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A PRELIMINARY OCEANOGRAPHIC SURVEY OF THE DAMARISCOTTA RIVER ESTUARY, LINCOLN COUNTY, MAINE

BERNARD J. MCALICE

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Bernard J. McAlice
Department of Oceanography, University of Maine
Ira C. Darling Center, Walpole, Maine 04573

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ABSTRACT

The Damariscotta River estuary is a narrow embayment which receives a limited amount of fresh water. The estuarine portion has a MLW volume of 123.4×10^6 m^3, a tidal volume of 56.2×10^6 m^3, and a mean summer flushing time of 4-5 weeks. The estuary is stratified near its head but approaches a well mixed condition further seaward. Seawater moving upstream at depth is important in the circulation.

Surficial sediments are for the most part poorly to extremely poorly sorted, clayey to sandy silts; 3-5ϕ are the modal size classes. Rocky bottoms and lag deposits occur in high energy areas. Sediments are apparently modern estuarine deposits of local origin and reworked glacial material.

Except for some bacterial pollution, sewage from Damariscotta and Newcastle has no noticeable effect on water quality. Seasonal and spatial differences in temperature, salinity, dissolved oxygen and inorganic nutrients are discussed.

INTRODUCTION

The Damariscotta River estuary (Fig. 1) is one of many embayments having a general northeast-southwest trend which dissect the central and western coast of Maine. It is a narrow embayment, properly a ria, which extends from the southern end of Inner Heron Island to the head of Salt Bay, a distance of about 29 km. The only significant single source of fresh water is the outflow from Damariscotta Lake into Salt Bay. Raw domestic sewage and restaurant and laundry waste water are discharged into the upper end of the estuary near the Main Street bridge; the taking of shellfish is prohibited north of Little Point.

There are few published reports on the abiotic characteristics of the estuary. Graham and Boyar (1965) gave some information on temperatures and salinities in the lower estuary, and Hulburt (1968) reported on limited hydrographic observations in the same area. The subaerial geology around Salt Bay was described by Leavitt and Perkins (1935). Myers (1965) discussed the circulation and post-glacial geology of Salt Bay.

The research described here was undertaken to determine the present hydrographic conditions, flushing times, and surficial sediment distribution in the estuary and to provide baselines for future studies.

METHODS

Morphometry

High and low water areas of the Damariscotta River from Fort Island to the Damariscotta-Newcastle bridge (Main Street bridge) were determined by planimetry from copies of the original 1:10,000 scale boat sheets of the 1943 Coast and Geodetic Survey study of the river. Mean low and high water depths and volume increments were calculated from these areas and the survey depths. Test soundings and comparison of the boat sheets with more recent aerial photographs (U.S. Coast and Geodetic Survey Project VLN by James W. Sewall Co., 1956, photographs GS-VLN--3-4, 3-5,3-24,3-25) were also made.

The high water area from the Main Street bridge to the head of Salt Bay was planimetered from C. S. Chart 314. The region between the bridge and the Indraft was surveyed by Goldthwait in 1932 (Goldthwait, 1935); his map is reproduced in Myers (1965). No adequate bathymetric survey of Salt Bay itself was found. Some depth measurements have been made by University of Maine personnel and these, together with aerial photographs, permitted volume approximations to be made.

Temperature and salinity

Ten mid-channel hydrographic stations were established (Fig. 2). Dates on which these stations were occupied are shown in Table 1. On several occasions additional stations near the east and west banks at each location were added to give cross-channel temperature and salinity profiles.

At each station temperature and salinity were measured at depths of 1/2, 3, 6, 9, 12, 18 and 24 m, or until bottom was reached. A Beckman RS5-3 field salinometer-thermometer was used. This instrument was checked periodically with a laboratory thermometer and a Beckman RS7B laboratory salinometer calibrated against standard seawater.

Dissolved oxygen and inorganic nutrients

Water samples were collected in 2.5 liter Van Dorn bottles. Dissolved oxygen was measured using prepackaged reagents (Hach Chemical Co.)in a modification of the standard Winkler technique which employs phenylarsine oxide instead of sodium thiosulfate for titration.

Reactive phosphate (PO_4-P) and reactive silicate (SiO_2-Si) were determined by the methods of Strickland and Parsons (1965); that of Mullin and Riley (1955) was used for combined nitrite and nitrate (NO_2-N + NO_3-N).

Flushing times

Since tidal action is the dominant mixing process in the Damariscotta River estuary, flushing rates can be approximated from morphometric data and the tidal range alone. The simplest determination is

$$t = \frac{V + P}{P} \tag{1}$$

where t is the flushing time in tidal periods, V is the low water volume of the estuary, and P is the volume of the tidal prism. This assumes complete mixing in the estuary and thus sets only a lower limit to the flushing time, since the assumption is rarely justified.

Ketchum (1951) refined the tidal prism method by dividing the estuary into several segments, each having a length equal to one tidal excursion and a high tide volume equal to the low tide volume of the next segment seaward. Complete mixing within each segment is assumed and an exchange ratio calculated for each. If V_n is the low water volume of the n^{th} segment and P_n the corresponding tidal prism, then the exchange ratio r_n for the segment is given by

$$r_n = \frac{P_n}{V_n + P_n} \tag{2}$$

The segment which receives the fresh water discharge is assigned a tidal prism equal to R, the volume of runoff during a tidal cycle. The volume of fresh water accumulated in the n^{th} segment, Q_n, is given by

$$Q_n = \frac{R}{r_n} \qquad (3)$$

and its flushing time in tidal cycles by

$$t = \frac{1}{r_n} = \frac{Q_n}{R} \; . \qquad (4)$$

The flushing time for the estuary is obtained by summing the flushing times of the several segments. If mixing within each segment is not complete, this method will underestimate the flushing time.

If the vertical distribution of salinity at a number of stations is known, together with the volume increments between stations, flushing time can be calculated following Bowden (1967). If S_o is the salinity of water outside the estuary which is available for mixing and S the salinity at any given point inside, then the fresh water content at that point is given by

$$f = \frac{S_o - S}{S_o} \; . \qquad (5)$$

The total volume of fresh water accumulated in the estuary is

$$F = f\int d(\text{volume})$$

integrated over the total volume. If a steady state is assumed, so that R is also the rate of removal of fresh water, then the flushing time is

$$t = \frac{F}{R} \; . \qquad (6)$$

The fresh water contents and flushing times of individual segments can be calculated in the same way.

Surface currents

Current drogues were released at various points in the estuary during the summer of 1970. Releases were made near high and low slack water and the drogues were tracked from a small boat during the succeeding ebb or flood tide. Drogue positions were determined from horizontal sextant angles subtended by prominent landmarks and estimated distances from shoreline features and navigation aids. It was found that only two drogues could be successfully tracked at once. Temperature and salinity measurements were made at the drogue positions at half-hour or hour intervals. Grounded drogues were reset into the channel. A total of 25 flood and 28 ebb tracks was obtained.

Sediments

Surficial sediments were sampled with a Ponar grab sampler at 50 locations in the Damariscotta River. Pint aliquots were taken from the top few centimeters in plastic containers and stored in a freezer upon return to the laboratory if analysis was not to begin immediately.

For moisture content determination a 20 g aliquot was weighed, oven dried at 100°C for 24 hours, cooled in a dessicator at room temperature for 24 hours and reweighed. The organic content of this aliquot was determined from weight loss of the dried material after ashing at 600°C for 24 hours.

Hydrometer analysis of a 100 g aliquot, dispersed with 10 ml of 5% sodium metaphosphate, was used to determine the particle size distribution of the <63 μ fraction. The same aliquot was then wet sieved through a set of 1ϕ interval (2000, 1000, 500, 250, 125 and 63 μ) ASTM sieves to obtain the size distribution of the >63 μ fraction. The organic contents of the various sieve residues were determined as above.

Size was plotted against cumulative weight percent on semilogarithmic graph paper and, wherever possible, the graphic mean (M_z), inclusive graphic standard deviation (σ_I) and inclusive graphic skewness (Sk_I) (Folk and Ward, 1957) were calculated.

M_z is a measure of average particle size and σ_I of sorting, higher values indicating more poorly sorted sediments. The cumulative curves were extrapolated to zero at 14ϕ as recommended by Folk and Ward (1957).

Sediments were classified according to the trilinear system of Shepard (1954) on the basis of their total percentages of gravel (>2 mm), sand (>63 μ to 2 mm), silt (>4 μ to 63 μ) and clay (<4 μ). The >2 mm fraction was not graded further. Those stations yielding no sievable sediments--that is, where the samples consisted only of pebble to boulder-sized rocks--were classified as "rocky", and those from which no material was recovered as "hard bottom".

RESULTS AND DISCUSSION

Morphology and morphometry

The Damariscotta River estuary occupies a drowned river valley having a northeast-southwest trend in the northern part, changing to north-south nearer the coast, following the general trend of the bedrock structure (Johnson, 1925). The valley is asymmetrical in section, with steeper western slopes, ascribed to the 30^{o}-50^{o} west-southwest dip of the bedrock foliation by Myers (1965), although Perkins and Smith (1925) noted the same asymmetry associated with vertical foliation in valleys a few miles to the northeast. The bedrock consists chiefly of metamorphosed early to middle Paleozoic sedimentary rocks, except for the vicinity of Fitch Point which is occupied by a granite intrusive body of late Paleozoic age (Doyle, 1967).

The valley deepens seaward but the gradient is not constant, being broken by basins and depressions separated by topographic highs (Figs. 3, 4). Extreme depths in the region northward from Fort Island exceed 30 m and there is a 27 m depression just north of Fitch Point.

In the Damariscotta River the estuarine region, defined as that area in which seawater is "measurably diluted with fresh water" (Pritchard, 1967), does not generally extend seaward of Fort Island. Vertical and lateral constrictions exist at Fort Island, Fitch Point and south of the Indraft, partitioning the estuary into three more or less distinct basins (Figs. 3, 4). Morphometric data for the estuary north of Fort Island are given in Table 2.

The volume of the tidal prism, the difference between low tide and high tide volumes, is 56×10^6 m^3 for the estuary north of Fort Island. This quantity of water flows in and out through the Fort Island narrows during each tidal cycle. Currents in the narrows are very strong. The cross-sectional area available for tidal flow at mid-tide is about 2400 m^2, so the mean current speed over a tidal period is about 1.1 m/sec. Peak celerities are considerably higher. Of the total water volume entering the estuary on a flood tide, 30.8×10^6 m^3 remains in the lower basin. This is 55% of the total tidal prism and represents a 33% increase in the low water volume of the basin.

The remainder of the tidal prism, 25.4×10^6 m^3, enters the middle basin through the constriction at Fitch Point, with an average speed of 0.8 m/sec. Of this water 20.1×10^6 m^3, which is 36% of the total tidal prism and 78% of the low water volume of the middle basin, stays in that basin. The last increment, 5.3×10^6 m^3, enters Salt Bay through the narrow channel north of the Main Street bridge. Mean current speed under the bridge is about 1 m/sec.

The tidal wave is impeded at each of the three major constrictions, so that the basins tend to fill in sequence, and high water at Newcastle occurs 18 min. later than at East Boothbay (Tide Tables, 1971). Flooding into Salt Bay continues for 30-60 min. after high stand at Newcastle. On the ebb the flow from Salt Bay is again retarded and low water at Newcastle lags that at East Boothbay by 24 min. (Tide Tables, 1971)

Temperature and salinity

Seasonal changes in temperature and salinity at stations D1 and D7 are shown in Figure 5. Figure 6 shows vertical sections of temperature and salinity from the Main Street bridge to Fort Island for comparison of tidal and seasonal differences.

The estuary is vertically and longitudinally stratified to some extent with respect to both salinity and temperature throughout most of the year. Thermal stratification is maximal in midsummer and becomes weak and inverse during the winter. Temperature decreases seaward from about April until mid-October; during the rest of the year the shallow upstream portion is cooler than the lower estuary. Pronounced vertical and longitudinal salinity gradients are general in the region between the Main Street bridge and Fitch Point or Kelsey Point.

Strong mixing occurs on the upriver sides of the Fort Island and Fitch Point constrictions on the flooding tide and conditions approaching vertical homogeneity are present in these areas at high water. During the flood, vertical inversions of temperature and salinity are common in these regions of strong mixing. Mixing is less effective on the ebb and marked vertical stratification extends south of Fitch Point as the relatively fresh upstream water overrides the denser water downstream.

The longitudinal salinity sections indicate the presence of a typical two-layered circulation pattern, with fresher water moving seaward at the surface and more saline water moving upriver near the bottom. Two seabed drifters, one released off Cape Cod by Woods Hole Oceanographic Institution and the other of unknown origin, have been recovered in the Damariscotta River, the former north of Wentworth Point and the latter near Hall Point. These recoveries substantiate the existence of a net landward flow at depth.

The cross-channel sections revealed no regular lateral gradients of temperature or salinity. There is a tendency for somewhat denser water to occupy the deeper portion of the channel at all stages of the tide south of Kelsey Point and to be found closer to both shores north of Fitch Point on the ebb with less dense water in mid-channel. Local surface lenses of low salinity water occur after rains and are attributed to localized fresh water runoff. High temperatures and salinities are sometimes found at the surface in the vicinity of tidal flats where solar heating is more effective. These phenomena all involve temperature and salinity differences on the order of $0.5^{\circ}C$ and $0.2\text{-}0.3^{\circ}/oo$ and are not considered important in the general dynamics of the system.

Dissolved oxygen and inorganic nutrients

Figure 7 shows the seasonal cycles of dissolved oxygen and nutrients at station D7. DO levels approach or exceed saturation values through much of the year. The lowest concentration found occurred during late summer but did not fall below 75% saturation.

Phosphate varied generally between about 0.5-1.5 μg at /l; no definite seasonality was detected. The "classical" phosphate cycle has a single maximum, with high winter and low summer levels. Smayda (1957) described an "atypical" phosphate cycle in Narragansett Bay where highest values were found during the summer.

The shape of the nitrate curves is that generally considered as typical of inshore waters. The high winter levels decline as nitrate is consumed to support the spring phytoplankton bloom. Low levels are then present from late spring until midsummer when a lesser augmentation occurs which supports a late summer surge of plankton growth. Nitrate is then reduced to low levels again until its winter enhancement. Uyeno (1966) reported the same sort of nitrate cycle in Malpeque Bay, Prince Edward Island, but Pratt (1965) found no summer increase in Narragansett Bay.

Silicate was highest in early winter, with a gradual decline to low summer levels being followed by renewal again in the fall. This sort of cycle seems to be typical for inshore temperate waters (Pratt, 1965; Ewins and Spencer, 1967).

Annual cycles and levels of DO and nutrients in the upper estuary are generally similar to those at station D7 (Petrie, unpublished data), though silicate tends to be present in higher concentrations closer to the head of the estuary. Both nitrate and silicate are generally less abundant in the Damariscotta than in the neighboring Sheepscot River estuary; phosphate levels are similar in the two areas (McAlice, unpublished data).

High and low tide sampling along the shores of Damariscotta and Newcastle revealed no substantial nutrient loading (Fig. 8). Relatively high phosphate concentrations were present close to the laundromat's outfall pipe. This enrichment was not detectable a few hundred feet away. The low tide nitrate levels were higher and more variable than those at high tide. Some nitrogen is probably present in this area in reduced form--ammonia and amino acids--which our method would not detect.

Classifications of SA, SB-1, SB-2 and SC are required by law (Maine Revised Statutes Annotated, Title 38, Section 370) for various portions of the Damariscotta River (Fig. 9). Since the entire Damariscotta River is a "shellfish growing area", the criteria for the first three classifications are identical (Table 3) and the entire river, except for the shores of South Bristol south of Jones Point, must meet SA standards. Bacterial contamination from business and domestic sewage is the only present impediment to attainment of these standards.

Flushing times

Segmentation of the Damariscotta River for flushing time determination using the method of Ketchum (1951) is shown in Figure 10. Volumes and calculated exchange ratios and flushing times are given in Table 4. The computed flushing time for Salt Bay is about 7 tidal periods (3 1/2 days), that for the region between the Indraft and Fitch Point about the same, and that for the area between Fitch Point and Fort Island about 14 tidal periods

(7 days). These are minimum flushing time estimates, based on the assumption of complete mixing within each segment.

The outflow, R, from Damariscotta Lake, is about 2.83 m^3/sec or 1.26 x 10^5 m^3 per tidal period during early summer but is reduced during the dry period of midsummer to about 50% of this value, or 0.63 x 10^5 m^3 per tidal period. The calculated quantity of fresh water accumulated in each segment, and the cumulative total fresh water in the river at high tide, using 1.26 x 10^5 m^3 for R and the exchange ratios from Table 4, are given in Table 5.

The flushing time method outlined by Bowden (1967) uses fresh water as a tracer and flushing time determination is based on the observed salinity distribution and fresh water inflow. The results summarized in Tables 6 and 7 were derived from several salinity sections obtained during the summer of 1968 close enough to the times of either high or low water so that no substantial volume error was introduced into the calculation. The normal R value of 1.26 x 10^5 m^3 was used for 1 July-23 July and the midsummer values of 0.63 x 10^5 m^3 for 29 July - 7 August, on the basis of the marked reduction in fresh water content of the river between 23-29 July. Adequate salinity data for two Salt Bay segments were available for two high tides only; no data were obtained for segment 0.

Comparison of Tables 4 and 5 with Tables 6 and 7 shows that the assumption of complete mixing leads to flushing time and fresh water accumulation predictions which are substantially lower than those obtained from the observed distribution of salinity. Mixing is not complete, as is apparent from the vertical distribution of salinity. The discrepancy is sufficiently large to argue against the use of the segmentation method for flushing time or pollution studies in the Damariscotta River estuary. The most poorly mixed section of the estuary is segment 4, and this is the only segment for which high tide and low tide salinity data yield substantially different flushing times. The average summer flushing time for the entire river north of Fort Island is, from these results, on the order of 5 weeks. Tidal action is the dominant factor in the system, and variations in fresh water runoff probably do not have a marked effect on flushing.

The net seaward non-tidal drift through a cross-section can be calculated from data on the cross-section area, river flow and fresh water fraction (Ketchum, 1950). The non-tidal drifts through the cross-sections at the seaward ends of segments 4-8 were calculated (Table 8). The product of the non-tidal drift and cross-section area gives the net volume of water moving seaward through the section during a tidal period. These volumes range from about 5-10 times the fresh water inflow into Salt Bay (Table 8). The balance of this seaward moving water must be made up by higher salinity water entrained from that moving upriver near the bottom. Its quantity (1-2.2 x 10^6 m^3 per tidal period) indicates that this landward flow is an important factor in the circulation.

According to Pritchard's (1955) classification, based on the salinity distribution, the Damariscotta River estuary is a type B or partially mixed estuary north of the vicinity of Wentworth Point and approaches a type D or vertically homogeneous condition between Wentworth Point and Fort Island. Hansen and Rattray (1966) proposed a classification scheme based on dynamic considerations. This is a two parameter classification. It employs a stratification parameter $\delta S/S_0$, which is the ratio of the surface to bottom salinity difference to the average salinity of the section, and a circulation parameter u_s/U_f, which is the ratio of the net surface current to the mean fresh water velocity through the section.

Ideally, vertical current and salinity profiles made simultaneously at several stations over a full tidal cycle and at several times of the year should be available. My data on morphometry, salinity and surface currents admit only a rough approximation of the two parameters for segments 4-8. These are plotted on a stratification-circulation diagram (Fig. 11) together with results from other estuaries (Bowden and Gilligan, 1971).

Segment 4 is type 1, with net flow seaward at all depths, ranging from type 1a, well mixed, at low water to type 1b, with considerable stratification, at high water. Water in this segment is mixed on the ebb as it flows through the narrow passage between the Indraft and the Main Street bridge and the channel between Hall and Little Points. On the flood, water of higher salinity from downstream underrides the less dense water upstream, with substantial mixing occurring only north of the Main Street bridge.

Segments 5-8 are type 2a, with a reversal of net flow at depth and upstream salt transfer by both advection and diffusion. In all these segments, mixing is more effective on the flood, while on the ebb water of lower salinity from further up the estuary enhances the stratification.

Surface currents

Paths of current drogues released on ebb and flood tides are shown in Figures 12 and 13 respectively. The current patterns are what would be expected in a long and narrow embayment, being largely up and down river with small local vagaries.

Ebb currents have a tendency to follow the river channel while flood currents are more diffuse. On the ebb there are eddies south of the Main Street bridge, Hall Point, Merry Island, and in the vicinity of Wentworth Point and the cove north of Miller Island. The ebb flow in the Carlisle Point area is entirely to the westward of Miller Island, and there seems always to be a residual northward flow to the east and north of the island. The main ebb flow south of Miller Island is along the east side of the embayment. On the flooding tide the initial flow north of Fort Island is east and south into Seal Cove; a similar pattern is found north of Fitch Point. Water floods past Miller Island on both sides; that portion eastward of the island continues directly upriver, while much of that to the westward enters Pleasant Cove on the early flood. On both tides the strongest surface flows occur on the down-current sides of major constrictions.

Sediments

Historical summary: The Damariscotta River occupies a bedrock valley which was modified, but not created, by Pleistocene glaciation (Johnson, 1925). Deglaciation began more than 13,000 years ago. As the ice retreated up the valley, ice-contact and outwash deposits were laid down (Leavitt and Perkins, 1935). Global glacial melting caused a eustatic rise in sea level which was more rapid than the isostatic crustal rebound so that the sea transgressed over large areas of coastal Maine and at times was at or near the retreating ice limit (Borns and Hagar, 1965). The maximum extent of the marine transgression is dated at about 12,900 years ago by Borns and Hagar (1965). Crustal rebound then caused a regression of the post-glacial sea to a level which Myers (1965) determined was about 6 m below present sea level in Salt Bay; Bloom (1963) found 11 m of post-glacial emergence at Scarboro, Maine. Relative sea level along the Maine coast has been rising again for the past 4200 years (Bloom, 1963).

