP/19/09
NNE	375	6.1	2.9	39059	4.2	11.2	SEP/02/17
NE	532	8.6	2.9	54856	5.9	10.1	JUL/16/15
ENE	735	11.9	3.4	90093	9.7	11.8	OCT/02/19
E	1305	21.1	4.2	199216	21.5	18.0	FEB/21/22
ESE	1752	28.3	6.3	394972	42.7	17.1	FEB/21/23
SE	275	4.4	3.3	33065	3.6	14.4	FEB/07/12
SSE	111	1.8	2.0	7883	.9	11.1	AUG/29/15
S	105	1.7	1.6	5911	.6	5.1	JAN/08/23
SSW	118	1.9	2.2	9187	1.0	7.6	AUG/20/07
SW	141	2.3	2.5	12931	1.4	8.1	JUL/29/09
WSW	85	1.4	2.4	7214	.8	6.5	JUL/28/09
W	80	1.3	2.3	6724	.7	12.6	DEC/15/13
WNW	101	1.6	4.6	16880	1.8	19.1	DEC/15/10
NW	151	2.4	4.1	22190	2.4	16.5	DEC/15/08
NNW	83	1.3	2.4	7052	.8	7.5	MAR/25/01
CALM	13	.2	.0	0	.0	.0	/00/00
TOTAL	6183	100.0		925196	100.0		

FREQUENCY DISTRIBUTION OF CURRENT BY DIRECTION

LAKE ONTARIO - PICKERING NGS

CM53 - 21M

PERIOD FROM JUL ~~01~~ 16/87 TO MAR 31/88

DIRECTION TO	NUMBER OF READINGS	% OF TOTAL	AVERAGE SPEED CM/S	TOTAL TRANSPORT METRES	% OF TOTAL	MAXIMUM SPEED CM/S	DATE OF MAXIMUM DAY/HOUR
N	278	4.5	3.5	34855	3.7	13.7	JUL/16/12
NNE	594	9.6	4.1	88099	9.4	11.9	NOV/05/16
NE	1037	16.8	4.8	179124	19.1	14.3	NOV/05/20
ENE	782	12.6	4.9	137231	14.6	13.3	FEB/07/13
E	402	6.5	4.7	68500	7.3	16.5	FEB/22/01
ESE	85	1.4	3.3	10033	1.1	12.3	DEC/15/23
SE	98	1.6	2.4	8600	.9	9.6	DEC/15/22
SSE	108	1.7	2.9	11300	1.2	8.1	AUG/27/08
S	241	3.9	4.1	35485	3.8	19.4	JUL/31/05
SSW	367	5.9	4.8	63302	6.7	18.0	JUL/31/11
SW	484	7.8	4.0	69933	7.5	11.5	JUL/30/15
WSW	569	9.2	4.2	86983	9.3	14.1	FEB/11/17
W	484	7.8	4.2	73047	7.8	12.5	FEB/11/19
WNW	248	4.0	3.2	28918	3.1	9.4	DEC/15/12
NW	198	3.2	2.7	18899	2.0	8.0	JUL/28/24
NNW	208	3.4	3.2	23637	2.5	9.0	AUG/05/14
CALM	3	.0	.0	0	.0	.0	/00/00
TOTAL	6186	100.0		937943	100.0		

PERCENTAGE FREQUENCY OF CURRENT BY DIRECTION AND SPEED RANGES

LAKE ONTARIO - PICKERING NGS

CM41 - 8M

PERIOD FROM JUL ~~01~~ 16/87 TO MAR 31/88

CURRENT SPEED RANGES IN CM/S

DIRECTION TO	.0 - 4.9	5.0 - 9.9	10.0 -14.9	15.0 -19.9	20.0 -24.9	25.0 -29.9	30.0 -34.9	35.0 -39.9	40.0 -44.9	>44.9	TOTAL %
N	3.3	.2									3.6
NNE	5.4	.6	.0								6.1
NE	7.8	.8	.0								8.6
ENE	9.8	1.9	.1								11.9
E	14.2	6.5	.3	.0							21.1
ESE	9.2	16.7	2.2	.2							28.3
SE	3.5	.9	.1								4.4
SSE	1.7	.0	.0								1.8
S	1.7	.0									1.7
SSW	1.8	.1									1.9
SW	2.0	.2									2.3
WSW	1.3	.1									1.4
W	1.2	.1	.0								1.3
WNW	1.1	.4	.2	.0							1.6
NW	1.6	.7	.1	.0							2.4
NNW	1.3	.1									1.3
CALM	.2										.2
TOTAL %	67.2	29.5	3.1	.3	.0	.0	.0	.0	.0	.0	100.0

