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Woods Hole, Massachusetts

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Reference No. 52-58

Hydrographic Survey in the Boston Area

Results of HAZEL III - Cruise 12

Prepared by D. F. Bumpus and C. G. Day

Interim Report No. 10
Submitted to Geophysics Branch, Office of Naval Research
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APPROVED FOR DISTRIBUTION ____________________
Director

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Introduction

Temperature, salinity, and transparency measurements were made in the Boston Harbor area during the period 1 - 4 April, 1952. The locationsof these observations are indicated in Figure 1. Similar observations in this area during other periods were reported in our Interim Report Nos. 1, 4, 5, 6, and 8; WHOI Reference Nos. 51-62, 51-93, 51-94, 52-19, and 52-43, respectively.

Temperature and Salinity at the Surface

The distrbution of temperature at the surface in the Boston area for this period is shown in Figure 2. Warmer temperatures were found inshore with isolated highs of 44.9°F. and 44.8°F., appearing south of Winthrop and at the mouth of the Charles River, respectively. Generally, temperatures of greater than 41.0°F. were found close to the shore while an intrusion of colder surface water, less than 41.0°F., penetrated from offshore through North Channel and into Hingham Bay. Surface temperatures for the Inner Harbor at both high and low water may be found in Figure 5.

Surface salinities, shown in Figure 3, to some extent paralleled the surface temperatures. The offshore values of greater than 31.0 ^{o}/oo penetrated in the direction of Deer Island. Lower values were found inshore, reaching a minimum of 20.72 ^{o}/oo near the mouth of the Charles River at high water. Further upstream there was an increase to 27.26 ^{o}/oo in Mystic River.

Distribution of Temperature, Salinity, Density, and Sound Velocity in Boston Harbor and Approaches

Temperatures in the section from Minots Light to Gloucester (Fig. 4) reveal the beginning of the vertical gradient charateristic of the warmer months. The warmest water in this section, greater than 41.0°F., appeared at the surface at Station Mc, while the coldest, 38.1°F., was found below one hundred feet. There was a consistent decrease in temperature with depth throughout, the difference between the extremes amounting to 3.5°F. for this area. This is a distinct contrast to the conditions found in late February and early March (WHOI Reference No. 52-43) when temperatures increased slightly with depth, the range being less than 1°F.

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Salinities ranged from 29.7 ^{o}/oo at the surface just south of Gloucester to greater than 32.0 ^{o}/oo below one hundred feet in the central part of the section. Values consistently increased with depth and, as with the temperatures, showed a more pronounced vertical gradient than had appeared a month previously.