During the inundation an extensive layer of marine blue-grey silt and clay was deposited in coastal and central Maine. This deposit, named the Presumpscot Formation by Bloom (1960), has been traced as far as the Kennebec River valley north of Madison by Borns and Hagar (1965), and Myers (1965) assigns to it the marine clay overlaying glacial drift around Salt Bay. The top of the Presumpscot Formation in central Maine is now over 120 m above sea level.

Textural characteristics: Sediment sampling stations are shown in Figure 14 and pertinent data from the textural analyses are summarized in Table 9.

Those portions of the study area which are not composed of bedrock or boulders are covered for the most part with poorly to extremely poorly sorted clayey to sandy silts (Figs. 15, 16, Table 9). The modal size classes of the sediments are very fine sand, coarse silt and medium silt (3-5ϕ). The finest sediments occur in the region between Little Point and Fitch Point and are restricted to the deeper portions of the channel south of Perkins Point. Rocky bottoms and lag deposits from which much of the fine material has been removed are found near the major constrictions in the river where tidal currents are strongest.

Of the samples for which skewness could be determined, all have positive skewness, showing an excess of fine material (Table 9). Duane (1964) concluded that positive skewness was indicative of low energy environments and areas of deposition, while negative skewness characterized high-energy areas of non-deposition or erosion.

It is not possible to reconstruct the depositional history of the river on the basis of grab samples alone but some speculation is possible. Borings taken about 40 m off Wentworth Point during construction of the Darling Center pier showed 3-4 m of "very loose" silty sand overlaying up to 6 m of silty clay which in turn rested on bedrock or sandy gravel. This silty clay can be tentatively assigned to the Presumpscot Formation, as can the extensive clay deposits along both banks of the river which once supported more than a score of brickyards. The sand would then represent recent deposition over the post-glacial clay. Castner (1956) noted that oyster beds were found beneath several feet of silt south of the Main Street bridge. The fine sediments present in the Damariscotta River now have a sand-silt-clay composition different from that of the Presumpscot clay, which is about 20% sand, 40% silt and 40% clay (Goldthwait, 1951; Bloom, 1960).

It seems likely that the present channel was cut into earlier sediments (clay and outwash sands) and is now floored by modern estuarine deposits of fine material and reworked glacial deposits.

The surficial sediments are probably mainly of local origin. The drainage area of Damariscotta Lake is not large and the lake is separated from Salt Bay by a natural dam so that it would act as a settling basin for all but the finest material washed into it by erosion. The clay deposits along the river would also supply fine sediments. Clearing of forests for pasture land may have led to an increase in sedimentation from subaerial erosion within historic times. Upriver transport of coastal sediments by the landward movement of high salinity bottom water has been demonstrated for estuaries of the Atlantic coastal plain (Meade, 1969) and such movement occurs in the Damariscotta River estuary. Sediments off the mouth of the estuary are predominantly gravel, sand and clay (Shepard, 1939) and landward migration of finer particles may occur. Fine material is constantly in suspension in the river and settles out on any surface covered by quiet water. The apparent absence of significant changes in the river during the past 28 years, however, indicates that it now is either in dynamic equilibrium or has a very low sedimentation rate.

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Table 1. Hydrographic sampling dates.

Date	Stations	Date	Stations
19 June 1968	D1-D7	2 July	D1-D10
25 June	D1-D8	9 July	"
2 July	"	25 July	"
5 July	"	7 August	D7
8 July	"	20 August	"
11 July	"	4 September	"
12 July	"	10 December	"
13 July	"	20 February 1970	"
15 July	"	13 March	"
16 July	"	7 April	"
23 July	D1-D10	7 May	"
29 July	D1-D8	16 June	"
30 July	D1-D10	30 June	"
3 August	"	13 July	"
7 August	"	28 July	"
15 August	"	12 August	"
20 August	"	31 August	"
27 August	"	22 September	"
29 August	D4-D10	7 October	"
13 June 1969	D1-D7	19 October	D2-D7
17 June	D1-D10	21 October	D7
26 June	"	11 November	"
1 December 1970	D1-D8	30 March	D7
12 January 1971	D7	13 April	"
27 January	"	23 April	D1-D8
17 February	"	11 May	D7
10 March	"	25 May	"
17 March	D1-D8		

Table 2. Morphometric data for the Damariscotta River north of Fort Island.

Region	Mean Low Water			Mean High Water		
	Area, km^2	Mean depth, m	Volume 10^6 m^3	Area, km^2	Mean depth, m	Volume 10^6 m^3
Salt Bay, north of Main St. bridge	2.26	1.38	3.11	3.01	2.80	8.42
Main St. bridge to Fitch Point	5.29	4.88	25.82	7.26	6.32	45.93
Fitch Point to Fort Island	9.67	9.76	94.42	11.33	11.05	125.23
Total	17.22	7.16	123.35	21.60	8.31	179.58

Table 3. Bacterial standards for marine waters in Maine. Data from Maine Revised Statutes Annotated, Title 38, Section 364.

		Shellfish Growing Area				Non-Shellfish Growing Area			
		Coliforms		Fecal Coliforms		Coliforms		Fecal Coliforms	
Class	Uses	1	2	1	2	1	2	1	2
SA	All clean water uses, including water contact and fishing	70	230	15	50	70	230	15	50
SB1	Same as SA	70	230	15	50	240	500	50	150
SB2	Recreational use, including water contact and fishing	70	230	15	50	500	1000	100	200
SC	Recreational boating, fishing and similar uses except primary water contact	700	2300	150	500	1500	5000	300	1000
SD	Power generation, navigation, industrial uses	"The numbers of coliform bacteria allowed in these waters shall...not, in the determination of the commission, indicate a condition harmful to the public health or impair any usage ascribed to this classification."							

1. The median numbers of coliform or fecal coliform bacteria in any series of representative samples shall not exceed the tabulated number per 100 milliliters.

2. Not more than 10% of the samples shall exceed the tabulated number per 100 milliliters.

Table 4. Damariscotta River segment volumes, exchange ratios and flushing times based on tidal prism.

Segment	Segment Volumes, 10^6 m^3 Low Water	High Water	Tidal Prism	Cumulative Volumes, 10^6 m^3 Low Water	High Water	Tidal Prism	Exchange Ratio r_n	Flushing time in Tidal Periods, t	Cumulative Flushing time in Tidal periods, t
0	0.230	0.356	0.126	0.230	0.355	0.125	0.354	2.82	2.82
1	0.356	0.673	0.317	0.585	1.028	0.443	0.472	2.12	4.94
2	0.673	1.596	0.923	1.258	2.624	1.366	0.578	1.73	6.67
3	1.596	3.785	2.189	2.854	6.409	3.555	0.578	1.73	8.40
4	3.785	13.379	9.594	6.639	19.788	13.149	0.717	1.39	9.79
5	13.379	18.100	4.721	20.018	37.888	17.870	0.261	3.83	13.62
6	18.100	24.617	6.517	38.118	62.505	24.387	0.265	3.78	17.40
7	24.617	33.660	9.043	62.735	96.165	33.430	0.269	3.72	21.12
8	33.660	44.721	11.061	96.395	140.886	44.491	0.247	4.04	25.16
9	44.721	57.120	12.399	141.116	198.006	56.890	0.217	4.61	29.79

Table 5. Calculated local and cumulative volumes of fresh water in Damariscotta River segments at high tide, based on a fresh water inflow volume of 1.26 x 10^5 m^3 per tidal cycle.

Segment	r_n	Q_n, 10^6 m^3	ΣQ_n, 10^6 m^3	Q_n as percentage of High Tide Volume
0	0.354	0.356	0.356	100.0
1	0.472	0.267	0.623	41.1
2	0.578	0.218	0.841	14.5
3	0.578	0.218	1.059	5.8
4	0.717	0.178	1.237	1.3
5	0.261	0.482	1.719	2.7
6	0.265	0.475	2.194	1.9
7	0.269	0.468	2.662	1.4
8	0.247	0.510	3.172	1.1
9	0.217	0.580	3.752	1.0

Table 6. Fresh water accumulated in Damariscotta River segments, calculated from salinity distribution, summer 1968. Values are in 10^6 m^3.

Date	Tide	1	2	3	4	5	6	7	8	9	Total
1-VII-68	High	0.587	0.419								
2-VII-68	Low			0.437	0.609	1.364	1.647	1.600	1.447	1.923	9.027
5-VII	Low			0.427	0.658	1.297	1.375	1.452	1.312	1.609	8.130
8-VII	High			0.598	1.632	1.520	1.403	1.514	1.744	2.227	10.638
11-VII	High			0.628	1.538	1.393	1.206	1.346	1.431	1.827	9.369
12-VII	High			0.620	1.511	1.303	1.255	1.009	1.162	1.485	8.345
13-VII	Low			0.545	0.915	1.351	1.303	1.230	1.380	1.833	8.557
16-VII	Low			0.470	0.696	1.351	1.448	1.304	1.582	1.923	8.774
23-VII	High			0.382	1.030	0.995	1.206	1.279	1.341	1.485	7.718
29-VII	Low			0.158	0.295	0.588	0.669	0.615	0.774	0.983	4.082
29-VII	High			0.223	0.642	0.705	0.836	0.740	0.581	0.628	4.355
30-VII	Low			0.145	0.268	0.535	0.633	0.689	0.639	0.849	3.758
30-VII	High	0.076	0.157								
3-VIII	Low			0.110	0.230	0.495	0.579	0.566	0.538	0.670	3.188
7-VIII	High			0.196	0.548	0.724	0.935	0.908	0.849	1.028	5.188
Mean, High Tide		0.332	0.288	0.441	1.150	1.107	1.140	1.133	1.185	1.447	7.603*
Mean, Low Tide				0.327	0.524	0.997	1.093	1.065	1.096	1.398	6.500*
Overall Mean				0.380	0.813	1.048	1.115	1.096	1.137	1.421	7.010*

*Segments 3-9 only.

Table 7. Flushing times for Damariscotta River segments, calculated from salinity distribution, summer 1968.

Date	Tide	1	2	3	4	5	6	7	8	9	Total
1-VII-68	High	4.65	3.32								
2-VII	Low			3.46	4.83	10.80	13.03	12.50	11.44	15.21	71.27
5-VII	Low			3.39	5.21	10.25	10.39	11.50	10.38	12.74	63.86
8-VII	High			4.74	12.92	12.03	11.10	11.98	13.81	17.62	84.20
11-VII	High			4.97	12.16	11.02	9.53	10.65	11.32	14.44	74.09
12-VII	High			4.92	11.96	10.31	9.94	7.97	9.19	11.76	66.05
13-VII	Low			4.32	7.26	10.78	10.31	9.74	10.92	14.51	67.84
16-VII	Low			3.72	5.52	10.78	11.47	10.31	12.52	15.22	69.54
23-VII	High			3.02	8.16	7.88	9.54	10.03	10.61	11.76	61.00
29-VII	Low			2.57	4.67	9.31	11.60	9.74	12.24	15.60	65.73
29-VII	High			3.53	10.05	11.15	13.22	11.72	9.20	9.94	68.81
30-VII	Low			2.30	4.25	8.47	10.01	10.91	10.12	13.42	59.48
30-VII	High	1.20	2.49								
3-VIII	Low			1.75	3.65	7.86	9.17	8.97	8.52	11.62	51.54
7-VIII	High			3.11	8.68	11.44	14.80	14.38	13.43	16.28	82.12
Mean, High Tide		2.92	2.90	4.05	11.12	10.64	11.36	11.12	11.26	13.64	73.19
Mean, Low Tide				3.07	5.06	9.75	10.85	10.53	10.89	12.13	62.28
Overall Mean		2.92	2.90	3.52	7.85	10.02	11.09	10.80	11.06	12.81	67.15
Exchange ratio, from High tide Mean		0.342	0.345	0.246	0.090	0.094	0.088	0.090	0.089	0.073	

Table 8. Net non-tidal drifts and ratios of non-tidal volume to fresh water inflow for Damariscotta River sections.

Section	Non-tidal Drift m/tide	Non-tidal Volume, 10^6 m^3	Non-tidal Volume / Fresh Water Inflow
Segment 4	185	0.67	5.3
Segment 5	95	0.57	4.5
Segment 6	90	0.74	5.9
Segment 7	80	1.14	9.1
Segment 8	145	1.23	9.8

Table 9. Textural characteristics of Damariscotta River sediments. Stations are listed in north-south order.

Station	Md	M_z	σ_I	Sk_I	% Gravel	% Sand	% Silt	% Clay	Sediment Type (Shepard, 1954)
47	4.33	5.0	2.47	0.51	0.2	27.8	57.7	14.3	Sandy Silt
48	4.76	6.05	2.71	0.39	0.4	13.0	78.4	8.2	Silt
49	4.62	5.12	2.82	0.58	3.7	16.6	65.7	14.0	Sandy Silt
50	4.15	5.15			8.9	33.3	51.0	6.8	Sandy Silt
23									Hard Bottom
1	2.17				20.6	71.8	4.0	3.6	Gravelly Sand
29	4.50	5.13	2.34	0.49	0.3	32.8	52.9	14.0	Sandy Silt
37	4.50	5.03	2.02	0.51	1.6	20.5	63.9	14.0	Sandy Silt
32	4.41	5.24	2.30	0.59	0.8	40.1	43.9	15.2	Sandy Silt
2	3.47	4.33	3.32	0.29	3.2	49.8	31.7	15.3	Silty Sand
17	1.58				34.2	48.9	12.9	3.8	Gravelly Sand
38	4.60	5.60	2.61	1.22	0.4	18.2	63.7	17.7	Sandy Silt
39	4.03	4.24	2.87	0.23	1.6	46.6	40.0	11.8	Silty Sand
3A	4.51	6.18	2.60	0.86	0	5.7	68.5	25.8	Clayey Silt
16	4.30	5,03	3.39	0.30	3.7	34.5	44.9	16.9	Sandy Silt
3B	4.57	4.91	4.34	0.14	4.3	23.2	48.7	23.8	Sand-Silt-Clay
4	4.60	6.07	3.24	0.60	0.1	24.6	50.7	24.6	Sand-Silt-Clay
5	4.46	5.83	2.98	0.65	0.4	24.8	52.6	22.2	Sand-Silt-Clay
40	4.24	4.92	2.67	0.41	1.6	40.2	43.0	15.2	Sandy Silt
6	4.60	6.11	2.81	0.34	0	12.8	64.4	22.8	Clayey Silt
41	4.12	5.00	2.58	0.53	1.0	45.9	39.3	14.8	Silty Sand
35	4.44	5.20	2.88	0.37	1.9	29.6	49.7	18.8	Sandy Silt
10	4.35	4.88	2.28	0.44	0	25.8	58.2	16.0	Sandy Silt
36					59.7	27.5	11.0	1.8	Sandy Gravel
25									Rocky
19									Rocky
9					78.5	9.8	7.7	4.0	Gravel

Table 9. (Continued)

Station	Md	M_z	σ_I	Sk_I	% Gravel	% Sand	% Silt	% Clay	Sediment Type (Shepard, 1954)
26	4.22	4.61	2.59	0.39	0	44.9	43.1	12.0	Silty Sand
8									Rocky
34	4.00	5.27	2.47	0.72	1.5	48.1	32.6	17.8	Silty Sand
7	3.19	2.80			11.1	72.2	11.7	5.0	Silty Sand
30	2.60	2.71	1.46	0.15	0	89.6	4.6	5.8	Sand
11	3.08	3.96	2.34	0.70	0.4	66.1	21.5	12.0	Silty Sand
31	4.41	5.63	2.58	0.66	0	13.4	67.6	19.0	Clayey Silt
42	4.63	4.99	2.49	1.04	0.4	22.5	63.0	14.1	Sandy Silt
43	5.00	5.49	2.07	0.47	0	13.8	74.4	11.8	Sandy Silt
27	4.60	5.55	2.18	1.28	0	10.7	73.6	15.7	Clayey Silt
12	4.18	3.89			13.9	32.9	37.2	16.0	Sandy Silt
28	4.58	5.71	2.42	0.64	0	15.9	64.6	19.5	Clayey Silt
44	4.02	4.41	2.36	0.44	0	48.3	41.4	10.3	Silty Sand
13	4.60	5.58	2.90	0.49	1.0	27.0	50.2	22.8	Sand-Silt-Clay
24									Rocky
14					51.1	43.1	0.8	5.10	Sandy Gravel
33	4.01	4.96	2.81	0.53	0.3	34.8	48.9	16.0	Sandy Silt
18									Rocky
22									Rocky
45	1.46				36.8	51.9	6.5	4.8	Gravelly Sand
46	4.92	5.43	2.35	0.46	0	20.5	64.0	15.5	Sandy Silt
20									Rocky
15	0.15				37.1	58.5	1.3	3.1	Gravelly Sand
21									Rocky

FIGURE LEGENDS

Figure 1. Location Map.

Figure 2. Hydrographic stations.

Figure 3. Damariscotta River bottom topography.

Figure 4. Damariscotta River channel profile.

Figure 5. Annual changes in temperature and salinity at stations D1 and D7.

Figure 6. Temperature and salinity profiles in the Damariscotta River at various times of the year.

Figure 7. Annual changes in nitrate, phosphate, silicate and dissolved oxygen at station D7. Solid line, surface; dashed line, 10 m depth.

Figure 8. High and low water concentrations of nitrate and phosphate at Damariscotta-Newcastle. L--laundromat. R--restaurant.

Figure 9. Damariscotta River showing water quality classifications established by the Maine legislature (Maine Revised Statutes Annotated, Title 38, Section 364) and town boundaries.

Figure 10. Damariscotta River showing segmentation for flushing time determination.

Figure 11. Circulation-stratification diagram showing classification of Damariscotta River segments. Other estuaries included are Mississippi River (M), Columbia River (C), James River (J), Strait of Juan de Fuca (JF), Silver Bay (S); C, D, E, and R are from the Mersey estuary (Bowden and Gilligan, 1971). (Based on Hansen and Rattray, 1966).

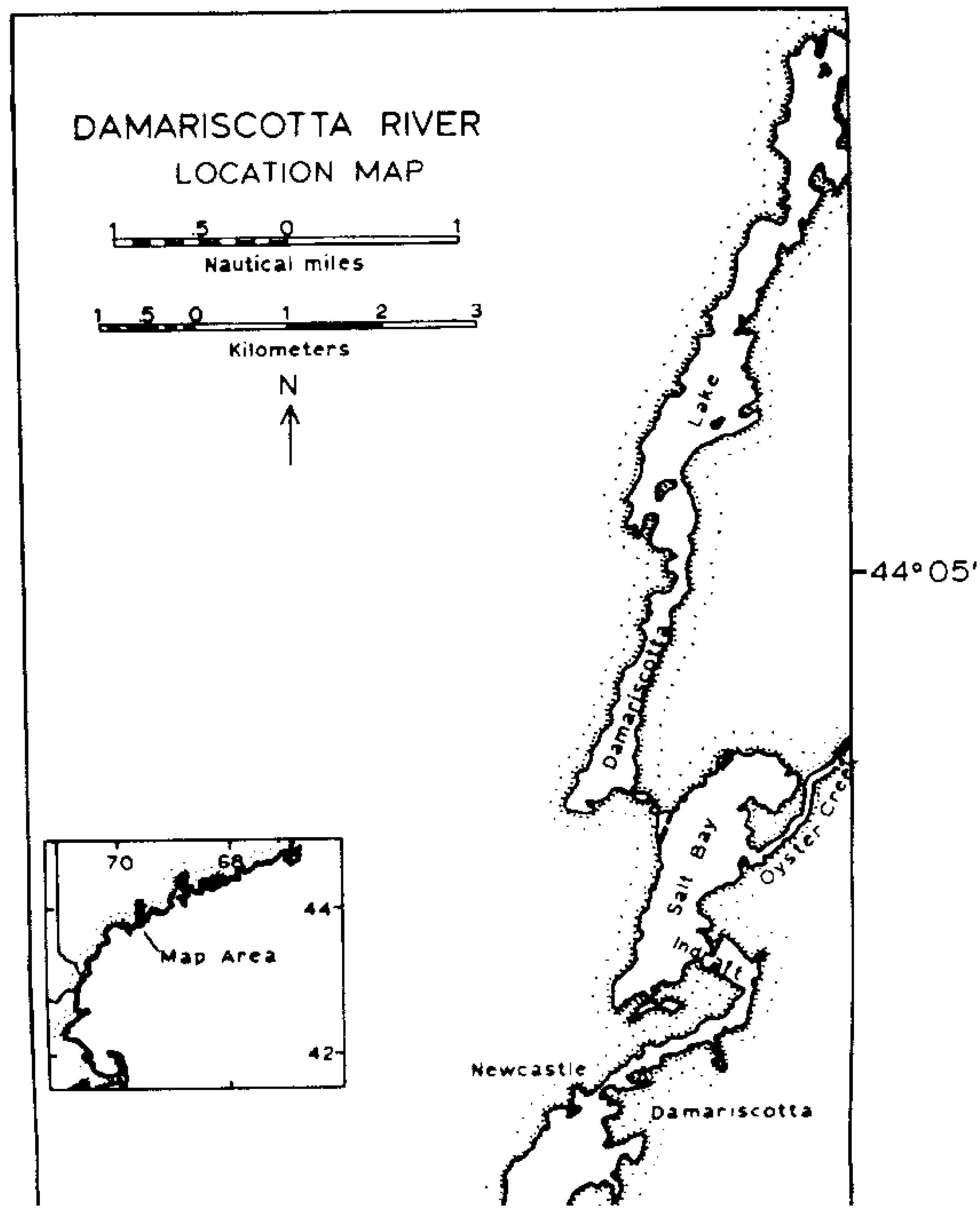
Figure 12. Damariscotta River showing ebb current drogue paths.