NET CURRENT SPEED = 3.0 CM/S TO 93.4 DEGREES
MEAN CURRENT SPEED = 4.2 CM/S
MAXIMUM CURRENT SPEED = 19.1 CM/S
PERSISTENCE FACTOR (V-NET/V-MEAN) = .73

PERCENTAGE FREQUENCY OF CURRENT BY DIRECTION AND SPEED RANGES

LAKE ONTARIO - PICKERING NGS

CM53 - 21M

PERIOD FROM JUL ~~01~~ 16/87 TO MAR 31/88

DIRECTION CURRENT SPEED RANGES IN CM/S

TO	.0 - 4.9	5.0 - 9.9	10.0 -14.9	15.0 -19.9	20.0 -24.9	25.0 -29.9	30.0 -34.9	35.0 -39.9	40.0 -44.9	>44.9	TOTAL %
N	3.4	1.1	.0								4.5
NNE	6.7	2.9	.1								9.6
NE	9.2	7.3	.3								16.8 ←
ENE	6.8	5.6	.2								12.6 ←
E	3.8	2.4	.3	.0							6.5
ESE	1.0	.3	.0								1.4
SE	1.5	.1									1.6
SSE	1.6	.2									1.7
S	2.8	.7	.3	.0							3.9
SSW	3.7	1.8	.3	.1							5.9
SW	5.4	2.4	.0								7.8
WSW	6.3	2.7	.1								9.2
W	5.2	2.4	.2								7.8
WNW	3.4	.6									4.0
NW	3.0	.2									3.2
NNW	2.8	.6									3.4
CALM	.0										.0
TOTAL %	66.7	31.3	1.9	.1	.0	.0	.0	.0	.0	.0	100.0

NET CURRENT SPEED = .8 CM/S TO 34.5 DEGREES
MEAN CURRENT SPEED = 4.2 CM/S
MAXIMUM CURRENT SPEED = 19.4 CM/S
PERSISTENCE FACTOR (V-NET/V-MEAN) = .19

Appendix 13: Summary of hindcast waves

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DPW * MD                                                                                                            PAGE  11
W/WANSYS                          SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS            PROJ PIX1
WAVENRGY                                                                                                            14-JAN-88
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                                   STATION: PICKERING - DEEP                    WAVE DIRECTION: ALL

                  WIND DATA FOR STATION: PICKERING OH        SELECTED FROM:  72/05/02  TO  86/12/31    (        TO        )


          *------------------------- W A V E   P E R I O D   ( S E C O N D S ) ------------------------*        SEE FOOTNOTE FOR
   WAVE     0.0  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  8.0  9.0 10.0 12.0 14.0          EXPLANATION OF
  HEIGHT     TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO    &   ROW   ROW & COL PERCENT
 (METRES)   0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  8.0  9.0 10.0 12.0 14.0 OVER TOTAL   A(%)   B(%)   C(%)


0.00-0.25   280 3668 6996 7880 8612 1098  493  141   61   45   15   15                                         29304  44.32  24.97  56.35
0.25-0.50                      1793 7855 5779 1092  386  190   86   63    7    2                               17253  26.09  14.70  31.38
0.50-0.75                             56 1557 4702 1750  369  185   64   38    1    1                           8723  13.19   7.43  16.67
0.75-1.00                                  7  315 2127 1493  311  113   65    3    2                           4436   6.71   3.78   9.24
1.00-1.25                                       6  149  700 1207  277   75   28    5                           2447   3.70   2.09   5.46

1.25-1.50                                            7   74  263  793  194   67    3                           1401   2.12   1.19   3.37
1.50-1.75                                                 3   26  178  538  115   21                            881   1.33    .75   2.18
1.75-2.00                                                      4   32  133  421   73                            663   1.00    .56   1.43
2.00-2.25                                                           2   17  106  259    1                       385    .58    .33    .87
2.25-2.50                                                                7   28  242    5                       282    .43    .24    .54