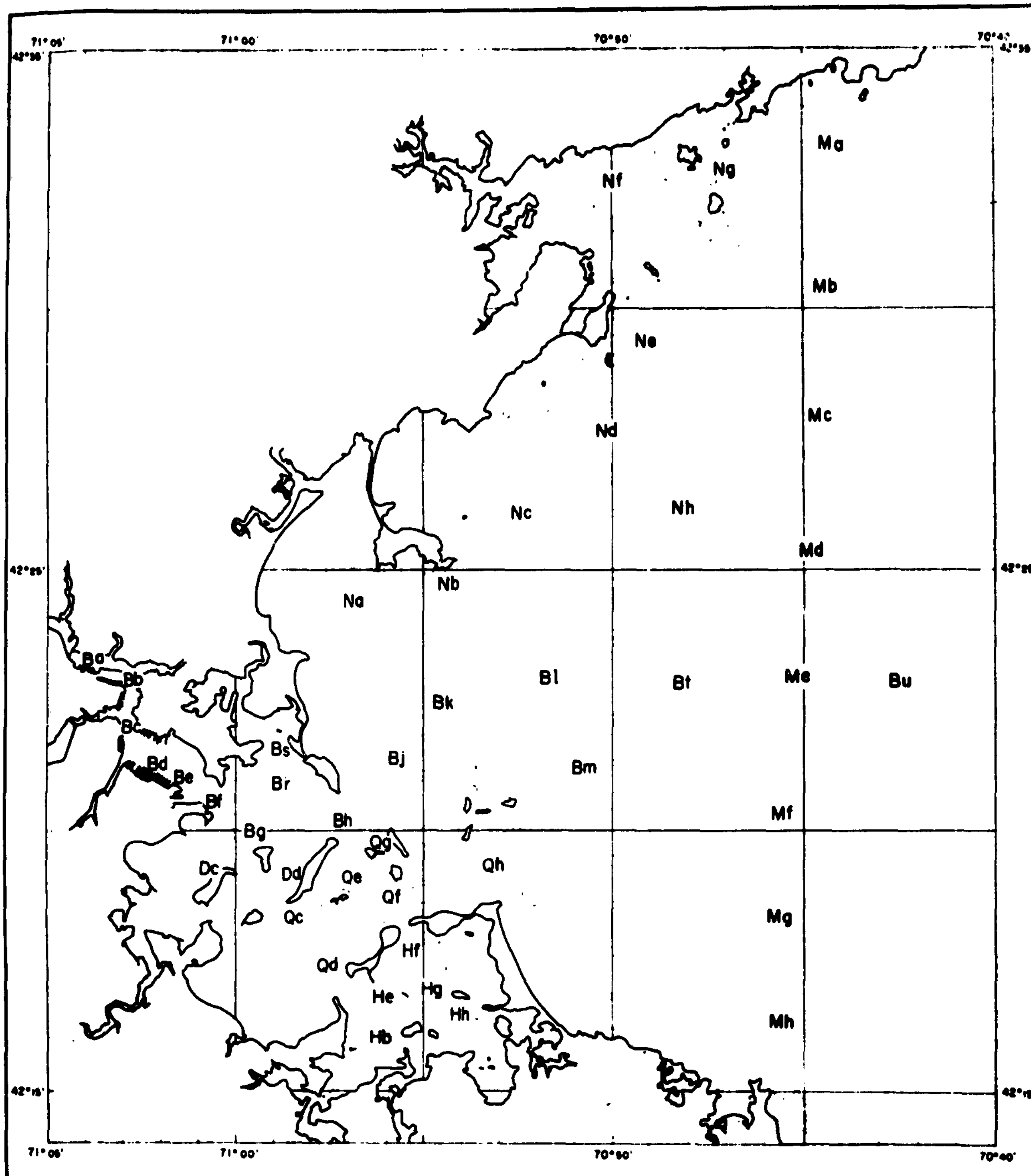

Fig. 1 Location of Stations, HAZEL III - Cruise 12, 1 - 4 April 1952.