Figure 13. Damariscotta River showing flood current drogue paths.

Figure 14. Sediment sampling stations.

Figure 15. Trilinear classification of Damariscotta River sediments. Numbers refer to station locations in Figure 14.

Figure 16. Damariscotta River showing distribution of surficial sediment types.


DAMARISCOTTA RIVER
LOCATION MAP
1 .5 0 1
Nautical miles
1 .5 0 1 2 3
Kilometers
N
70
68
44
42
Map Area
44°05'
Lake
Damariscotta
Salt Bay
Oyster Cre
Newcastle
Damariscotta

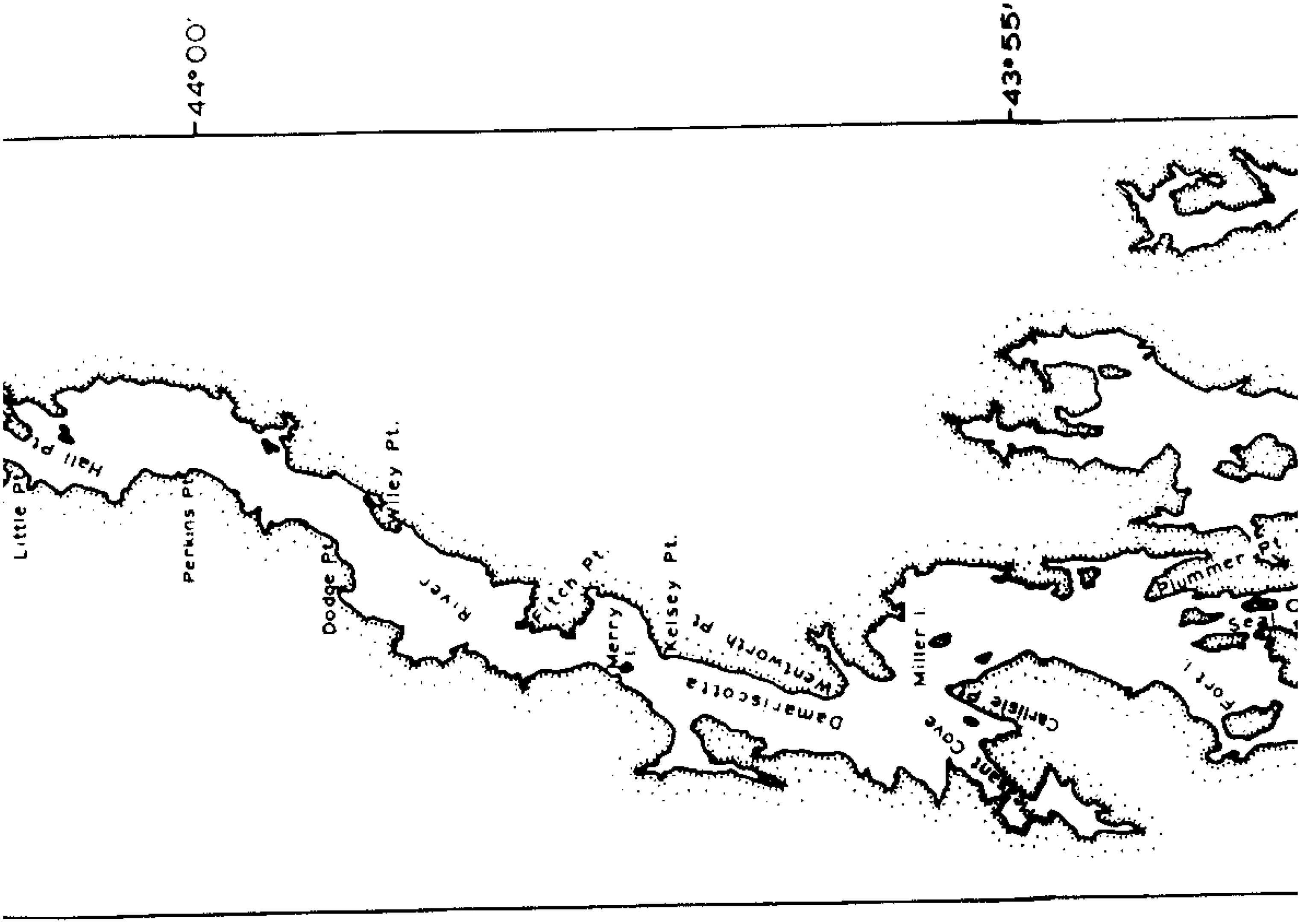
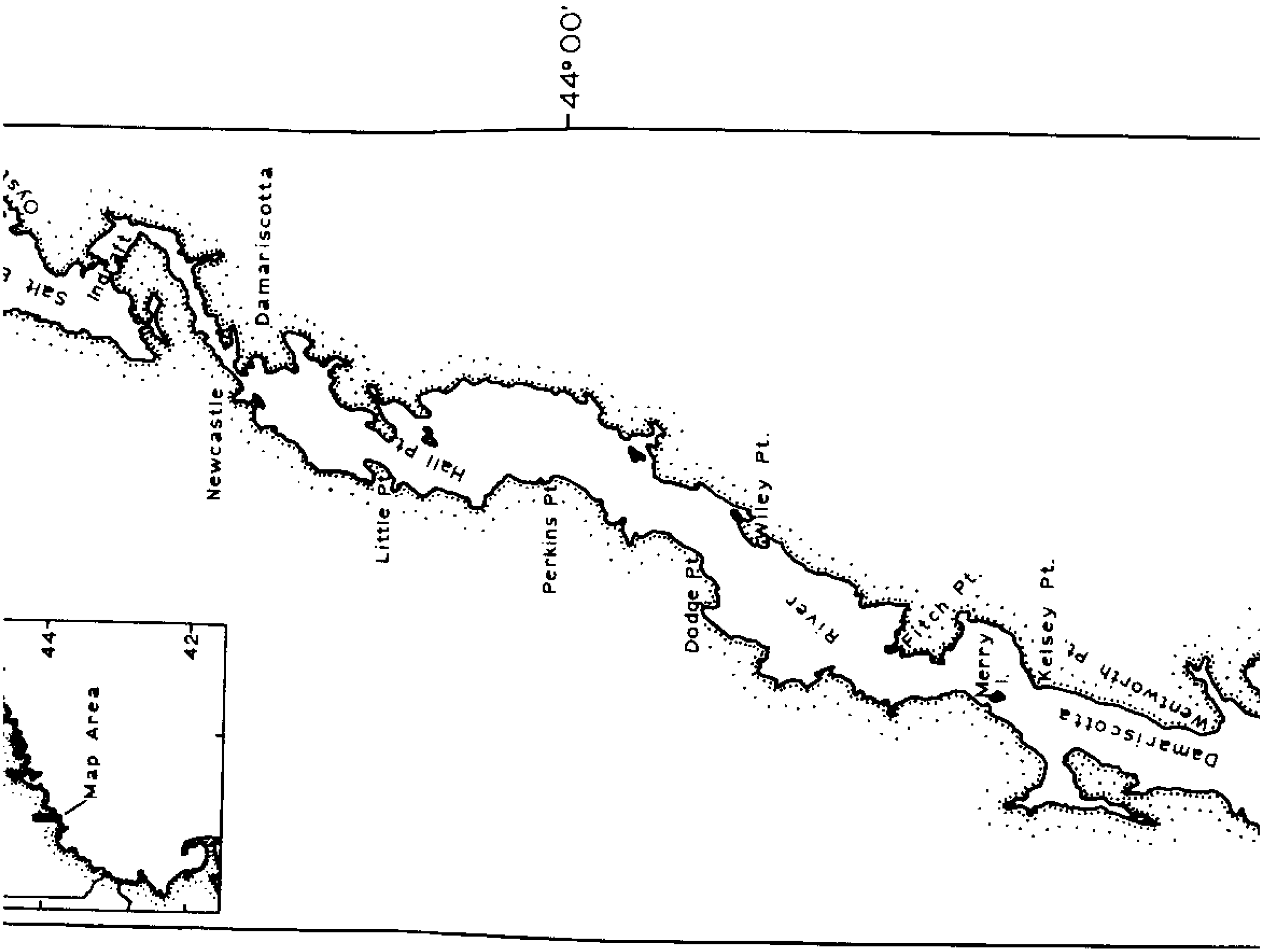
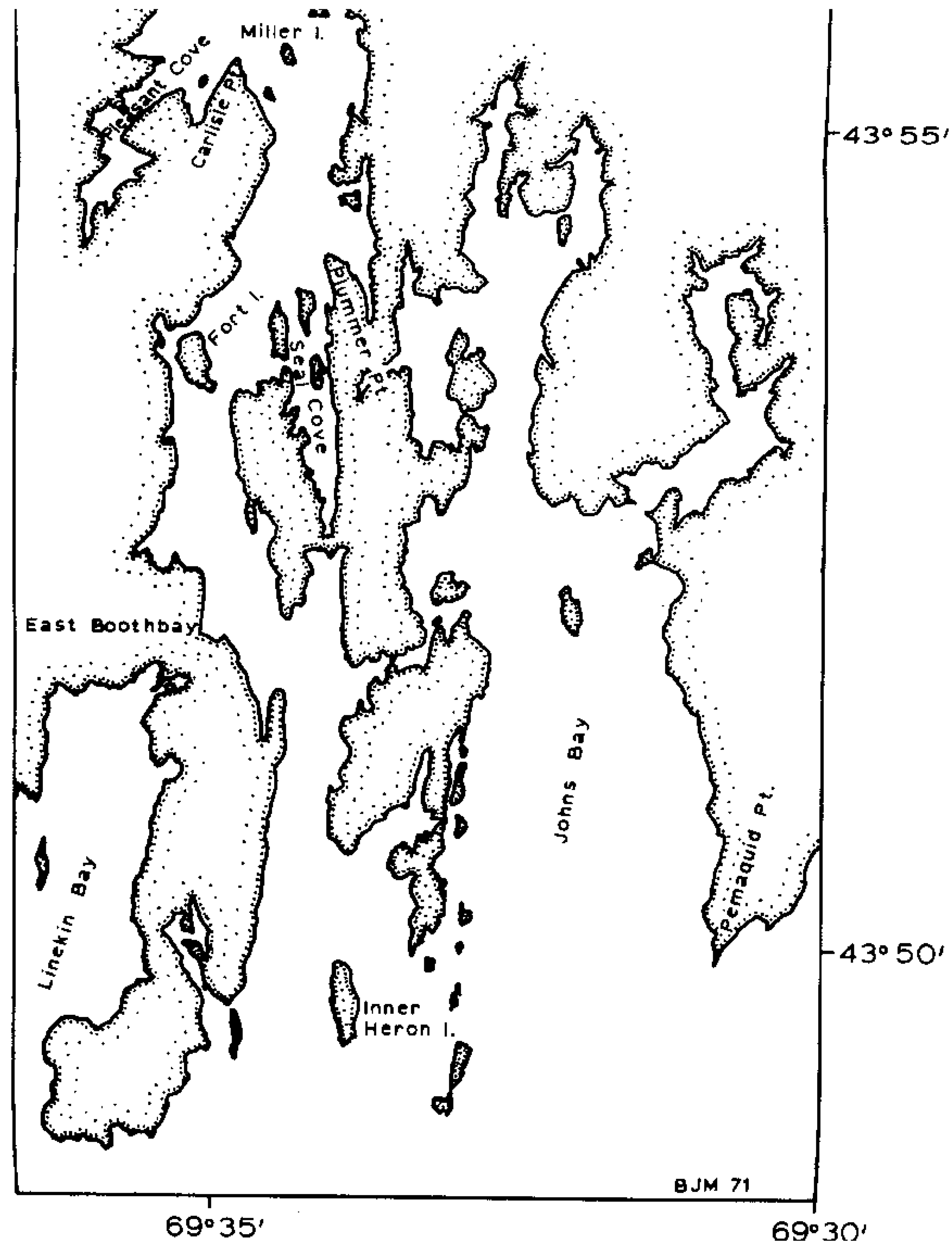

44°00'
43°55'
Little Pt.
Hall Pt.
Perkins Pt.
Dodge Pt.
Wiley Pt.
River
Fitch Pt.
Merry I.
Kelsey Pt.
Wentworth Pt.
Damariscotta
Miller I.
Carlisle Pt.
Cove
Plummer Pt.
Fort I.

Figure 1



44°00'
Damariscotta
Newcastle
Hall Pt.
Little Pt.
Perkins Pt.
Dodge Pt.
River
Fitch Pt.
Kelsey Pt.
Merry I.
Wentworth Pt.
Damariscotta
Map Area
44
42

Figure 1


Miller I.
Pleasant Cove
Carlisle Pt.
Fort I.
Seal Cove
Plummer Pt.
East Boothbay
Linekin Bay
Johns Bay
Pemaquid Pt.
Inner Heron I.
BJM 71
43°55′
43°50′
69°35′
69°30′

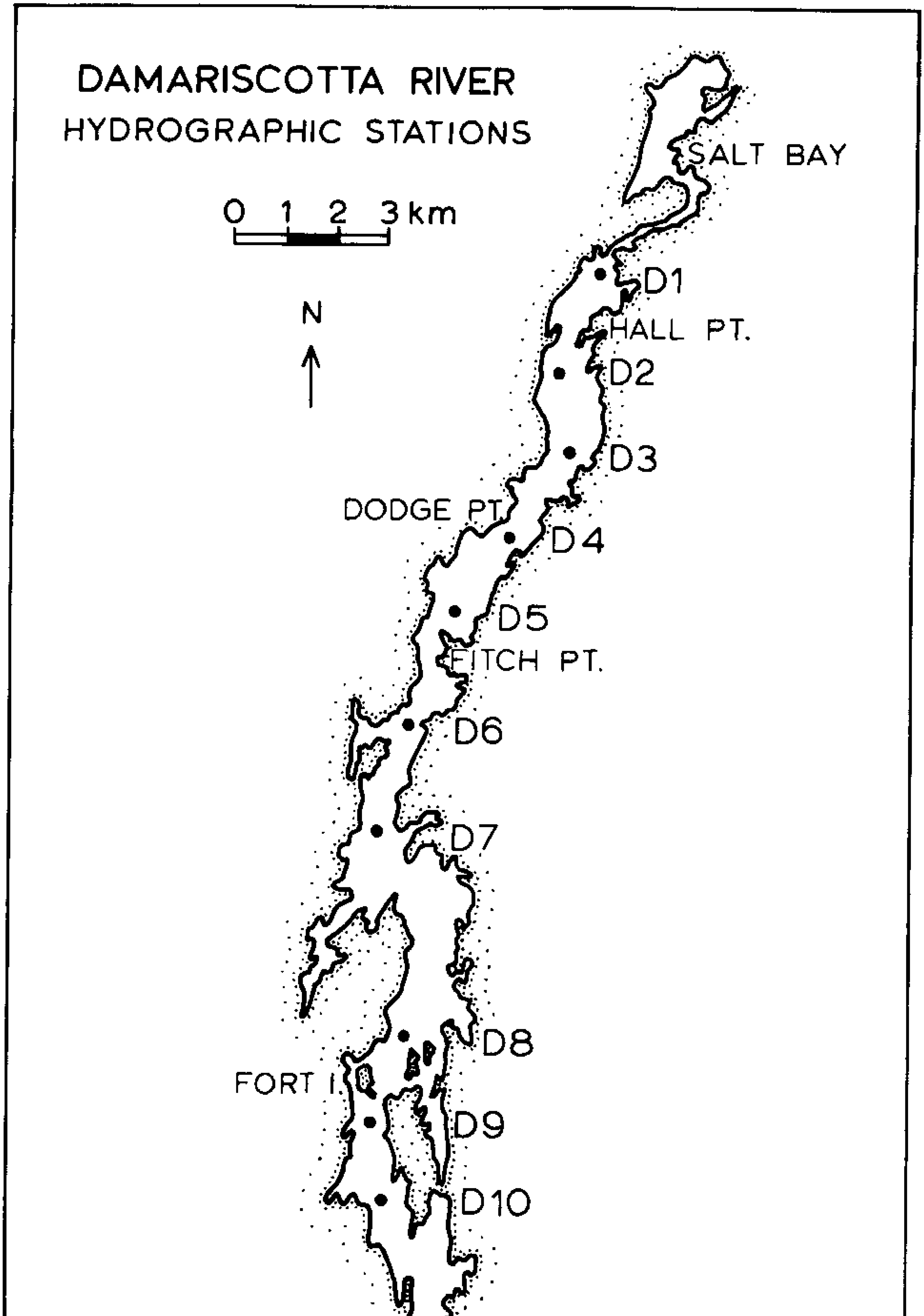
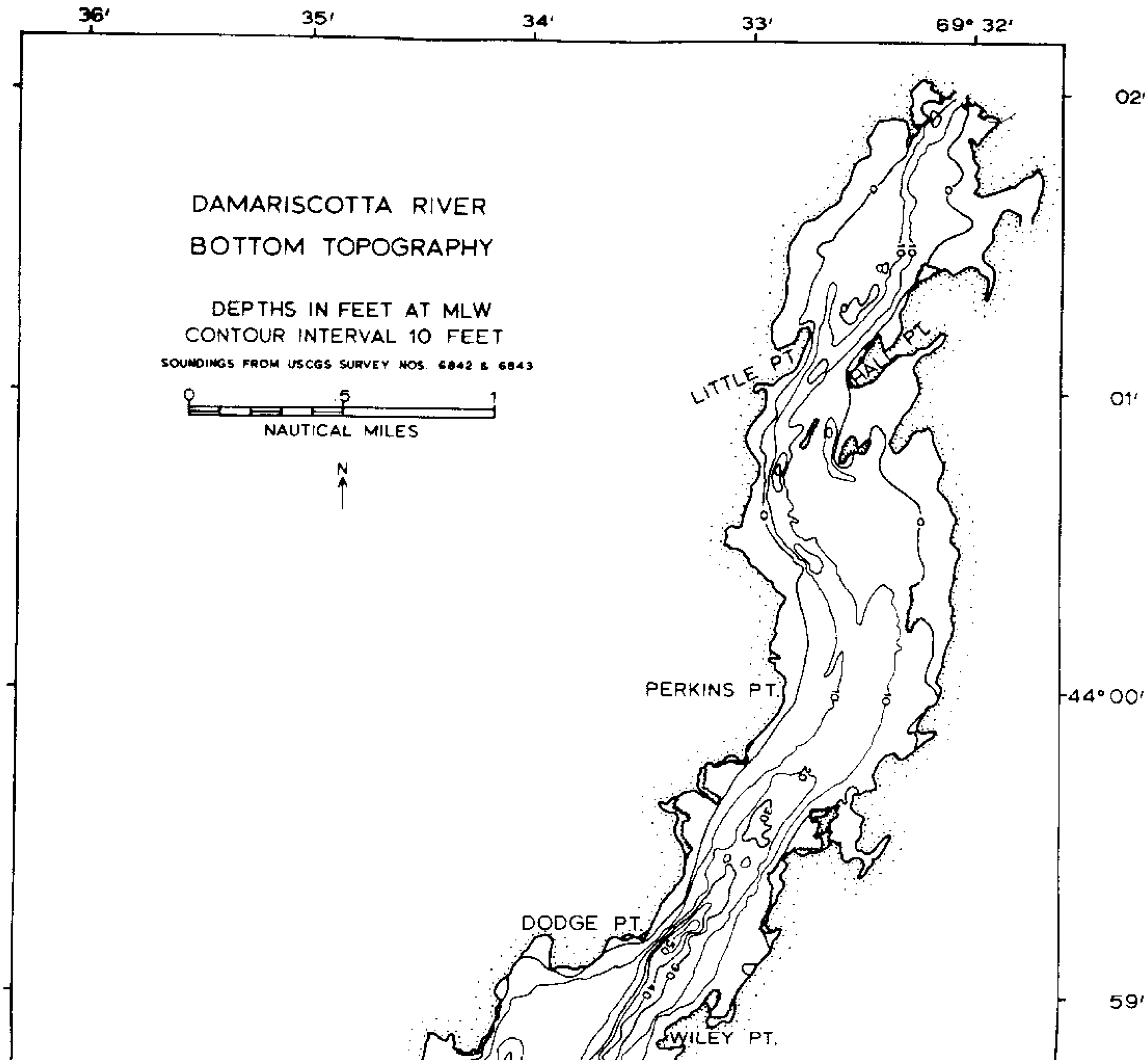

DAMARISCOTTA RIVER
HYDROGRAPHIC STATIONS
0 1 2 3 km
N
SALT BAY
D1
HALL PT.
D2
D3
DODGE PT.
D4
D5
FITCH PT.
D6
D7
D8
FORT I.
D9
D10

Figure 2


36′
35′
34′
33′
69° 32′
02′
01′
44° 00′
59′
DAMARISCOTTA RIVER
BOTTOM TOPOGRAPHY
DEPTHS IN FEET AT MLW
CONTOUR INTERVAL 10 FEET
SOUNDINGS FROM USCGS SURVEY NOS. 6842 & 6843
0
.5
1
NAUTICAL MILES
N
LITTLE PT.
HAL PT.
PERKINS PT.
DODGE PT.
WILEY PT.