2.50-3.00                                                                     7  153   98                       258    .39    .22    .30
3.00-3.50                                                                              49    2                   51    .08    .04    .08
3.50-4.00                                                                                   31                   31    .05    .03    .03
4.00-4.50                                                                                    8                    8    .01    .01    .01
4.50-5.00                                                                                                         0    .00    .00    .00

5.00-5.50                                                                                                         0    .00    .00    .00
5.50-6.00                                                                                                         0    .00    .00    .00
6.00-6.50                                                                                                         0    .00    .00    .00
6.50-7.00                                                                                                         0    .00    .00    .00
7.00-7.50                                                                                                         0    .00    .00    .00

7.5 &OVER                                                                                                         0    .00    .00    .00

COL TOTAL   280      6996     10405      7836      4480      2097      1074       759        41         0     66123
               3668      7880      9009      6256      2874      1537       778       153         0         0

   A(%)      .4  5.5 10.6 11.9 15.7 13.6 11.9  9.5  6.8  4.3  3.2  2.3  1.6  1.2  1.1   .2   .1   .0   .0   .0

   B(%)      .2  3.1  6.0  6.7  8.9  7.7  6.7  5.3  3.8  2.4  1.8  1.3   .9   .7   .6   .1   .0   .0   .0   .0

   C(%)    56.3 56.1 53.0 47.0 40.3 31.4 23.8 17.1 11.8  7.9  5.5  3.7  2.4  1.5   .8   .2   .0   .0   .0   .0

     NUMBER OF HOURLY RECORDS THIS DIRECTION:  66123          ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:
        TOTAL HOURLY RECORDS ALL DIRECTIONS: 117346
               PER CENT IN THIS DIRECTION:  56.35              A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
                                                               B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
     NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS          C -- PERCENTAGE EXCEEDANCE DERIVED FROM  B
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DPW # MD
W/WANSYS
WAVENRGY

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

PAGE
PROJ PIX1
14-JAN-88

STATION: PICKERING -19.8M   WAVE DIRECTION: ALL

WIND DATA FOR STATION: PICKERING OH   SELECTED FROM: 72/05/02 TO 86/12/31 (TO)

------------------------- W A V E   P E R I O D   (S E C O N D S) -------------------------

SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT

WAVE HEIGHT (METRES)	0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.00-0.25	280	3668	6996	7880	8612	1098	493	141	63	46	16	18		1							29312	44.33	24.98	56.35
0.25-0.50					1793	7855	5779	1094	389	192	87	68	7	1							17265	26.11	14.71	31.37
0.50-0.75						56	1557	4706	1829	378	196	64	49	2	1						8838	13.37	7.53	16.66
0.75-1.00							7	309	2058	1577	349	141	71	6	4						4522	6.84	3.85	9.13
1.00-1.25								6	134	614	1231	426	111	45	4						2571	3.89	2.19	5.27
1.25-1.50									7	65	196	697	371	139	11						1486	2.25	1.27	3.08
1.50-1.75										2	19	105	405	283	74						888	1.34	.76	1.81
1.75-2.00											3	16	48	266	199	1					533	.81	.45	1.06
2.00-2.25												2	11	27	297	5					342	.52	.29	.60
2.25-2.50													1	8	163	26					198	.30	.17	.31
2.50-3.00															6	116	1				123	.19	.10	.14
3.00-3.50																5	32				37	.06	.03	.04
3.50-4.00																	8				8	.01	.01	.01
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.5 &OVER																					0	.00	.00	.00
COL TOTAL	280	3668	6996	7880	10405	9009	7836	6256	4480	2874	2097	1537	1074	778	759	153	41	0	0	0	66123			
A(%)	.4	5.5	10.6	11.9	15.7	13.6	11.9	9.5	6.8	4.3	3.2	2.3	1.6	1.2	1.1	.2	.1	.0	.0	.0				
B(%)	.2	3.1	6.0	6.7	8.9	7.7	6.7	5.3	3.8	2.4	1.8	1.3	.9	.7	.6	.1	.0	.0	.0	.0				
C(%)	56.3	56.1	53.0	47.0	40.3	31.4	23.8	17.1	11.8	7.9	5.5	3.7	2.4	1.5	.8	.2	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 66123
TOTAL HOURLY RECORDS ALL DIRECTIONS: 117346
PER CENT IN THIS DIRECTION: 56.35