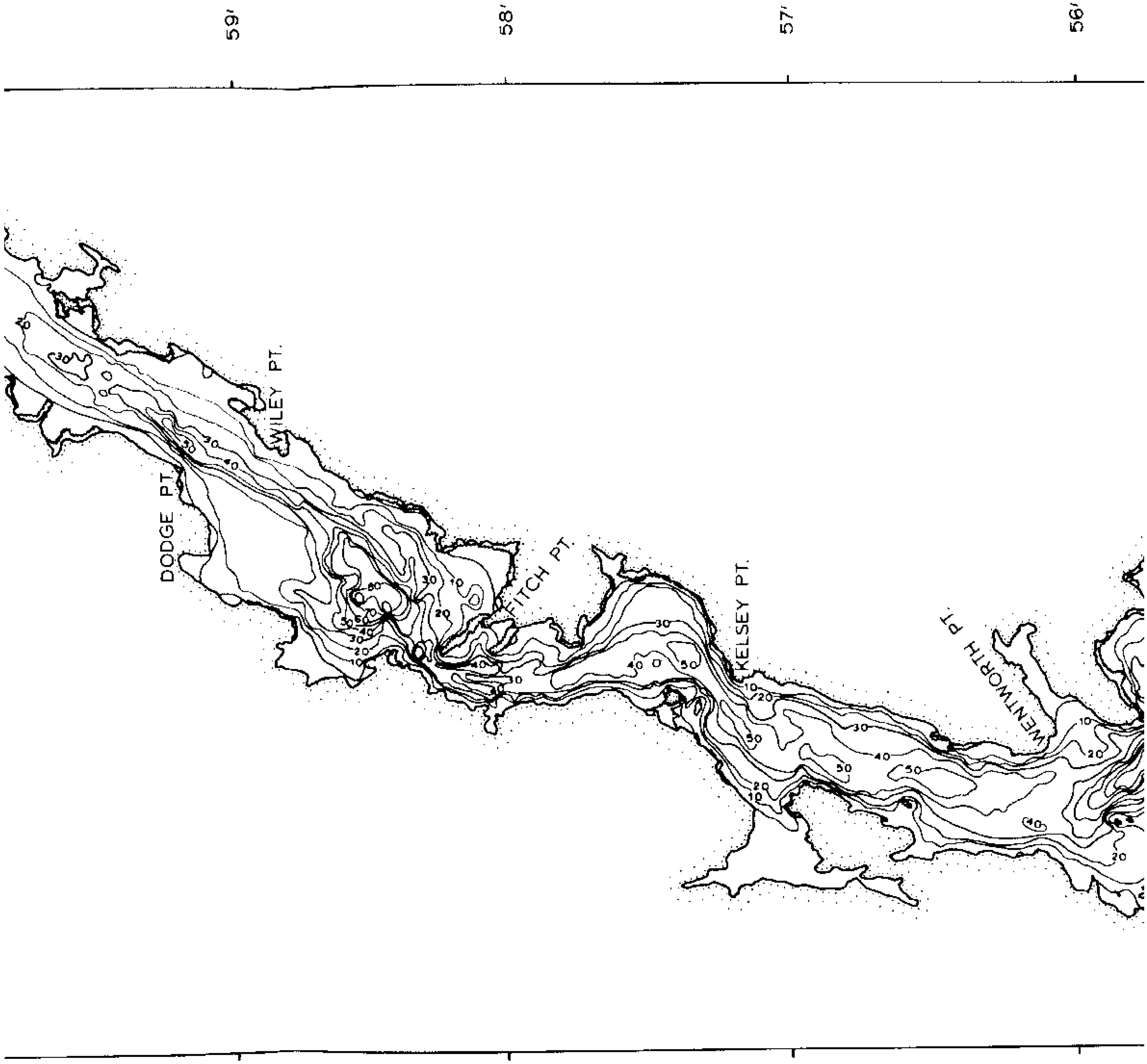
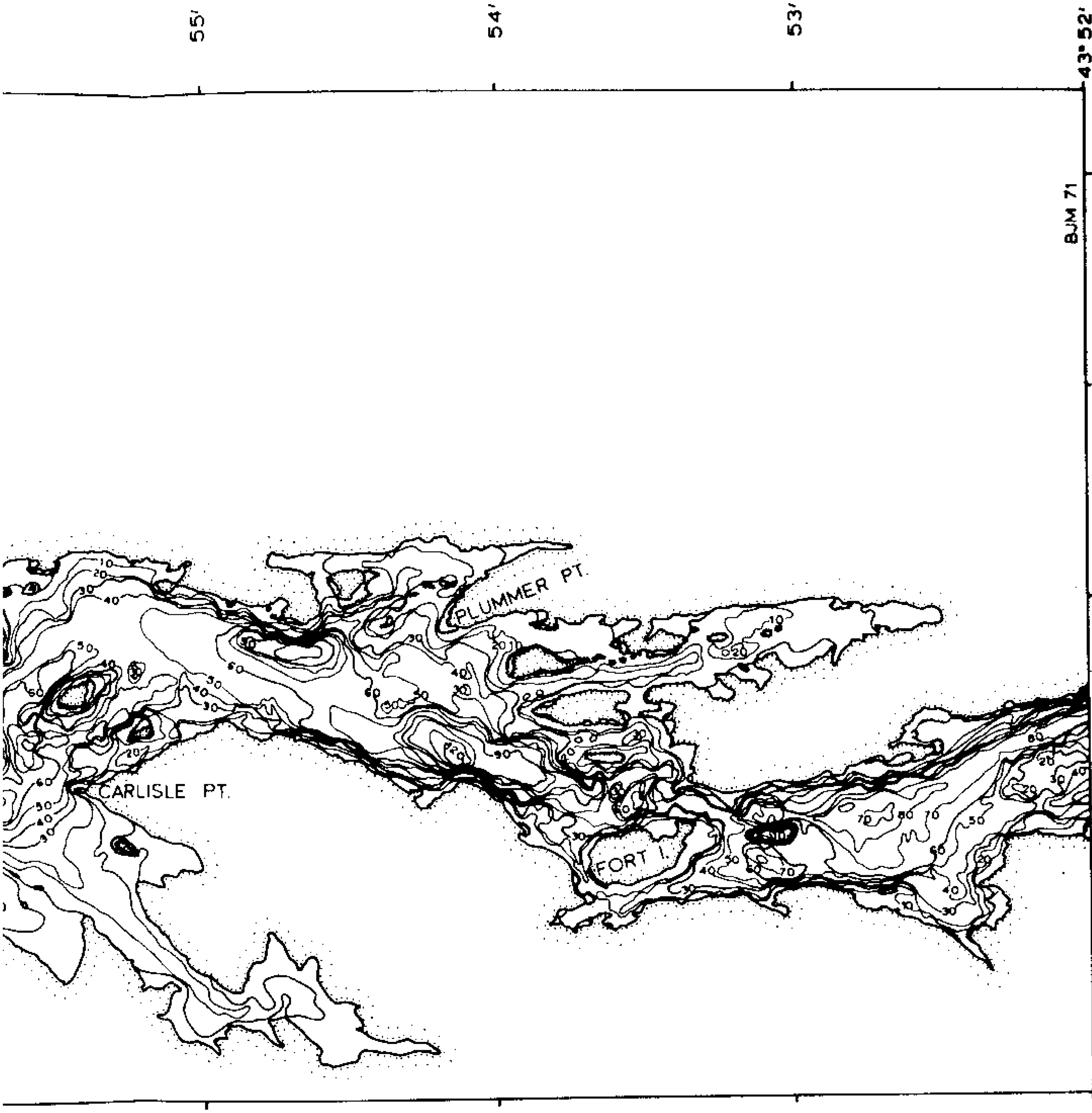


Figure 3


55'
54'
53'
43° 52'
BJM 71
PLUMMER PT.
CARLISLE PT.
FORT I.

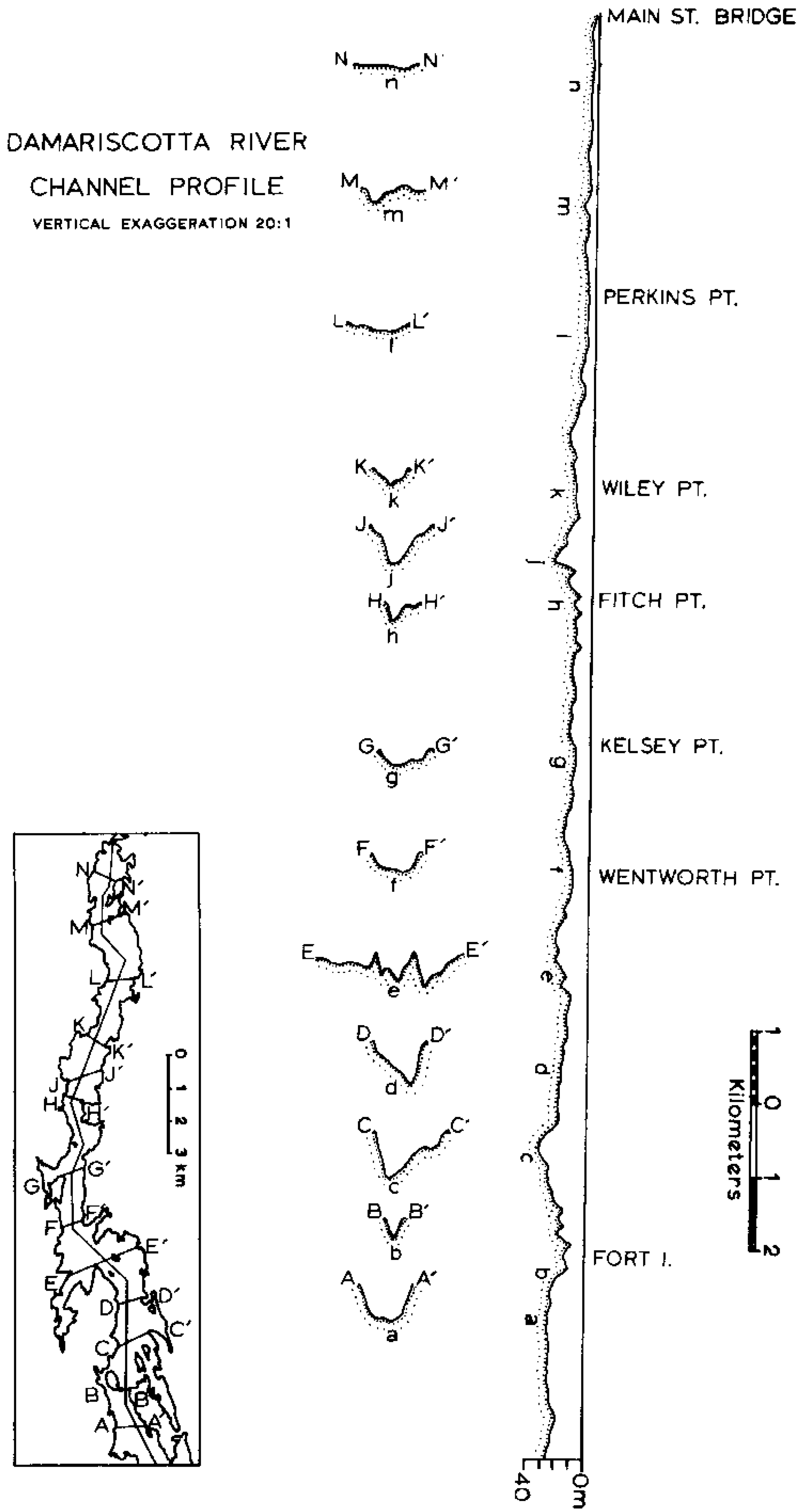

DAMARISCOTTA RIVER
CHANNEL PROFILE
VERTICAL EXAGGERATION 20:1
MAIN ST. BRIDGE
PERKINS PT.
WILEY PT.
FITCH PT.
KELSEY PT.
WENTWORTH PT.
FORT I.
Kilometers
40
0m
0 1 2 3 km

Figure 4

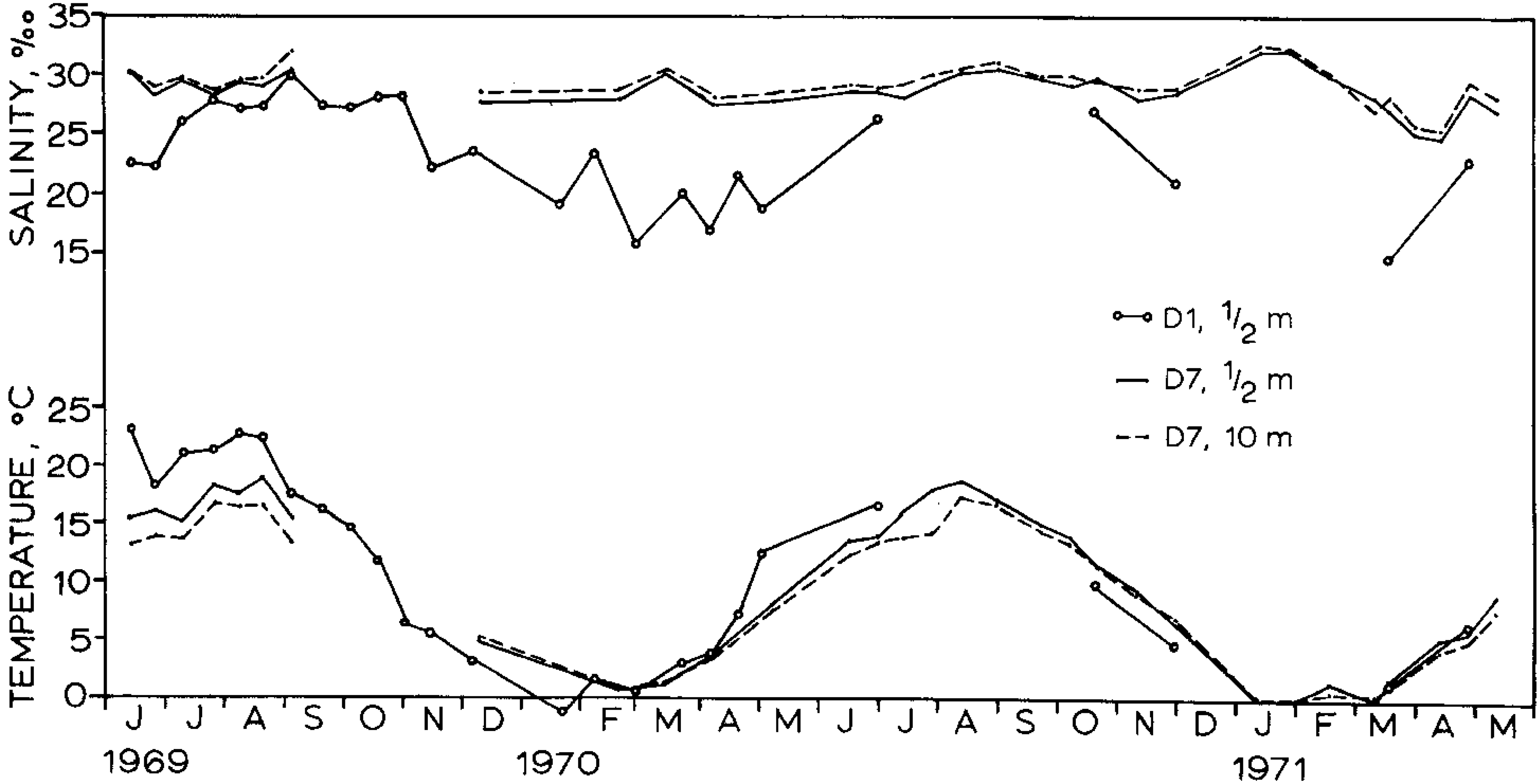
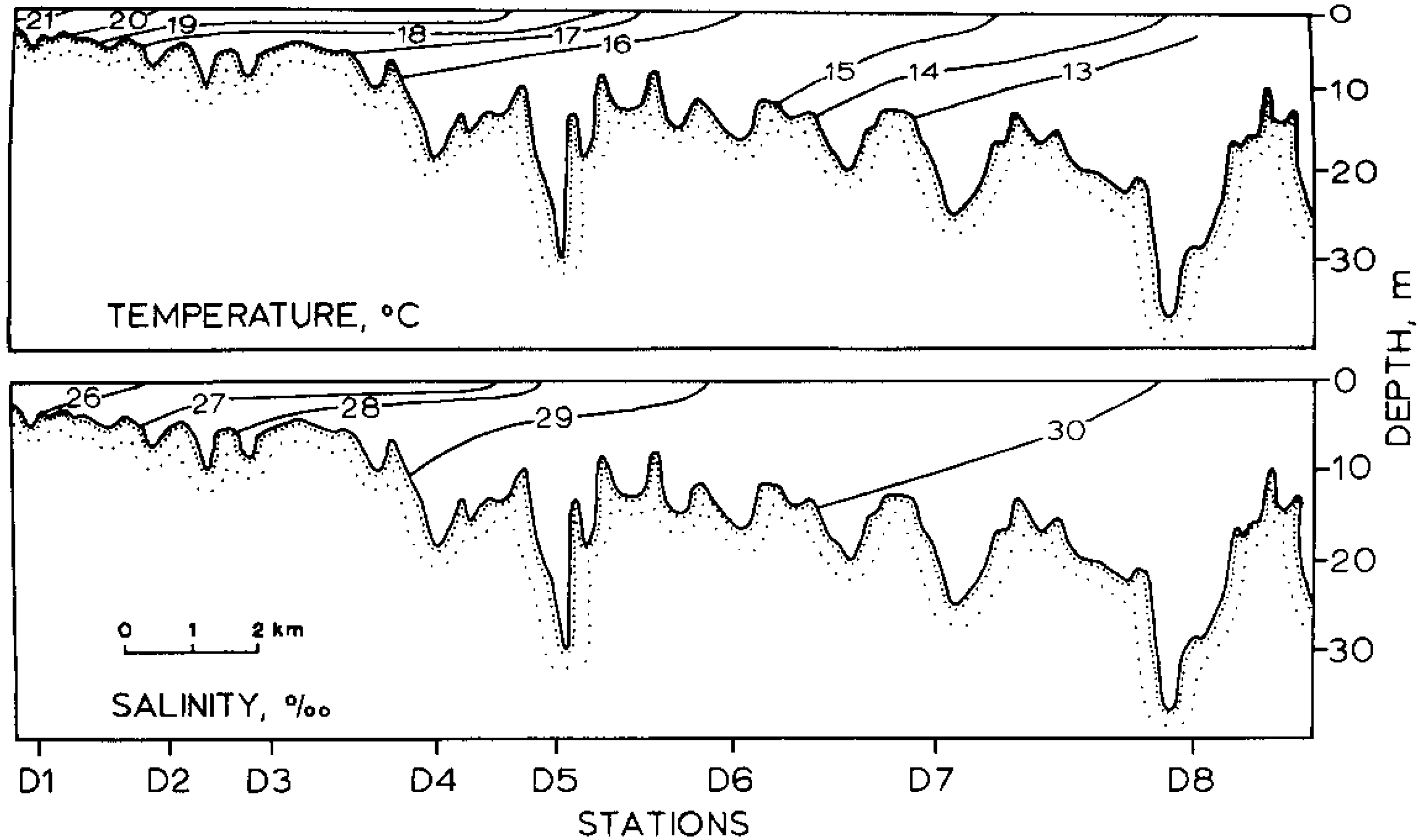
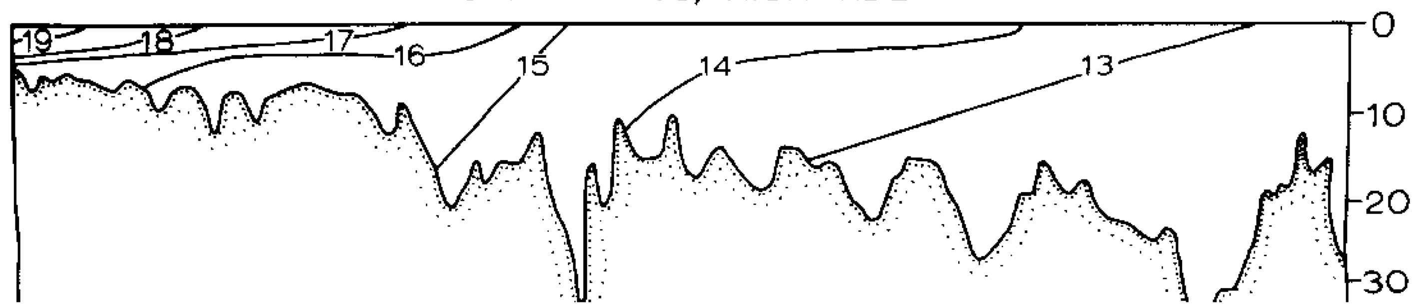

SALINITY, ‰
35
30
25
20
15
TEMPERATURE, °C
25
20
15
10
5
0
D1, 1/2 m
D7, 1/2 m
D7, 10 m
J J A S O N D F M A M J J A S O N D J F M A M
1969
1970
1971