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM B

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DPW * MD                                                                                                                                          PAGE
W/WANSYS                     SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS                                              PROJ PIXX
WAVENRGY                                                                                                                                          14-JAN-88
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                                      STATION: PICKERING - 9.8M                     WAVE DIRECTION: ALL

                     WIND DATA FOR STATION: PICKERING ON        SELECTED FROM:  72/05/02  TO  86/12/31   (        TO         )

             *----------------------------- W A V E   P E R I O D   ( S E C O N D S ) ------------------------------*          SEE FOOTNOTE FOR
                                                                                                                                  EXPLANATION OF
    WAVE       0.0   0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0   5.5   6.0   6.5   7.0   8.0   9.0  10.0  12.0  14.0          ROW & COL PERCENT
   HEIGHT      TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO     &     ROW
  (METRES)     0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0   5.5   6.0   6.5   7.0   8.0   9.0  10.0  12.0  14.0  OVER  TOTAL   A(%)   B(%)   C(%)

0.00-0.25      280  3668  6996  7880  9278  1415   511   149    70    54    22    23           1                                      30347  45.89  25.86  56.35
0.25-0.50                             1127  7560  5984  1222   438   235   117    74    10     2                                      16769  25.36  14.29  30.49
0.50-0.75                                     34  1335  4662  2525   544   253    97    60     1     1                                 9512  14.39   8.11  16.20
0.75-1.00                                            6   218  1378  1782   688   262   110    18     4                                 4466   6.75   3.81   8.09
1.00-1.25                                                  5    66   238   925   620   217   136     6                                 2213   3.35   1.89   4.29

1.25-1.50                                                        3    21    85   405   447   134    45                                 1140   1.72    .97   2.40
1.50-1.75                                                                    6    52   209   377    80                                  724   1.09    .62   1.43
1.75-2.00                                                                    1     4    14    91   274     2                            386    .58    .33    .81
2.00-2.25                                                                                7    17   242     5                            271    .41    .23    .48
2.25-2.50                                                                                      1   104    43                            148    .22    .13    .25

2.50-3.00                                                                                            3    98     1                      102    .15    .09    .13
3.00-3.50                                                                                                  5    29                       34    .05    .03    .04
3.50-4.00                                                                                                       11                       11    .02    .01    .01
4.00-4.50                                                                                                                                 0    .00    .00    .00
4.50-5.00                                                                                                                                 0    .00    .00    .00

5.00-5.50                                                                                                                                 0    .00    .00    .00
5.50-6.00                                                                                                                                 0    .00    .00    .00
6.00-6.50                                                                                                                                 0    .00    .00    .00
6.50-7.00                                                                                                                                 0    .00    .00    .00
7.00-7.50                                                                                                                                 0    .00    .00    .00

7.5 &OVER                                                                                                                                 0    .00    .00    .00

COL TOTAL      280        6996       10405        7836        4480        2097        1074         759          41           0         66123
                    3668        7880        9009        6256        2874        1537         778         153           0           0

    A(%)        .4   5.5  10.6  11.9  15.7  13.6  11.9   9.5   6.8   4.3   3.2   2.3   1.6   1.2   1.1    .2    .1    .0    .0    .0

    B(%)        .2   3.1   6.0   6.7   8.9   7.7   6.7   5.3   3.8   2.4   1.8   1.3    .9    .7    .6    .1    .0    .0    .0    .0

    C(%)      56.3  56.1  53.0  47.0  40.3  31.4  23.8  17.1  11.8   7.9   5.5   3.7   2.4   1.5    .8    .2    .0    .0    .0    .0


      NUMBER OF HOURLY RECORDS THIS DIRECTION:   66123              ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:
          TOTAL HOURLY RECORDS ALL DIRECTIONS: 117346
                    PER CENT IN THIS DIRECTION:   56.35              A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
                                                                     B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
      NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS               C -- PERCENTAGE EXCEEDANCE DERIVED FROM  B
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SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: PICKERING - 4.8M WAVE DIRECTION: ALL

WIND DATA FOR STATION: PICKERING OH SELECTED FROM: 72/05/02 TO 86/12/31 (TO)