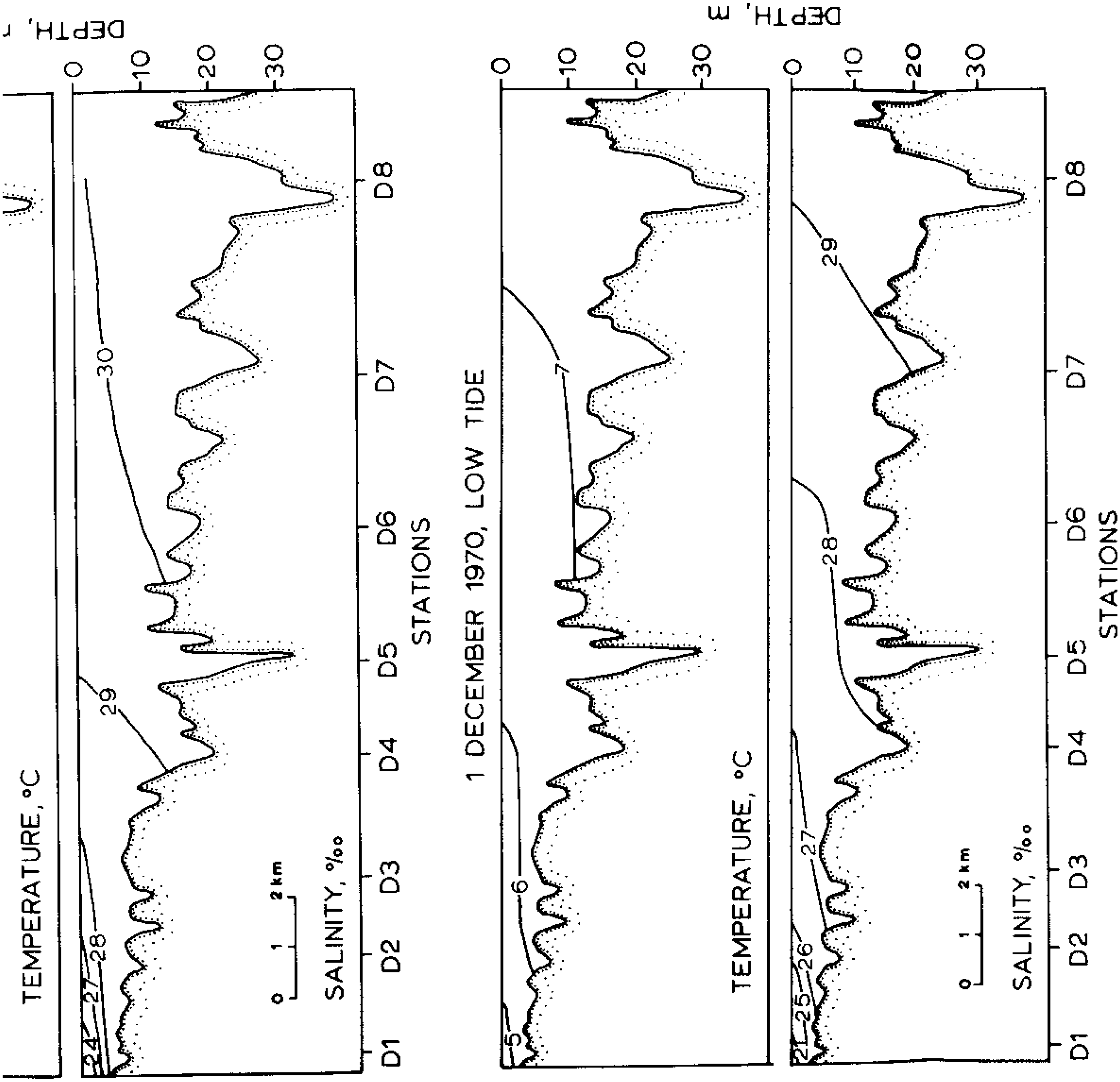
Figure 5

5 JULY 1968, LOW TIDE



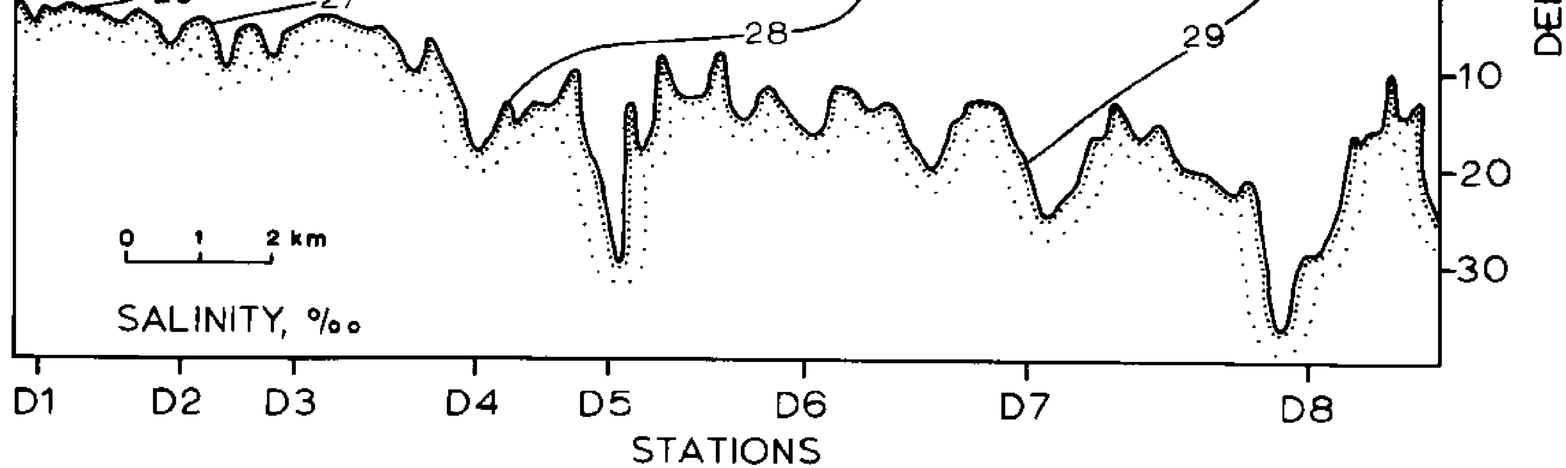
8 JULY 1968, HIGH TIDE



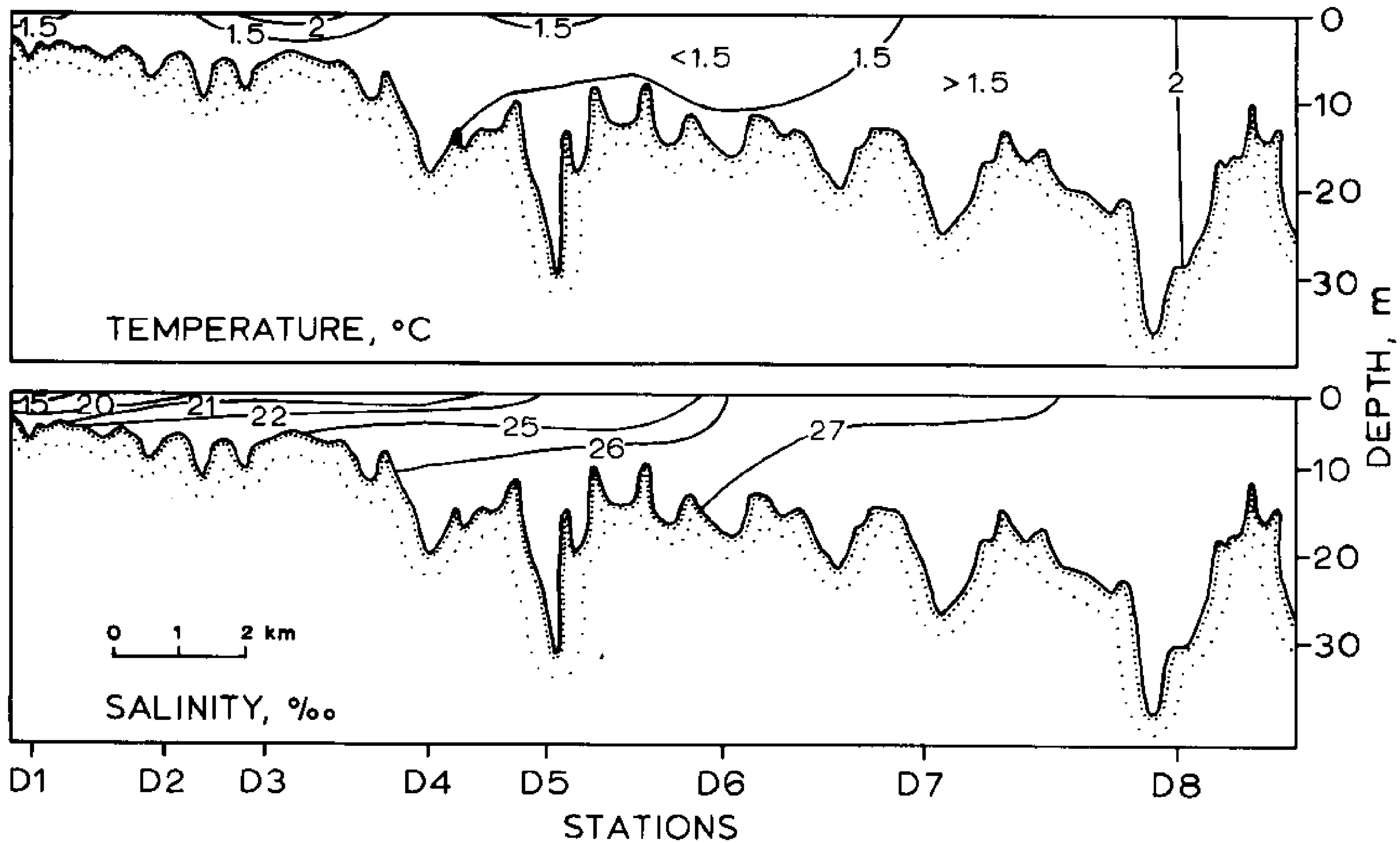


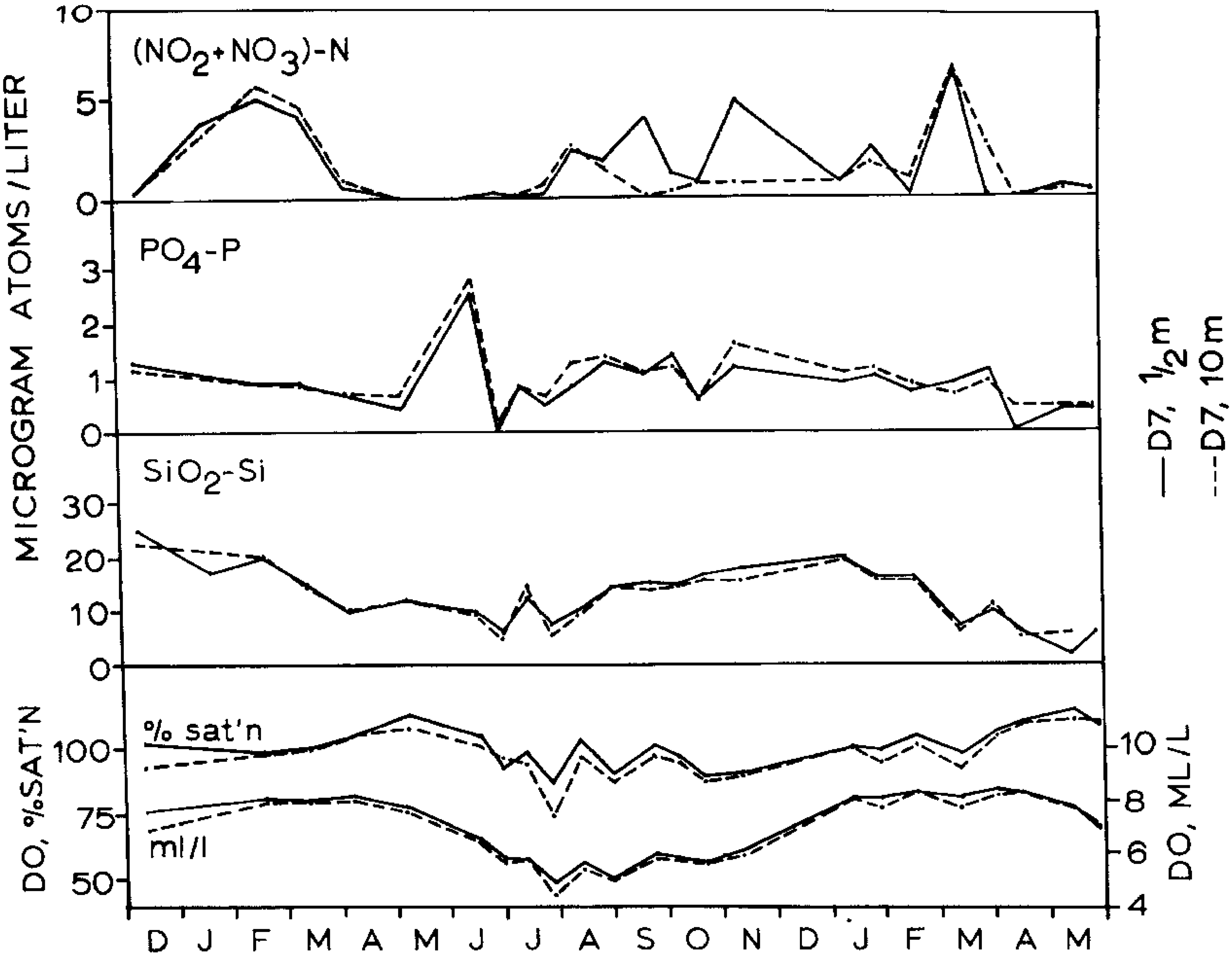
DEPTH, m
TEMPERATURE, °C
SALINITY, ‰
1 DECEMBER 1970, LOW TIDE
STATIONS
D1
D2
D3
D4
D5
D6
D7
D8
0 1 2 km

Figure 6



17 MARCH 1971, LOW TIDE





(NO2+NO3)-N
PO4-P
SiO2-Si
MICROGRAM ATOMS/LITER
10
5
0
3
2
1
0
30
20
10
0
% sat'n
ml/l
DO, %SAT'N
100
75
50
DO, ML/L
10
8
6
4
—D7, 1/2 m
---D7, 10 m
D J F M A M J J A S O N D J F M A M
1970
1971

Figure 7

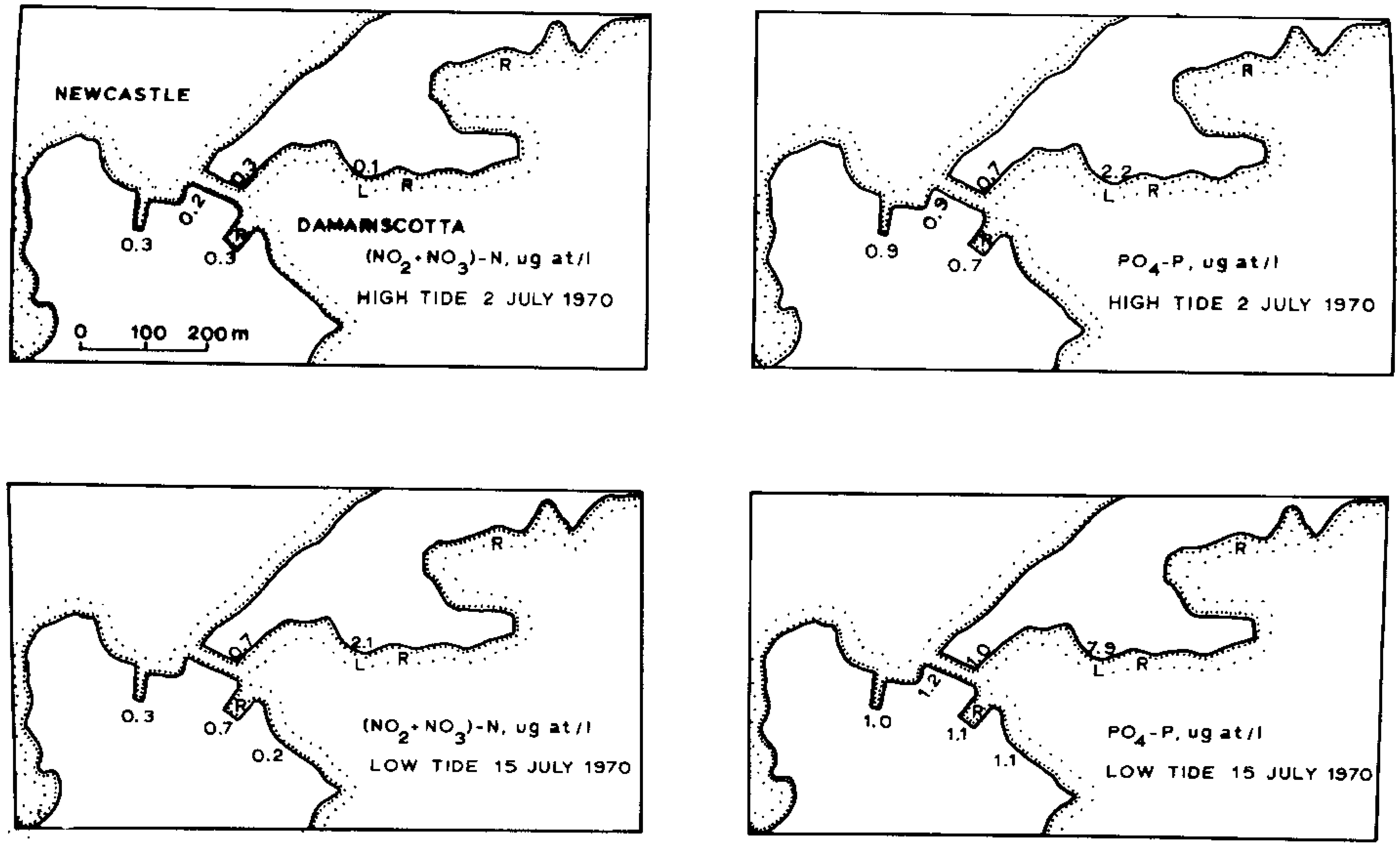

NEWCASTLE
DAMARISCOTTA
(NO2+NO3)-N, ug at/l
HIGH TIDE 2 JULY 1970
0 100 200m
0.3
0.2
0.3
0.3
0.1
L
R
R
PO4-P, ug at/l
HIGH TIDE 2 JULY 1970
0.9
0.9
0.7
0.7
2.2
(NO2+NO3)-N, ug at/l
LOW TIDE 15 JULY 1970
0.3
0.7
0.7
0.2
2.1
PO4-P, ug at/l
LOW TIDE 15 JULY 1970
1.0
1.2
1.0
1.1
1.1
7.9

Figure 8

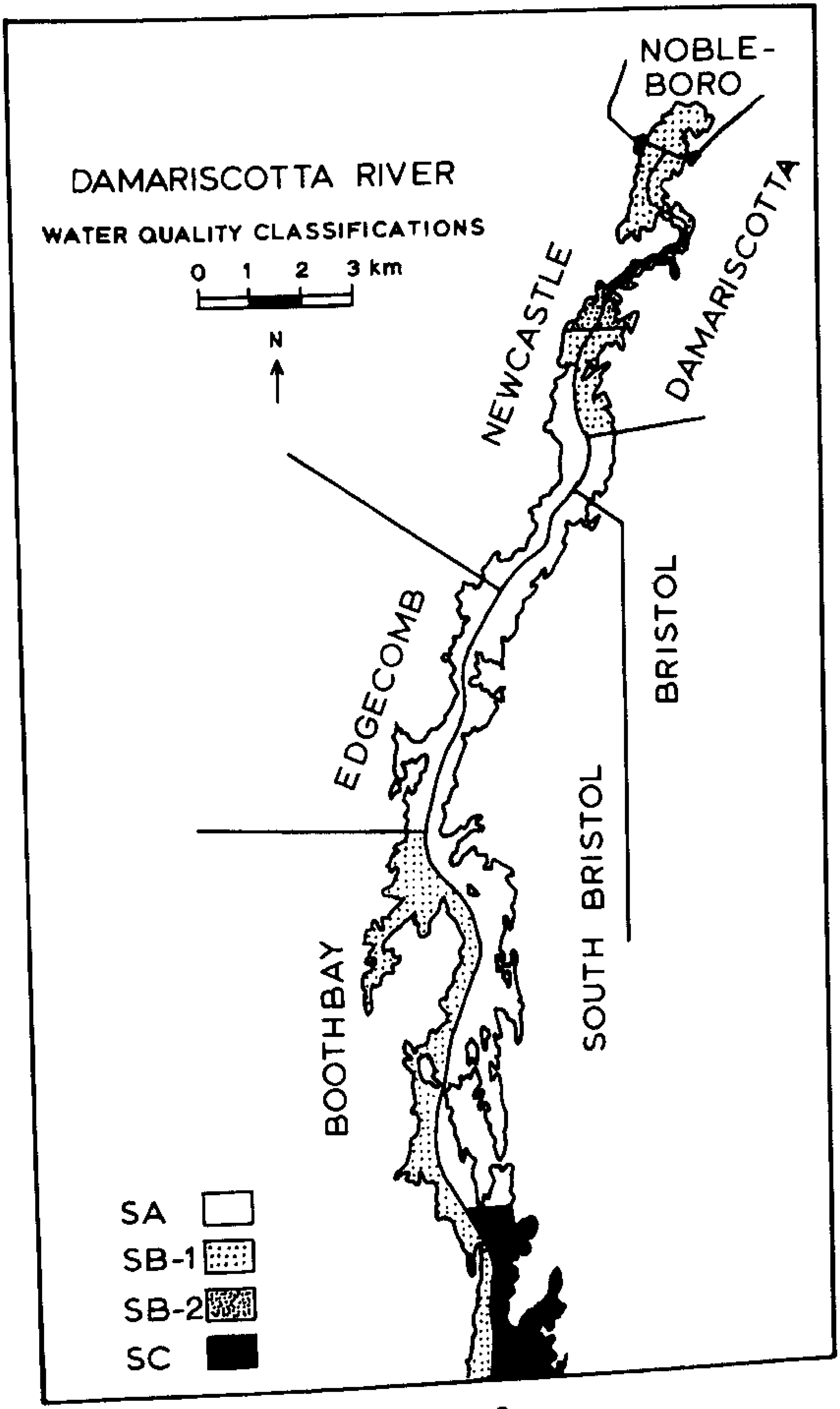

DAMARISCOTTA RIVER
WATER QUALITY CLASSIFICATIONS
0 1 2 3 km
N
NOBLE-
BORO
DAMARISCOTTA
NEWCASTLE
BRISTOL
EDGECOMB
SOUTH BRISTOL
BOOTHBAY
SA
SB-1
SB-2
SC