	*---------------------------- W A V E	P E R I O D	(S E C O N D S)	------------------------*																		SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT		
WAVE HEIGHT (METRES)	0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.00-0.25	280	3668	6996	7880	9988	3848	1014	471	224	114	45	38		1							34567	52.28	29.46	56.35
0.25-0.50					417	5152	6416	2953	1030	498	267	118	30	2							16883	25.53	14.39	26.89
0.50-0.75						9	406	2761	2839	1108	367	239	169	8	3						7909	11.96	6.74	12.50
0.75-1.00								70	368	1065	1071	382	151	147	19						3273	4.95	2.79	5.76
1.00-1.25								1	19	86	324	622	371	127	36						1586	2.40	1.35	2.98
1.25-1.50										3	21	131	317	373	86						931	1.41	.79	1.62
1.50-1.75											2	6	32	100	333	2					475	.72	.40	.83
1.75-2.00												1	3	16	256	12					288	.44	.25	.43
2.00-2.25													1	4	23	99					127	.19	.11	.18
2.25-2.50															3	35	1				39	.06	.03	.07
2.50-3.00																5	33				38	.06	.03	.04
3.00-3.50																	7				7	.01	.01	.01
3.50-4.00																					0	.00	.00	.00
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.5 &OVER																					0	.00	.00	.00
COL TOTAL	280	3668	6996	7880	10405	9009	7836	6256	4480	2874	2097	1537	1074	778	759	153	41	0	0	0	66123			
A(%)	.4	5.5	10.6	11.9	15.7	13.6	11.9	9.5	6.8	4.3	3.2	2.3	1.6	1.2	1.1	.2	.1	.0	.0	.0				
B(%)	.2	3.1	6.0	6.7	8.9	7.7	6.7	5.3	3.8	2.4	1.8	1.3	.9	.7	.6	.1	.0	.0	.0	.0				
C(%)	56.3	56.1	53.0	47.0	40.3	31.4	23.8	17.1	11.8	7.9	5.5	3.7	2.4	1.5	.8	.2	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 66123
TOTAL HOURLY RECORDS ALL DIRECTIONS: 117346
PER CENT IN THIS DIRECTION: 56.35

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM B

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DPW * MD                                                                                                                     PAGE   11
W/WANSYS                    SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS                          PROJ PIX8
WAVENRGY                                                                                                                    04-MAY-88
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                                  STATION: PICKERING NGS OS                        WAVE DIRECTION: ALL

                   WIND DATA FOR STATION: PICKERING OH       SELECTED FROM:  87/03/01  TO  88/03/30    (        TO        )

                *------------------------- W A V E   P E R I O D   ( S E C O N D S ) ------------------------*     SEE FOOTNOTE FOR
                                                                                                                    EXPLANATION OF
   WAVE      0.0   0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0   5.5   6.0   6.5   7.0   8.0   9.0  10.0  12.0  14.0     ROW & COL PERCENT
  HEIGHT      TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO     &    ROW
 (METRES)    0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0   5.5   6.0   6.5   7.0   8.0   9.0  10.0  12.0  14.0  OVER  TOTAL   A(%)   B(%)   C(%)

0.00-0.25     24   207   488   544   567    77    50    24           5     2                                                       1988  43.68  24.47  56.01
0.25-0.50                            111   485   404   127    27     8    16                                                       1178  25.88  14.50  31.54
0.50-0.75                                    1    59   310   173    21    15     5                                                  584  12.83   7.19  17.05
0.75-1.00                                                20   143   207    20    18                                                  408   8.97   5.02   9.86
1.00-1.25                                                      9    45    85    22     5                                            166   3.65   2.04   4.84

1.25-1.50                                                            3    14    44    17                                             78   1.71    .96   2.79
1.50-1.75                                                                  4     5    36     6                                       51   1.12    .63   1.83
1.75-2.00                                                                              9    34                                       43    .94    .53   1.21
2.00-2.25                                                                  1          16    24                                       41    .90    .50    .68
2.25-2.50                                                                              3     3                                        6    .13    .07    .17

2.50-3.00                                                                                    3     1                                  4    .09    .05    .10
3.00-3.50                                                                                          4                                  4    .09    .05    .05
3.50-4.00                                                                                                                             0    .00    .00    .00
4.00-4.50                                                                                                                             0    .00    .00    .00
4.50-5.00                                                                                                                             0    .00    .00    .00

5.00-5.50                                                                                                                             0    .00    .00    .00
5.50-6.00                                                                                                                             0    .00    .00    .00
6.00-6.50                                                                                                                             0    .00    .00    .00
6.50-7.00                                                                                                                             0    .00    .00    .00
7.00-7.50                                                                                                                             0    .00    .00    .00

7.5 &OVER                                                                                                                             0    .00    .00    .00

COL TOTAL     24         488         678         513         352         156          67          30           0           0          4551
                   207         544         563         481         289          95          59           5           0           0

   A(%)       .5   4.5  10.7  12.0  14.9  12.4  11.3  10.6   7.7   6.4   3.4   2.1   1.5   1.3    .7    .1    .0    .0    .0    .0

   B(%)       .3   2.5   6.0   6.7   8.3   6.9   6.3   5.9   4.3   3.6   1.9   1.2    .8    .7    .4    .1    .0    .0    .0    .0

   C(%)     56.0  55.7  53.2  47.2  40.5  32.1  25.2  18.9  13.0   8.6   5.1   3.2   2.0   1.2    .4    .1    .0    .0    .0    .0

    NUMBER OF HOURLY RECORDS THIS DIRECTION:    4551             ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:
        TOTAL HOURLY RECORDS ALL DIRECTIONS:    8125
                 PER CENT IN THIS DIRECTION:   56.01              A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
                                                                  B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
    NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS              C -- PERCENTAGE EXCEEDANCE DERIVED FROM  B
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DPW * MD
W/WANSYS                                                                                                                    PAGE  11
WAVENRGY          SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS (COEFFICIENTS APPLIED)             PROJ PIX8
                                                                                                                           04-MAY-88
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                          STATION: PICKERING AT 55M                        WAVE DIRECTION: ALL

             WIND DATA FOR STATION: PICKERING OH          SELECTED FROM:  87/03/01  TO  88/03/30    (        TO        )

            *------------------------- W A V E    P E R I O D    ( S E C O N D S ) -------------------------*
WAVE         0.0  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  8.0  9.0 10.0 12.0 14.0       SEE FOOTNOTE FOR
HEIGHT        TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO    &        EXPLANATION OF
(METRES)     0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  8.0  9.0 10.0 12.0 14.0 OVER   ROW  ROW & COL PERCENT
                                                                                                            TOTAL   A(%)   B(%)   C(%)

0.00-0.25     24  207  488  544  567   77   50   24         5    2
0.25-0.50                         111  485  404  127   29    9   17                                              1988  43.68  24.47  56.01
0.50-0.75                                1   59  310  174   22   15    6                                         1182  25.97  14.55  31.54
0.75-1.00                                          20  140  211   21   19                                         587  12.90   7.22  17.00
1.00-1.25                                                9   40   88   28    7                                    411   9.03   5.06   9.77
                                                                                                                  172   3.78   2.12   4.71
1.25-1.50                                                     2   11   40   30
1.50-1.75                                                          2    1   27   23                                83   1.82   1.02   2.60
1.75-2.00                                                               1    3   31   17                           53   1.16   0.65   1.58
2.00-2.25                                                                         4   10    1                      52   1.14   0.64   0.92
2.25-2.50                                                                         1    3    4                      15   0.33   0.18   0.28
                                                                                                                    8   0.18   0.10   0.10
2.50-3.00
3.00-3.50                                                                                                           0   0.00   0.00   0.00
3.50-4.00                                                                                                           0   0.00   0.00   0.00
4.00-4.50                                                                                                           0   0.00   0.00   0.00
4.50-5.00                                                                                                           0   0.00   0.00   0.00
                                                                                                                    0   0.00   0.00   0.00
5.00-5.50
5.50-6.00                                                                                                           0   0.00   0.00   0.00
6.00-6.50                                                                                                           0   0.00   0.00   0.00
6.50-7.00                                                                                                           0   0.00   0.00   0.00
7.00-7.50                                                                                                           0   0.00   0.00   0.00
                                                                                                                    0   0.00   0.00   0.00
7.5 &OVER

COL TOTAL     24       488       678       513       352       156        67        30         0         0          0   0.00   0.00   0.00
                 207       544       563       481       289        95        59         5         0         0   4551