Figure 9

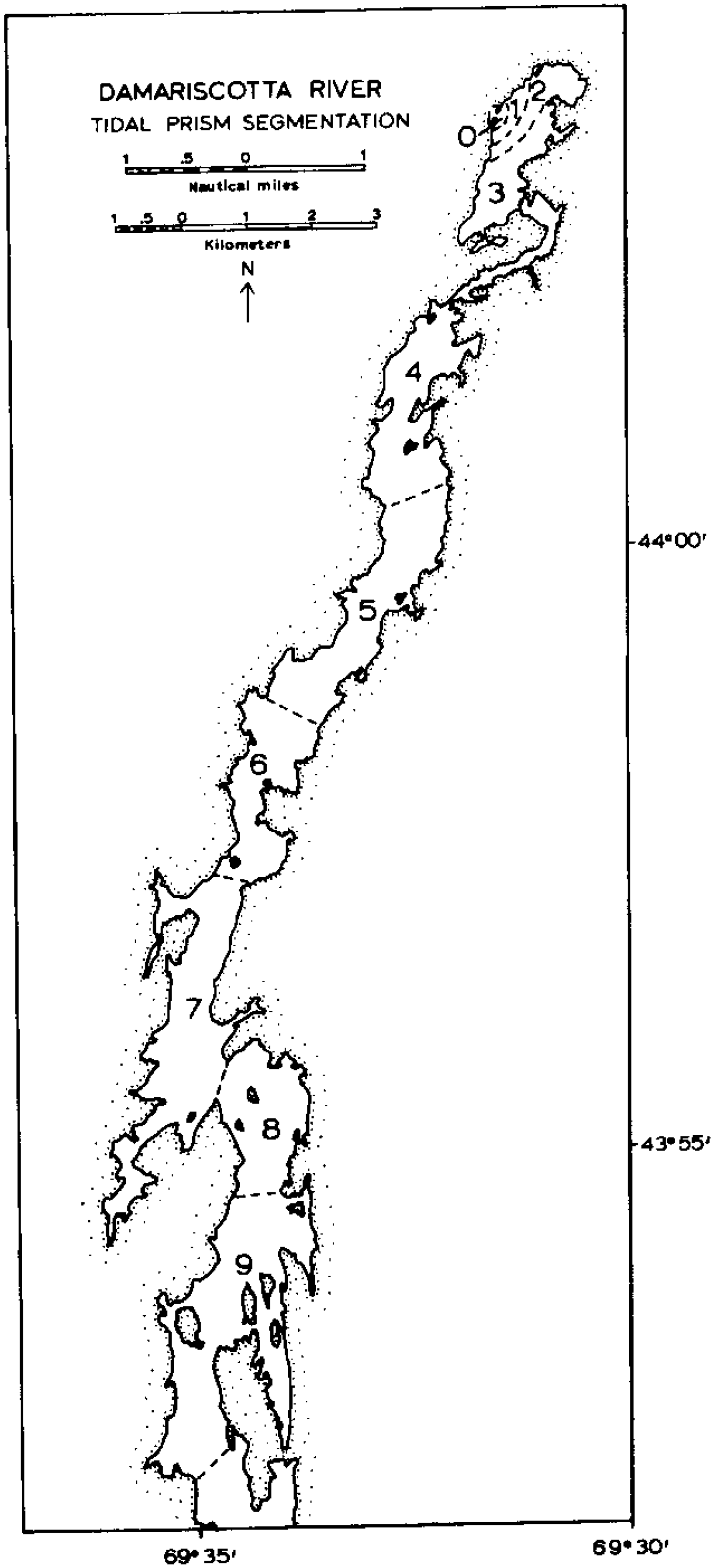
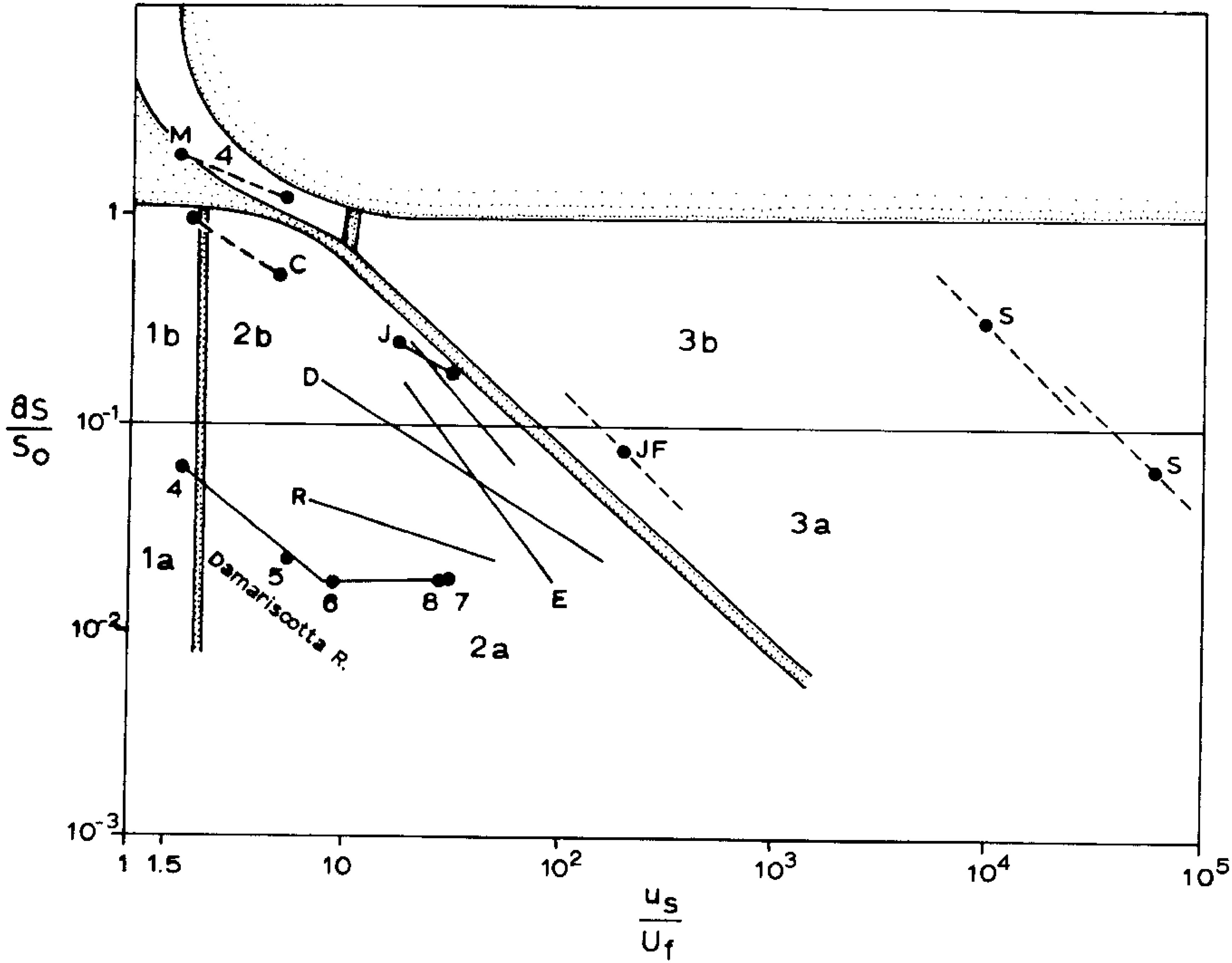
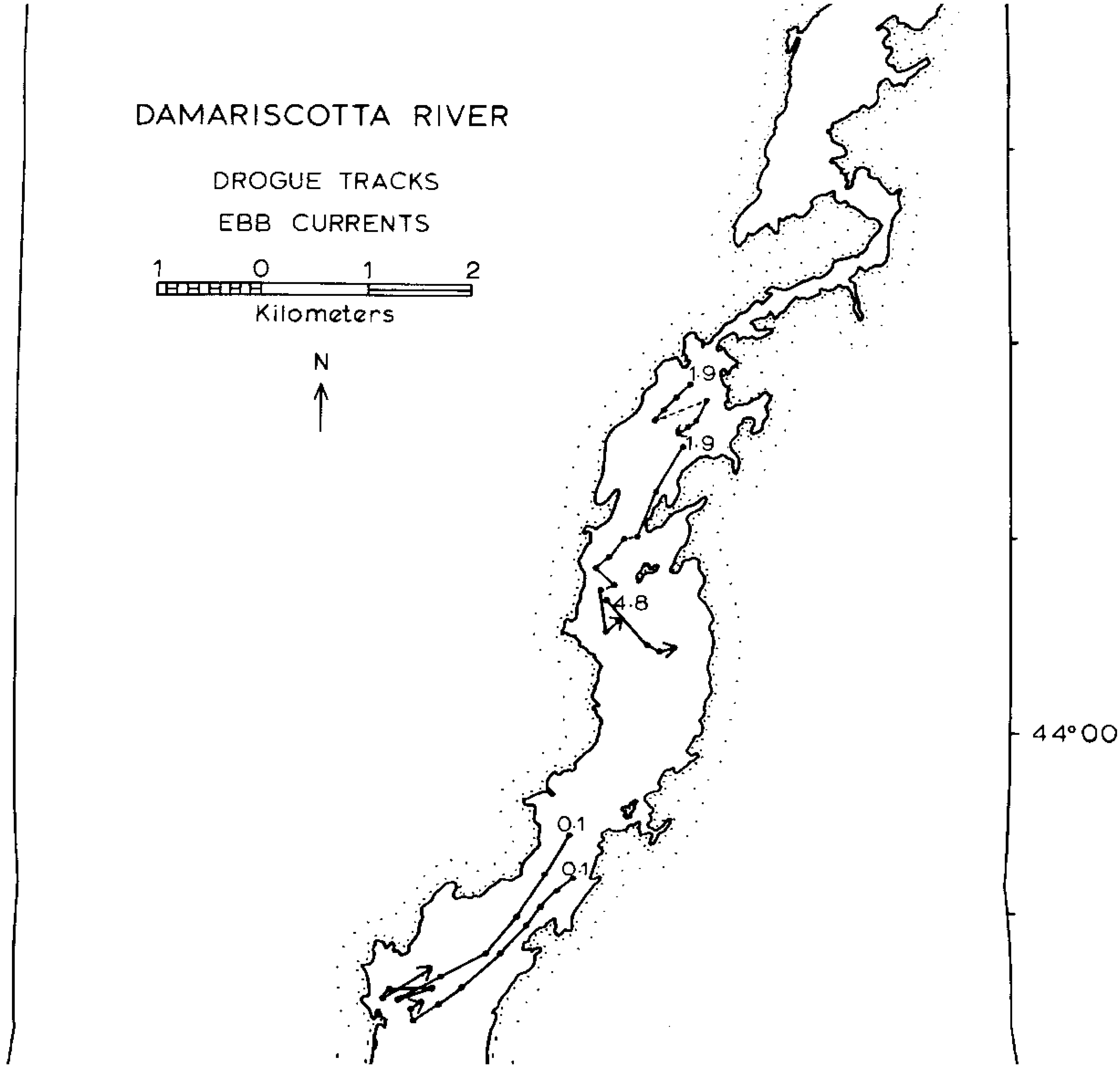

DAMARISCOTTA RIVER
TIDAL PRISM SEGMENTATION
1 .5 0 1
Nautical miles
1 .5 0 1 2 3
Kilometers
N
0
1
2
3
4
5
6
7
8
9
44°00'
43°55'
69°35'
69°30'

Figure 10



δS
S₀
1
10⁻¹
10⁻²
10⁻³
1
1.5
10
10²
10³
10⁴
10⁵
uₛ
U_f
M
4
C
1b
2b
1a
2a
3b
3a
J
D
R
E
JF
S
S
5
6
8
7
Damariscotta R.

Figure 11


DAMARISCOTTA RIVER
DROGUE TRACKS
EBB CURRENTS
1 0 1 2
Kilometers
N
1.9
1.9
4.8
0.1
0.1
44°00′

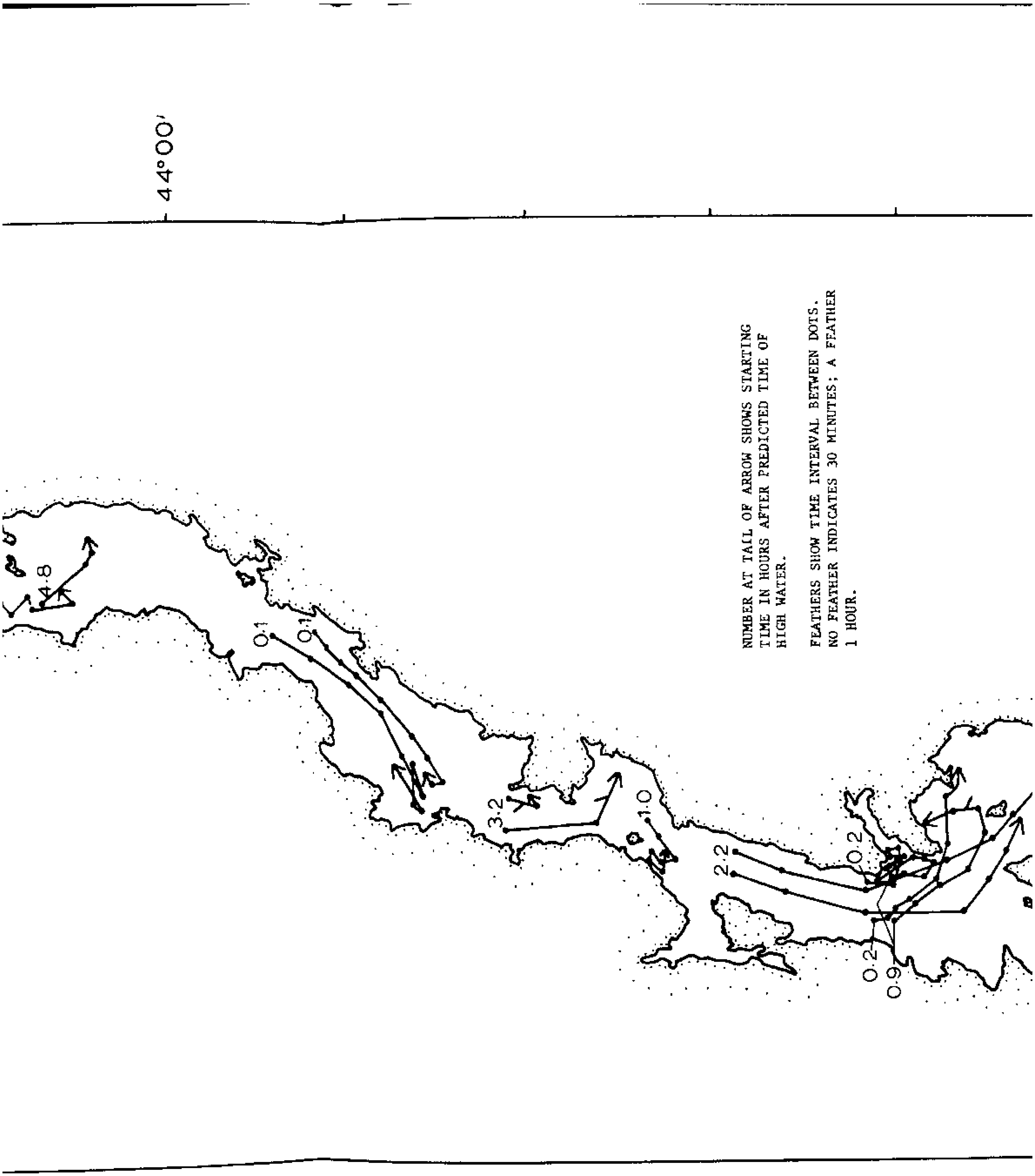
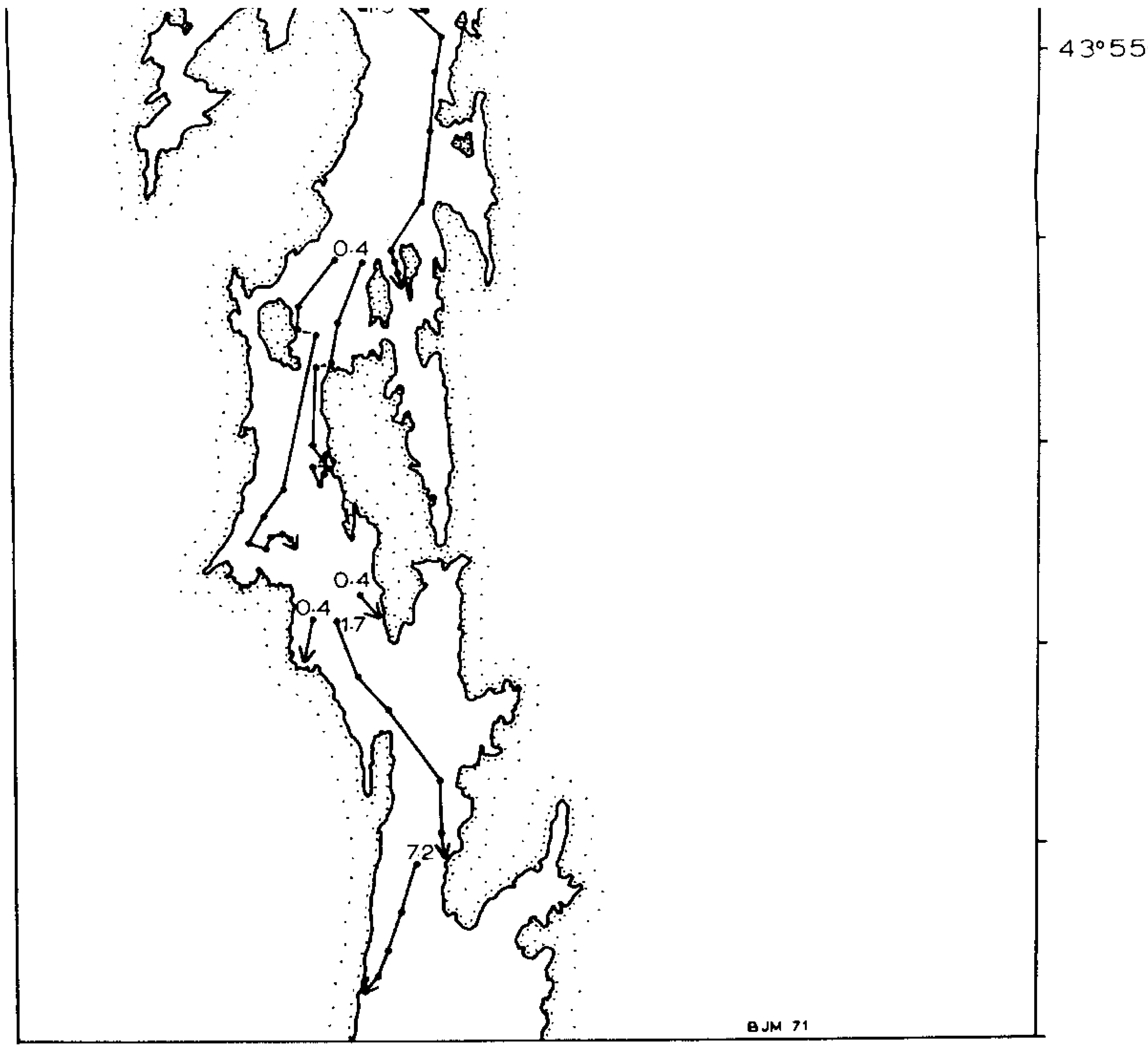
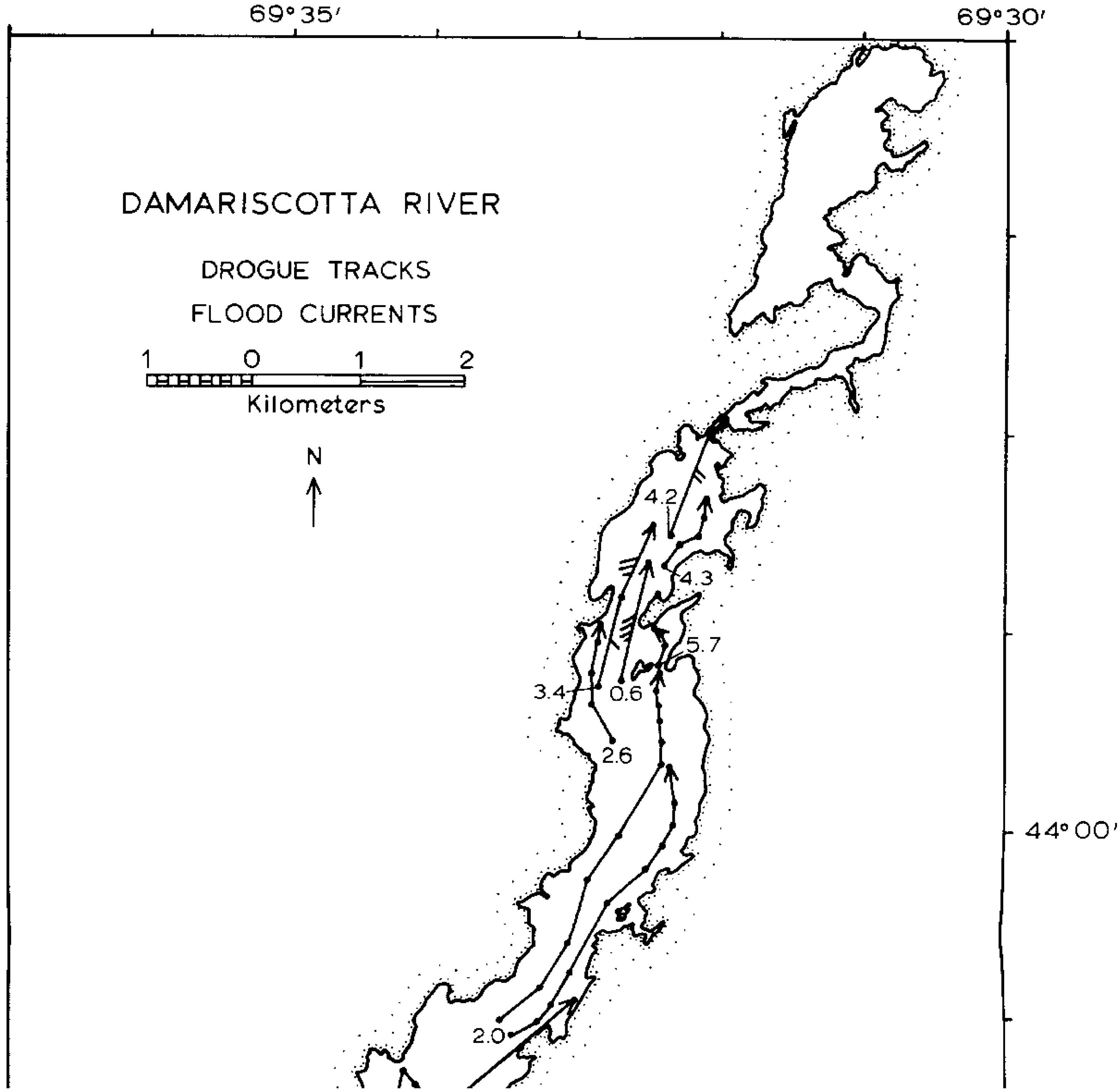