 A(%)         .5  4.5 10.7 12.0 14.9 12.4 11.3 10.6  7.7  6.4  3.4  2.1  1.5  1.3   .7   .1   .0   .0   .0   .0

 B(%)         .3  2.5  6.0  6.7  8.3  6.9  6.3  5.9  4.3  3.6  1.9  1.2   .8   .7   .4   .1   .0   .0   .0   .0

 C(%)       56.0 55.7 53.2 47.2 40.5 32.1 25.2 18.9 13.0  8.6  5.1  3.2  2.0  1.2   .4   .1   .0   .0   .0   .0

  NUMBER OF HOURLY RECORDS THIS DIRECTION:   4551          ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:
       TOTAL HOURLY RECORDS ALL DIRECTIONS:   8125
                   PER CENT IN THIS DIRECTION:  56.01          A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
                                                              B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
  NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS            C -- PERCENTAGE EXCEEDANCE DERIVED FROM  B
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JPW # MD                                                                                                          PAGE   11
W/WANSYS         SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS (COEFFICIENTS APPLIED)    PROJ PIX8
WAVENRGY                                                                                                      12-MAY-88
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                               STATION: PICKERING AT 65M   10 m         WAVE DIRECTION: ALL

            WIND DATA FOR STATION: PICKERING OH        SELECTED FROM:  87/03/01  TO  88/03/30   (         TO          )

            *------------------------- W A V E   P E R I O D  ( S E C O N D S ) ----------------------*       SEE FOOTNOTE FOR
                                                                                                              EXPLANATION OF
                                                                                                             ROW & COL PERCENT
 WAVE     0.0  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  8.0  9.0 10.0 12.0 14.0
HEIGHT    TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO    &    ROW
(METRES)  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  8.0  9.0 10.0 12.0 14.0 OVER TOTAL   A(%)  B(%)  C(%)

0.00-0.25  24  207  488  544  607  102   54   26          7    4                                           2063  45.33 25.39 56.01
0.25-0.50                           71  460  405  147   36    9   20                                      1148  25.23 14.13 30.62
0.50-0.75                                1   54  292  221   50   15   10                                   643  14.13  7.91 16.49
0.75-1.00                                          16   88  196   46   30    1                              377   8.28  4.64  8.58
1.00-1.25                                                7   25   64   37   18                              151   3.32  1.86  3.94

1.25-1.50                                                     2    7   17   33    4    1                     64   1.41  0.79  2.08
1.50-1.75                                                                   13   36    1                     50   1.10  0.62  1.29
1.75-2.00                                                               1    2   15   24    3                45   0.99  0.55  0.68
2.00-2.25                                                                         3    1    2                 6   0.13  0.07  0.12
2.25-2.50                                                                         1    3                      4   0.09  0.05  0.05

2.50-3.00                                                                                                     0   0.00  0.00  0.00
3.00-3.50                                                                                                     0   0.00  0.00  0.00
3.50-4.00                                                                                                     0   0.00  0.00  0.00
4.00-4.50                                                                                                     0   0.00  0.00  0.00
4.50-5.00                                                                                                     0   0.00  0.00  0.00

5.00-5.50                                                                                                     0   0.00  0.00  0.00
5.50-6.00                                                                                                     0   0.00  0.00  0.00
6.00-6.50                                                                                                     0   0.00  0.00  0.00
6.50-7.00                                                                                                     0   0.00  0.00  0.00
7.00-7.50                                                                                                     0   0.00  0.00  0.00

7.5 &OVER                                                                                                     0   0.00  0.00  0.00

COL TOTAL  24       488       678       513       352       156        67        30         0         0   4551
                207       544       563       481       289        95        59         5         0         0