44°00'
NUMBER AT TAIL OF ARROW SHOWS STARTING TIME IN HOURS AFTER PREDICTED TIME OF HIGH WATER.
FEATHERS SHOW TIME INTERVAL BETWEEN DOTS. NO FEATHER INDICATES 30 MINUTES; A FEATHER 1 HOUR.
4.8
0.1
0.1
3.2
1.0
2.2
2.2
0.2
0.2
0.9

Figure 12


43°55'
0.4
0.4
0.4
1.7
7.2
BJM 71


69°35′
69°30′
44°00′
DAMARISCOTTA RIVER
DROGUE TRACKS
FLOOD CURRENTS
1 0 1 2
Kilometers
N
4.2
4.3
5.7
3.4
0.6
2.6
2.0

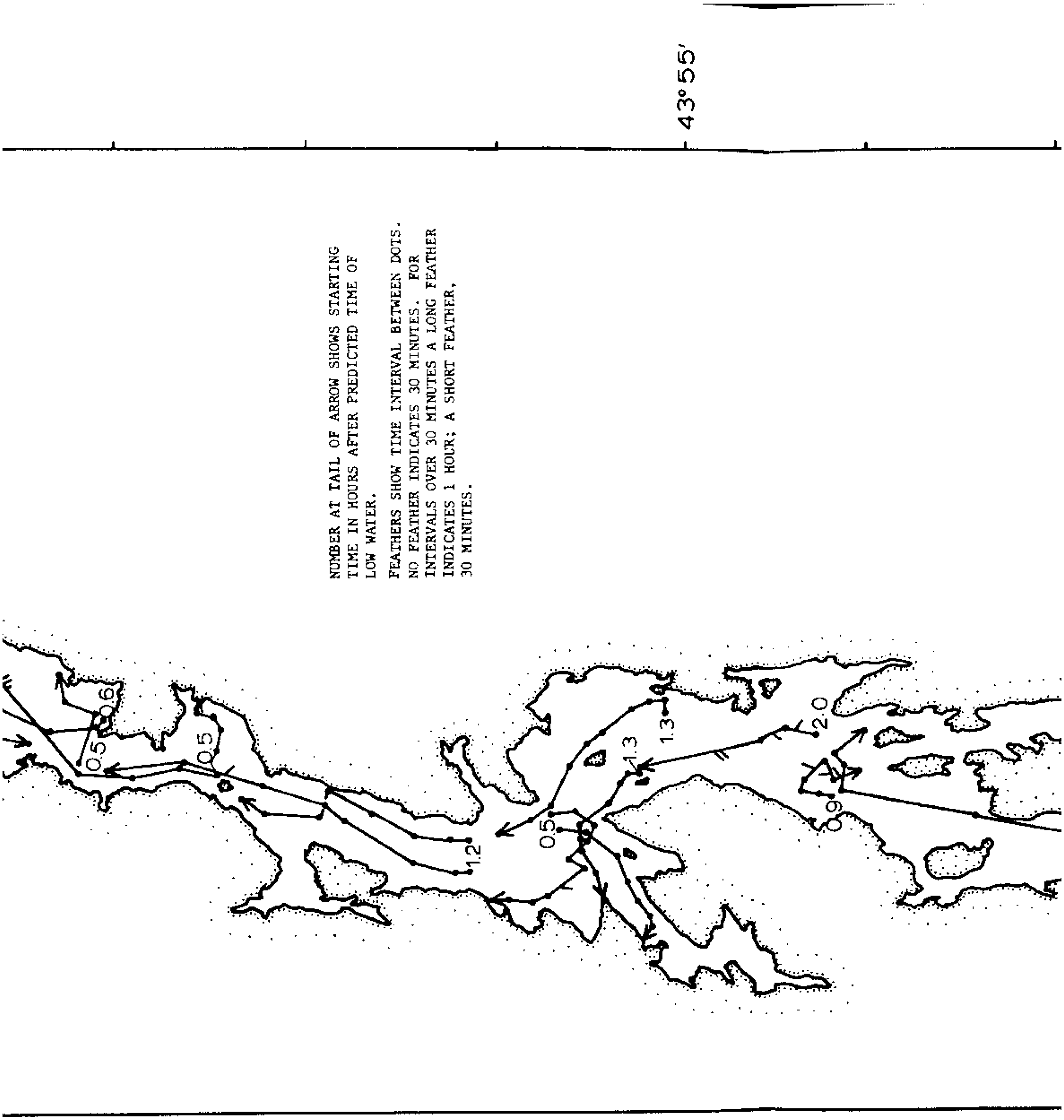
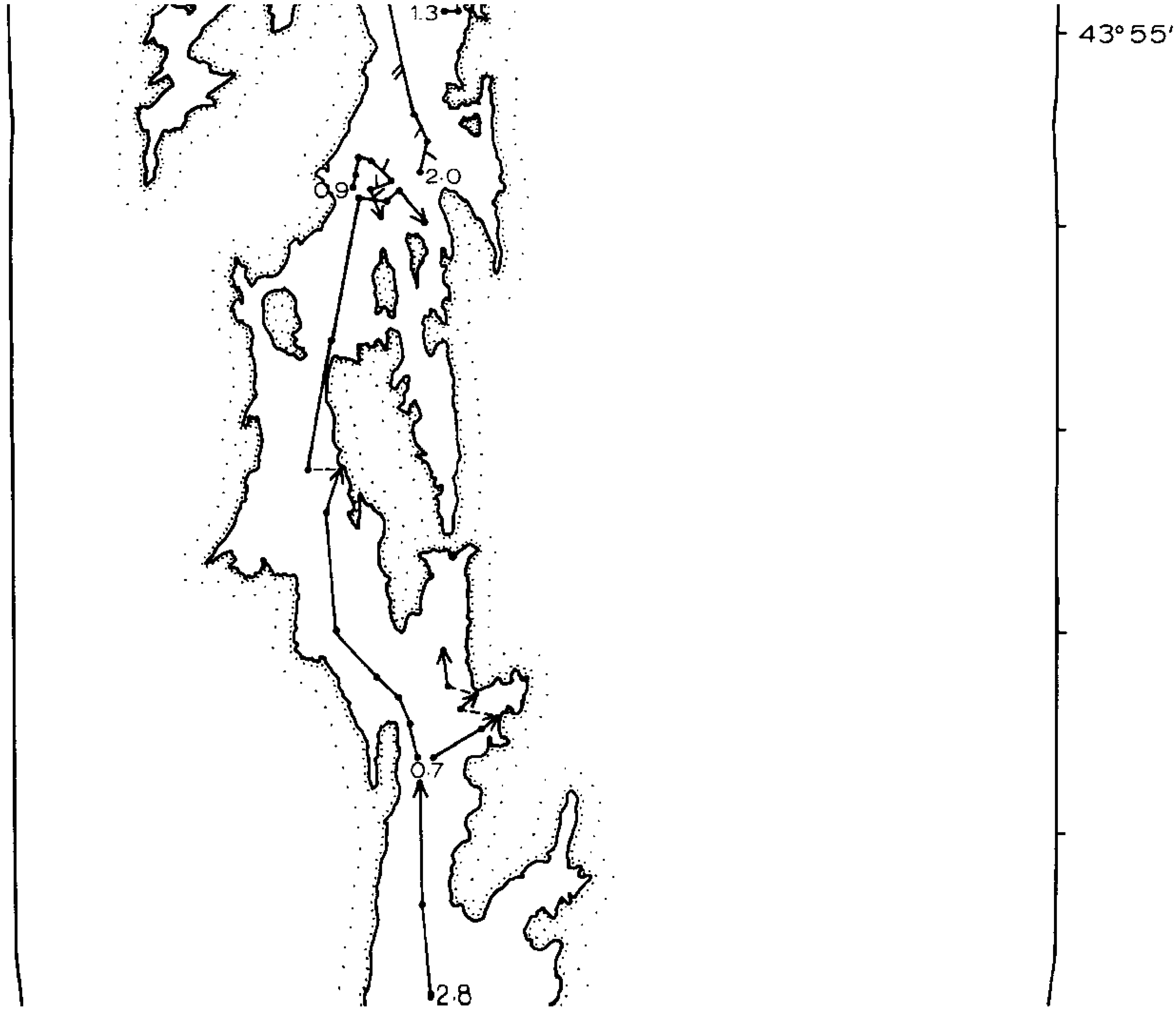
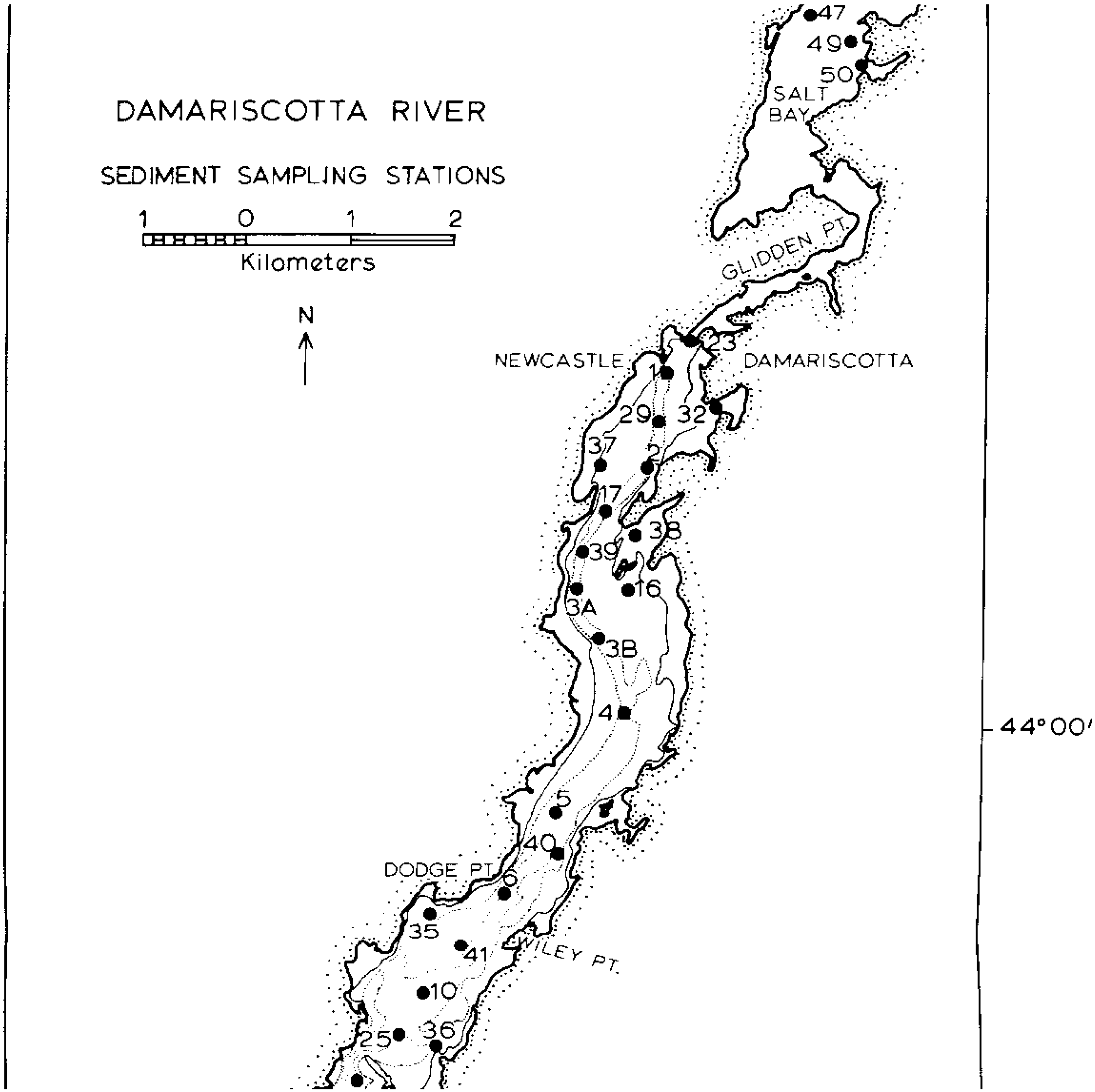

43°55′
NUMBER AT TAIL OF ARROW SHOWS STARTING TIME IN HOURS AFTER PREDICTED TIME OF LOW WATER.
FEATHERS SHOW TIME INTERVAL BETWEEN DOTS. NO FEATHER INDICATES 30 MINUTES. FOR INTERVALS OVER 30 MINUTES A LONG FEATHER INDICATES 1 HOUR; A SHORT FEATHER, 30 MINUTES.
0.6
0.5
0.5
1.2
0.5
1.3
1.3
2.0
0.9

Figure 13


43°55′
1.3
2.0
0.9
0.7
2.8


DAMARISCOTTA RIVER
SEDIMENT SAMPLING STATIONS
1 0 1 2
Kilometers
N
47
49
50
SALT BAY
GLIDDEN PT.
23
NEWCASTLE
DAMARISCOTTA
1
29
32
37
2
17
38
39
16
3A
3B
4
44°00′
5
40
DODGE PT.
6
35
41
WILEY PT.
10
25
36

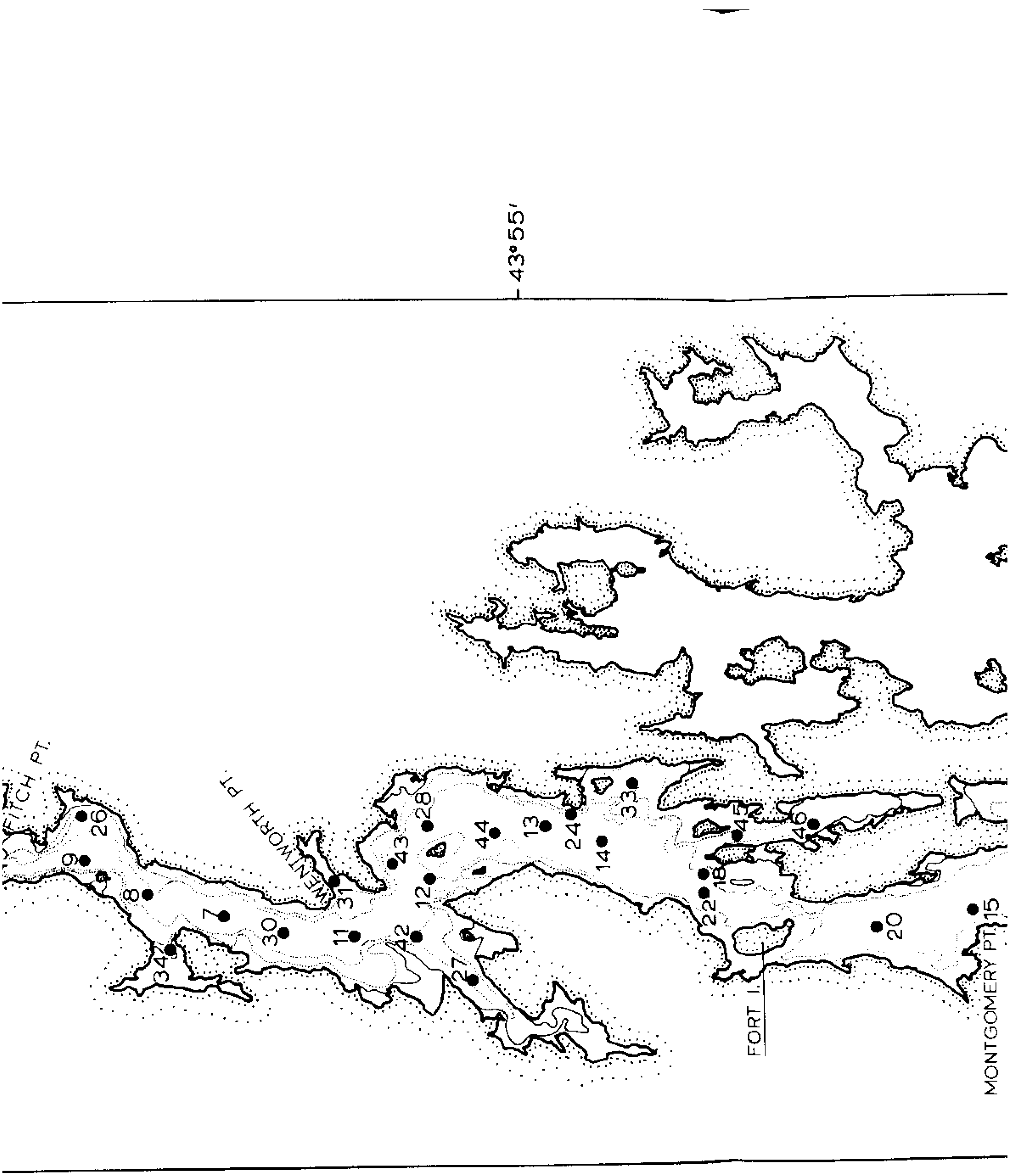
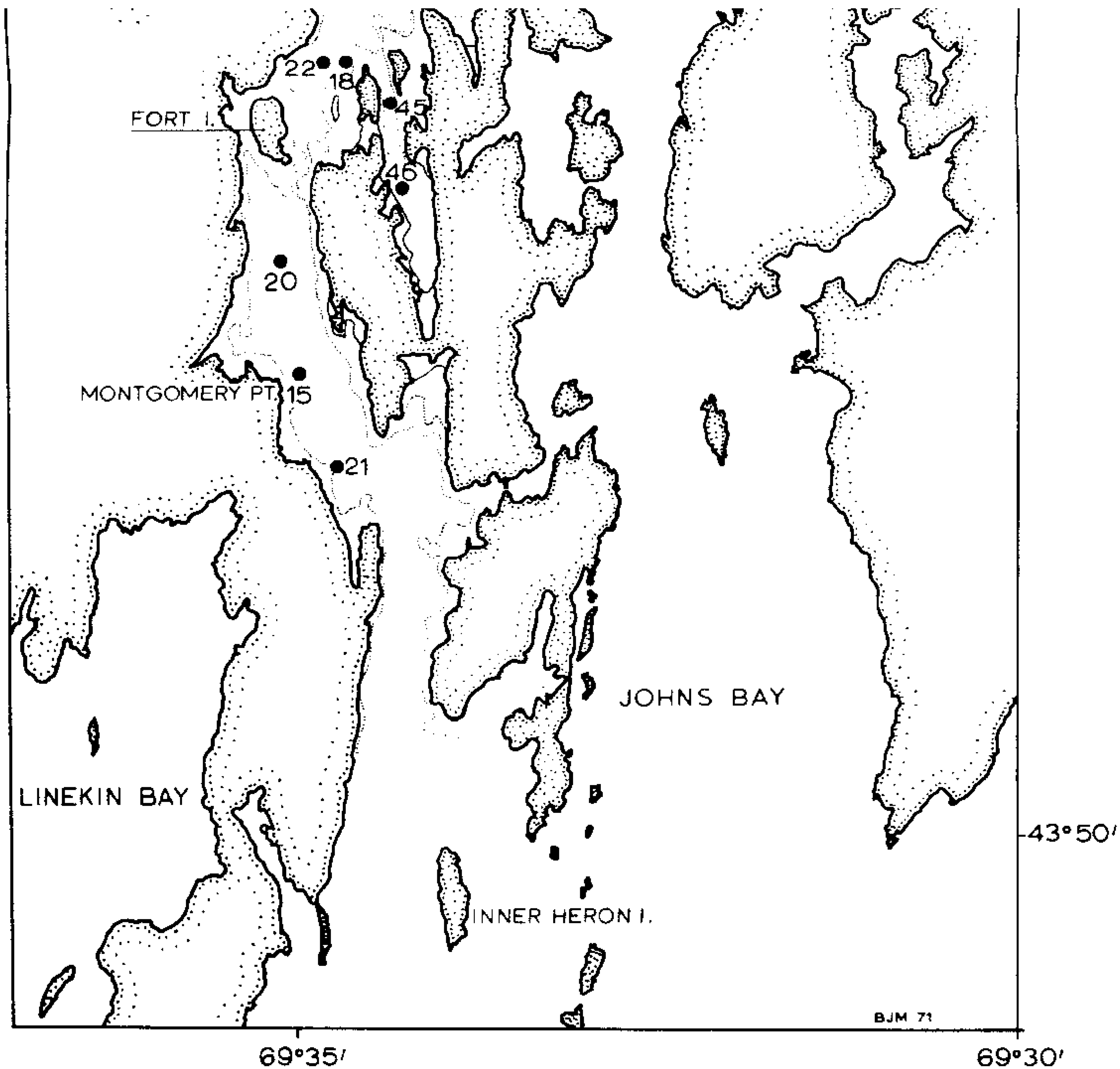
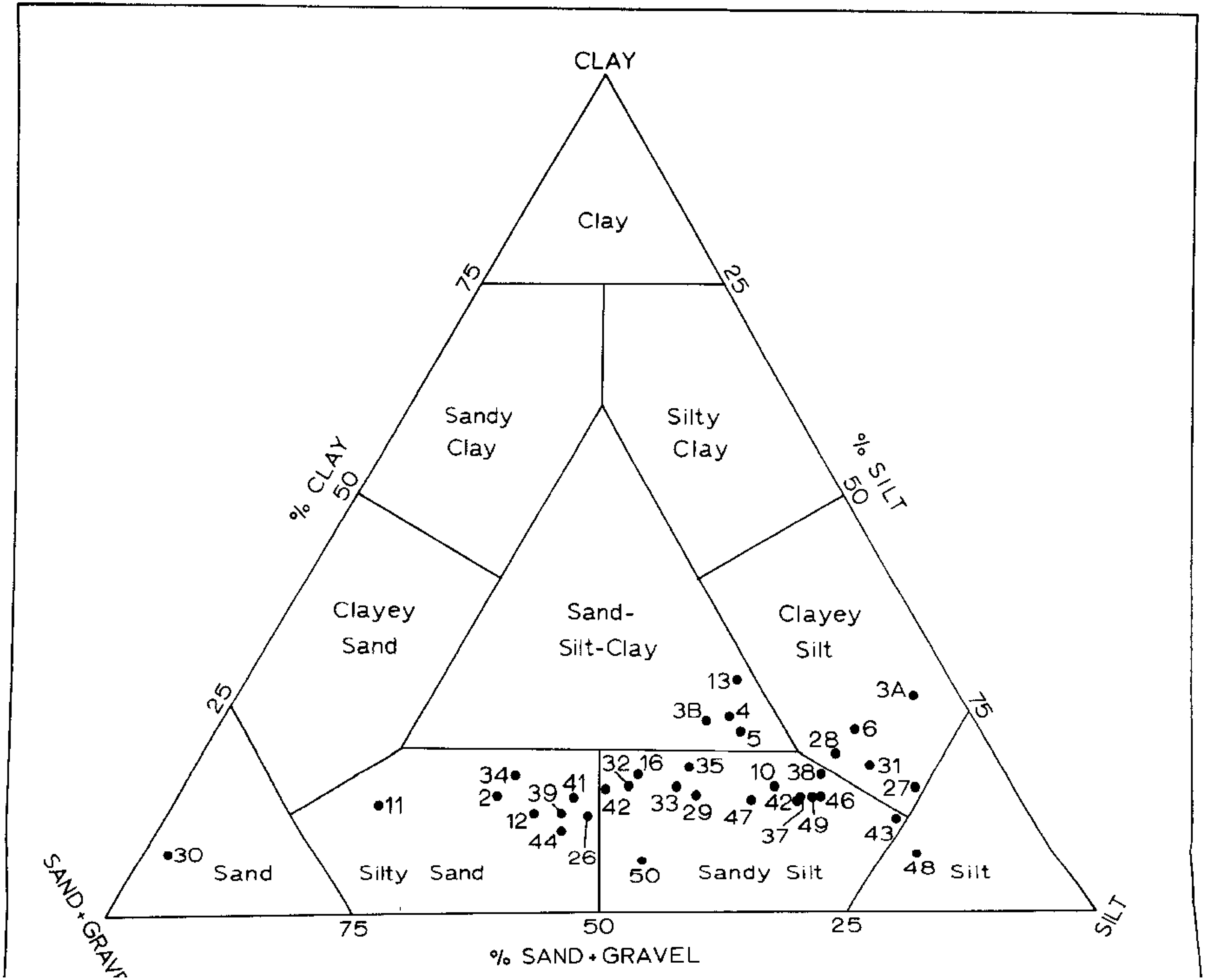