  A(%)     .5  4.5 10.7 12.0 14.9 12.4 11.3 10.6  7.7  6.4  3.4  2.1  1.5  1.3   .7   .1   .0   .0   .0   .0

  B(%)     .3  2.5  6.0  6.7  8.3  6.9  6.3  5.9  4.3  3.6  1.9  1.2   .8   .7   .4   .1   .0   .0   .0   .0

  C(%)   56.0 55.7 53.2 47.2 40.5 32.1 25.2 18.9 13.0  8.6  5.1  3.2  2.0  1.2   .4   .1   .0   .0   .0   .0

   NUMBER OF HOURLY RECORDS THIS DIRECTION:    4551         ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:
       TOTAL HOURLY RECORDS ALL DIRECTIONS:    8125
                   PER CENT IN THIS DIRECTION: 56.01        A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
                                                            B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
   NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS         C -- PERCENTAGE EXCEEDANCE DERIVED FROM  B
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DPW * MD
W/WANSYS            SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS (COEFFICIENTS APPLIED)                        PAGE   11
WAVENRGY                                                                                                                                 PROJ PIX8
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                                                                                                                                         04-MAY-88
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                                    STATION: PICKERING AT 70M                              WAVE DIRECTION: ALL

                    WIND DATA FOR STATION: PICKERING OH          SELECTED FROM:  87/03/01  TO  88/03/30    (         TO         )

             *--------------------------- W A V E   P E R I O D   ( S E C O N D S ) -------------------------*          SEE FOOTNOTE FOR
  WAVE         0.0   0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0   5.5   6.0   6.5   7.0   8.0   9.0  10.0  12.0  14.0            EXPLANATION OF
 HEIGHT         TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO    TO     &    ROW    ROW & COL PERCENT
(METRES)       0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0   5.5   6.0   6.5   7.0   8.0   9.0  10.0  12.0  14.0  OVER  TOTAL   A(%)   B(%)   C(%)

0.00-0.25       24   207   488   544   647   241    80    52    18    12     6                                                       2319  50.96  28.54  56.01
0.25-0.50                                 31   321   417   212    65    33    36     2                                                 1117  24.54  13.75  27.47
0.50-0.75                                        1    16   210   232   112    23    31     4                                            629  13.82   7.74  13.72
0.75-1.00                                                    7    33   120    57    24     7     1                                      249   5.47   3.06   5.98
1.00-1.25                                                          4    12    29    32    34     1     2                                114   2.50   1.40   2.92

1.25-1.50                                                                      5     5    16    34           3                           63   1.38   0.78   1.51
1.50-1.75                                                                            1     6    18    23     2                           50   1.10   0.62   0.74
1.75-2.00                                                                                        4     1                                  5   0.11   0.06   0.12
2.00-2.25                                                                                        1     4                                  5   0.11   0.06   0.06
2.25-2.50                                                                                                                                 0   0.00   0.00   0.00

2.50-3.00                                                                                                                                 0   0.00   0.00   0.00
3.00-3.50                                                                                                                                 0   0.00   0.00   0.00
3.50-4.00                                                                                                                                 0   0.00   0.00   0.00
4.00-4.50                                                                                                                                 0   0.00   0.00   0.00
4.50-5.00                                                                                                                                 0   0.00   0.00   0.00

5.00-5.50                                                                                                                                 0   0.00   0.00   0.00
5.50-6.00                                                                                                                                 0   0.00   0.00   0.00
6.00-6.50                                                                                                                                 0   0.00   0.00   0.00
6.50-7.00                                                                                                                                 0   0.00   0.00   0.00
7.00-7.50                                                                                                                                 0   0.00   0.00   0.00

7.5 &OVER                                                                                                                                 0   0.00   0.00   0.00

COL TOTAL       24         488         678         513         352         156          67          30           0           0        4551
                     207         544         563         481         289          95          59           5           0           0

   A(%)         .5   4.5  10.7  12.0  14.9  12.4  11.3  10.6   7.7   6.4   3.4   2.1   1.5   1.3    .7    .1    .0    .0    .0    .0

   B(%)         .3   2.5   6.0   6.7   8.3   6.9   6.3   5.9   4.3   3.6   1.9   1.2    .8    .7    .4    .1    .0    .0    .0    .0

   C(%)       56.0  55.7  53.2  47.2  40.5  32.1  25.2  18.9  13.0   8.6   5.1   3.2   2.0   1.2    .4    .1    .0    .0    .0    .0

    NUMBER OF HOURLY RECORDS THIS DIRECTION:    4551              ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:
        TOTAL HOURLY RECORDS ALL DIRECTIONS:    8125
                 PER CENT IN THIS DIRECTION:   56.01               A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
                                                                   B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
    NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS               C -- PERCENTAGE EXCEEDANCE DERIVED FROM  B
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