43°55'
FITCH PT.
WENTWORTH PT.
FORT I.
MONTGOMERY PT.
26
9
8
7
34
30
31
11
42
43
12
28
44
13
24
14
33
27
18
22
20
15

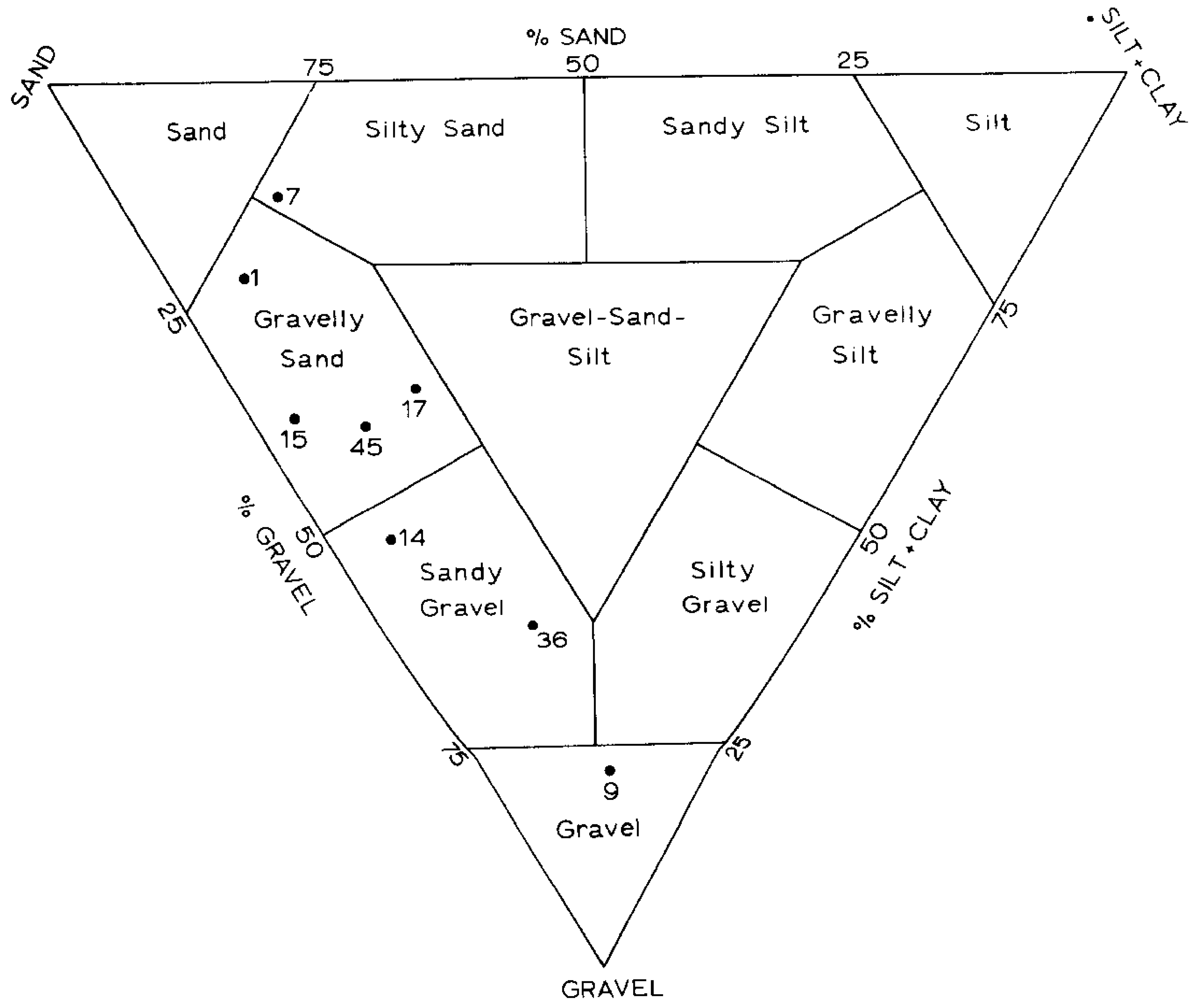
Figure 14



22
18
FORT I.
45
46
20
MONTGOMERY PT.
15
21
JOHNS BAY
LINEKIN BAY
INNER HERON I.
43°50′
BJM 71
69°35′
69°30′

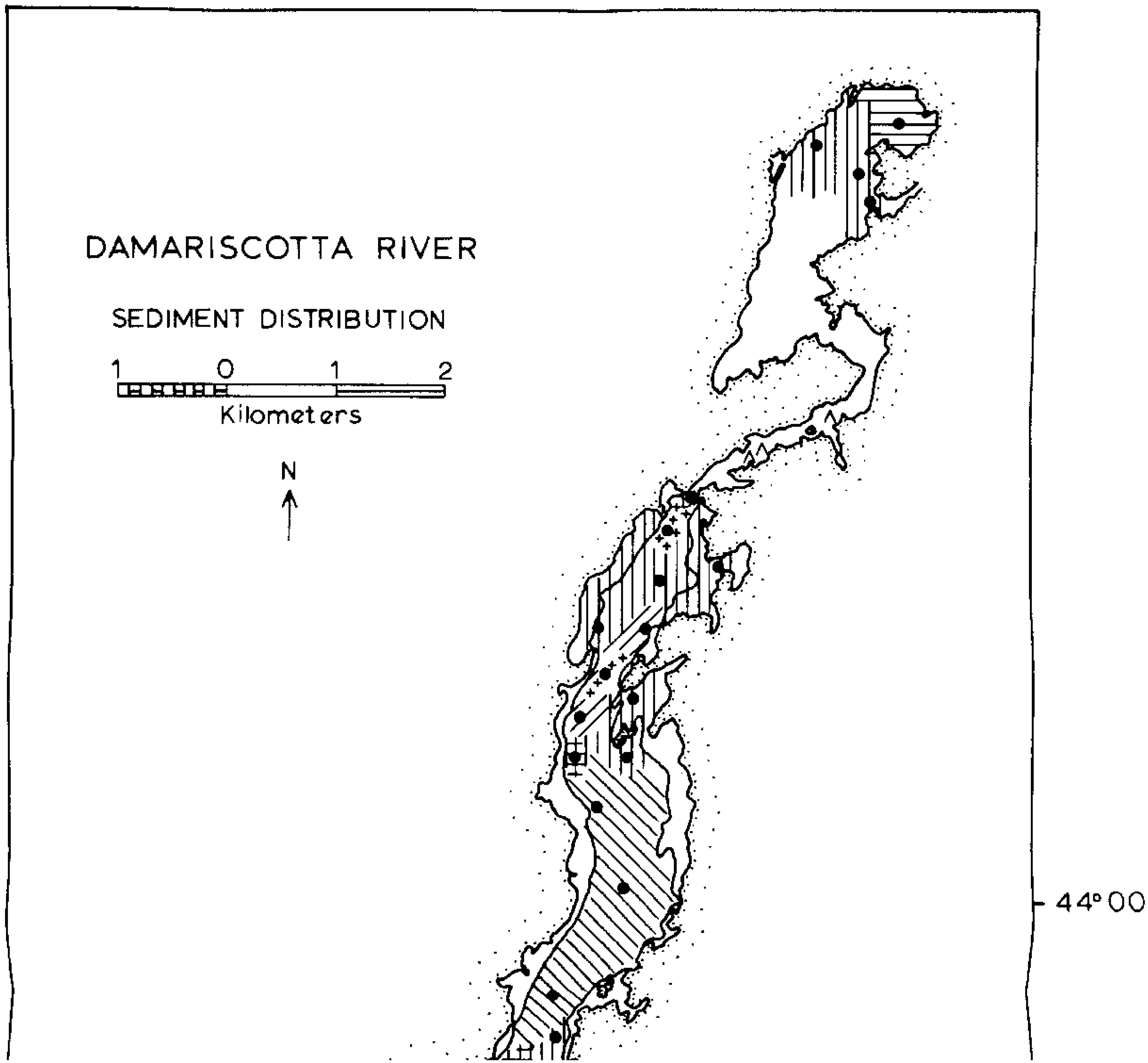

CLAY
Clay
Sandy Clay
Silty Clay
% CLAY
% SILT
Clayey Sand
Sand-Silt-Clay
Clayey Silt
Sand
Silty Sand
Sandy Silt
Silt
SAND + GRAVEL
SILT
% SAND + GRAVEL
75
50
25
3A 6 28 31 27 13 3B 4 5 34 2 39 41 12 44 26 32 16 42 33 29 35 10 38 47 42 37 49 46 43 48 11 30 50

Fig

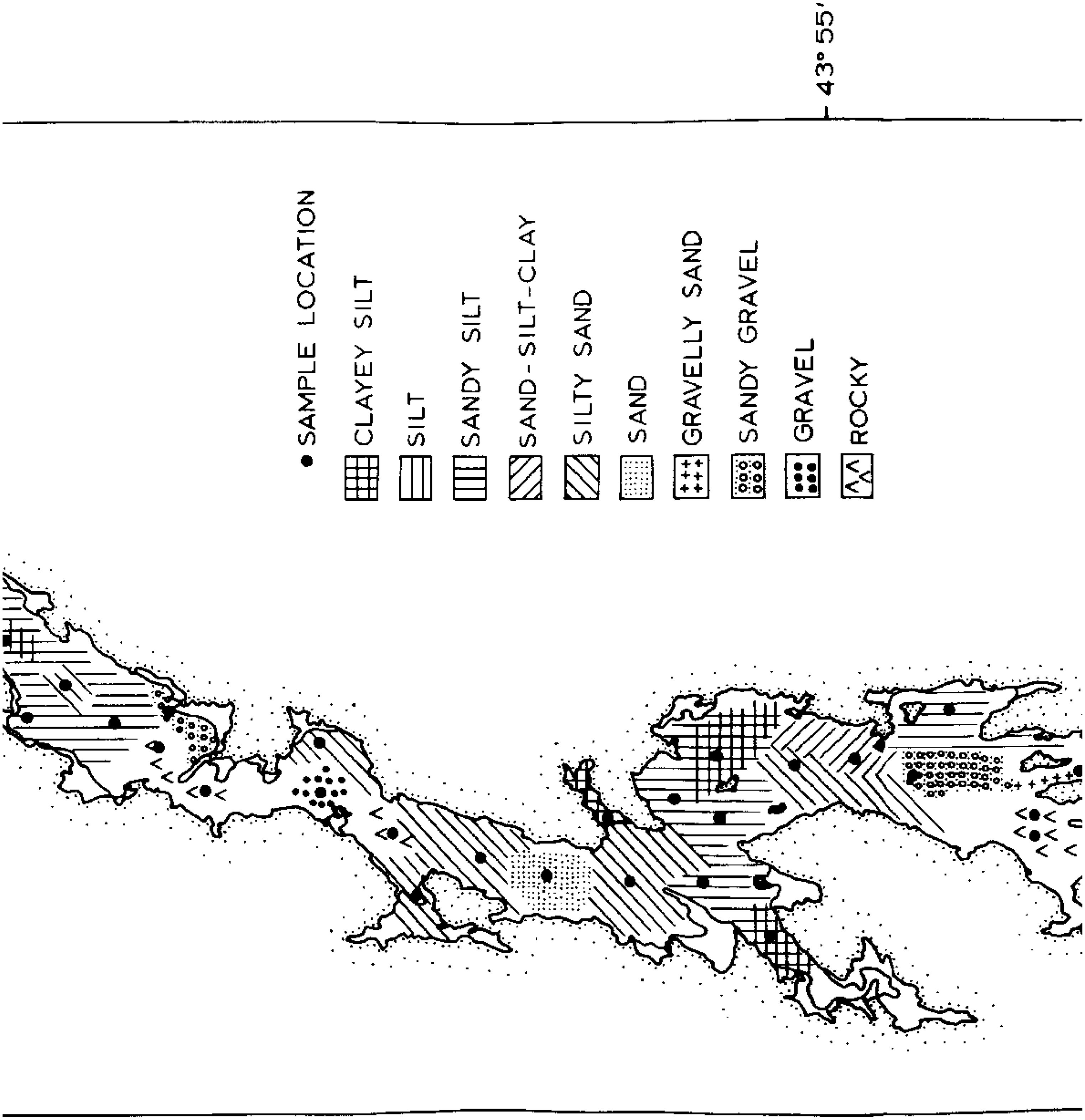


SAND
% SAND
75
50
25
SILT + CLAY
Sand
Silty Sand
Sandy Silt
Silt
7
1
Gravelly Sand
Gravel-Sand-Silt
Gravelly Silt
17
15
45
25
75
% GRAVEL
50
14
Sandy Gravel
36
Silty Gravel
50
% SILT + CLAY
75
25
9
Gravel
GRAVEL

ure 15

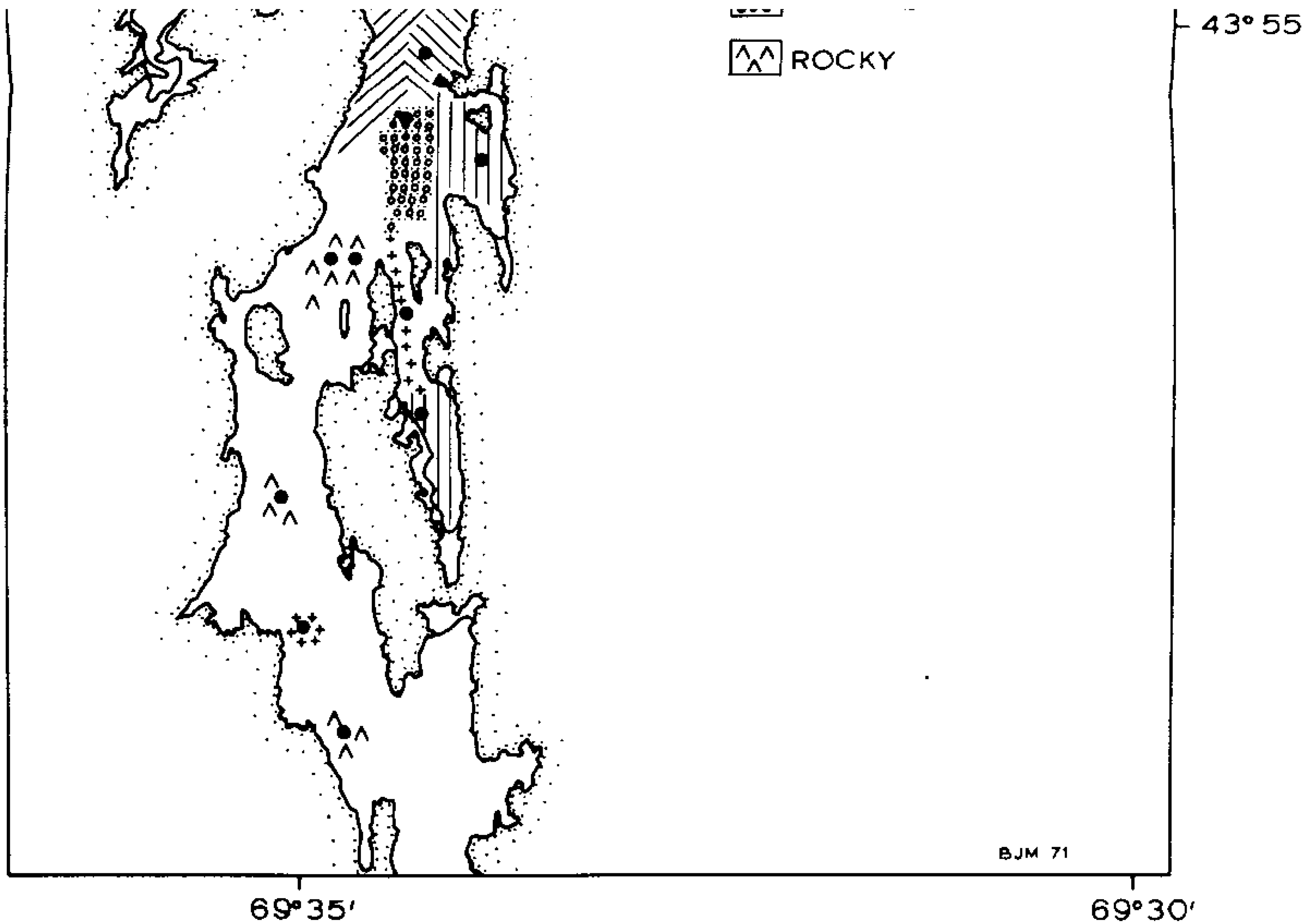


DAMARISCOTTA RIVER
SEDIMENT DISTRIBUTION
1 0 1 2
Kilometers
N
44° 00′



43° 55'
SAMPLE LOCATION
CLAYEY SILT
SILT
SANDY SILT
SAND-SILT-CLAY
SILTY SAND
SAND
GRAVELLY SAND
SANDY GRAVEL
GRAVEL
ROCKY

Figure 16


ROCKY
43° 55′
BJM 71
69°35′
69°30′