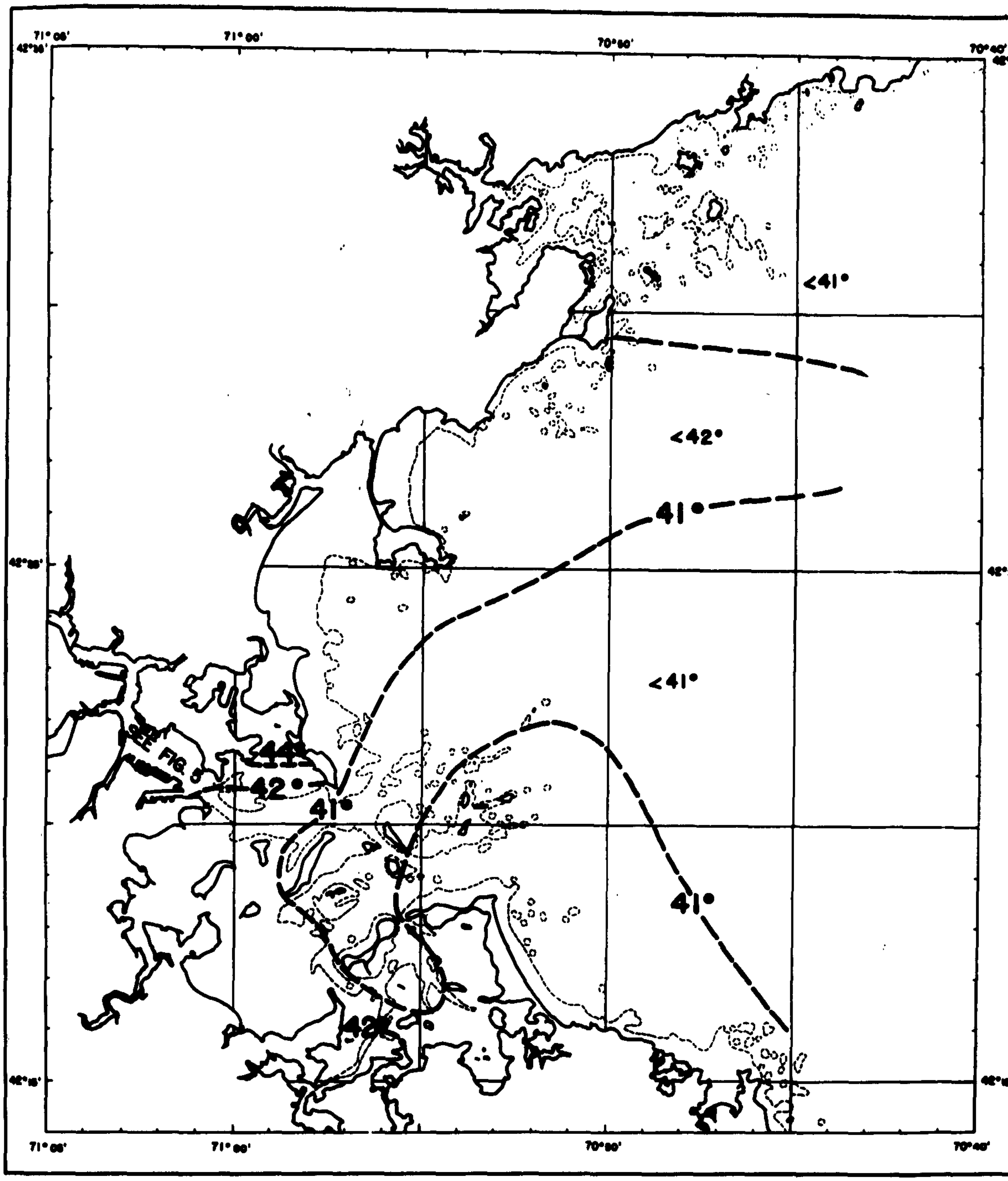

Fig. 2 Distribution of temperature (°F.) at the surface, HAZEL III - Cruise 12, 1 - 4 April 1952.

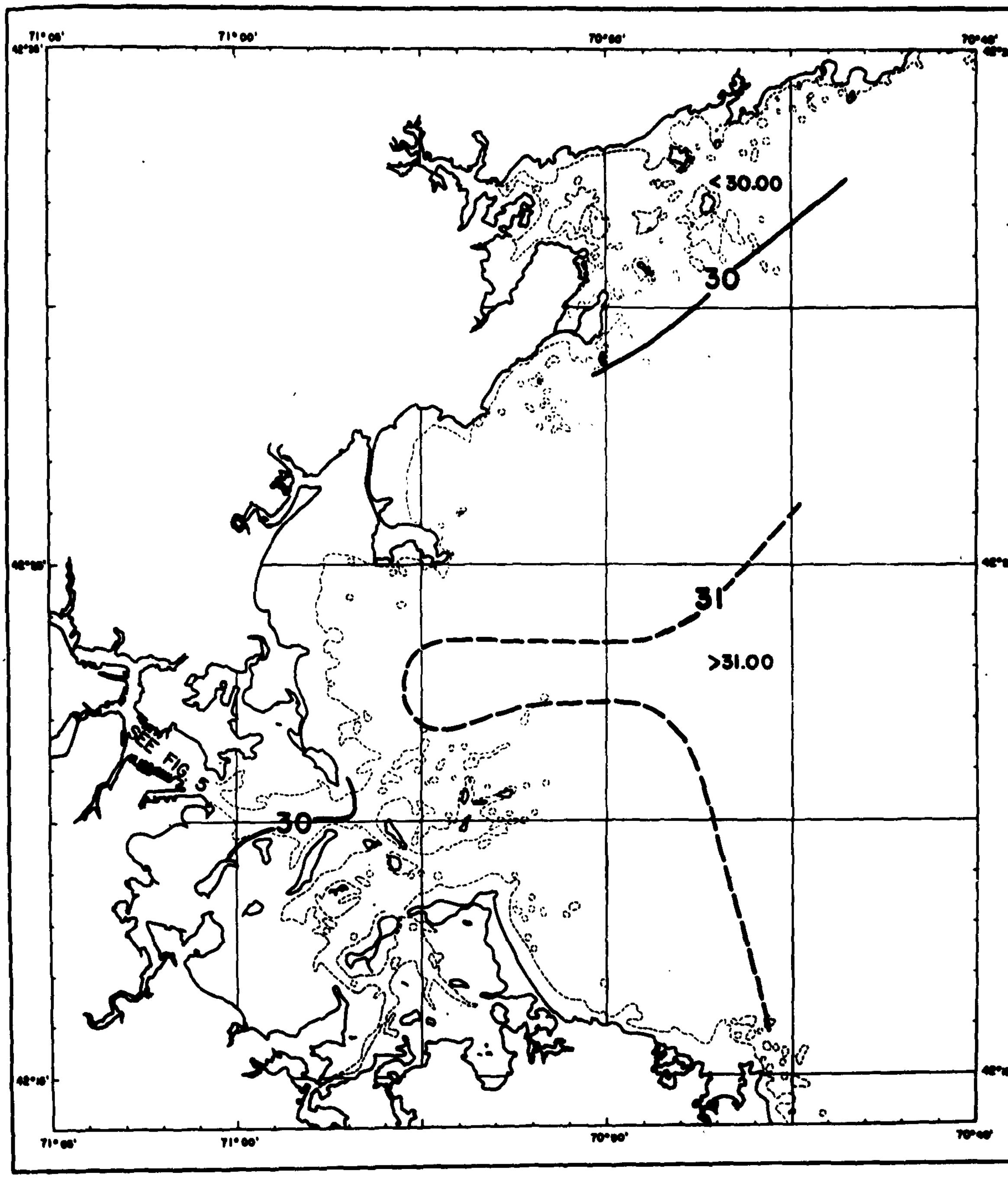

Fig. 3 Distribution of salinity (°/oo) at the surface, HAZEL III - Cruise 12, 1 - 4 April 1952.

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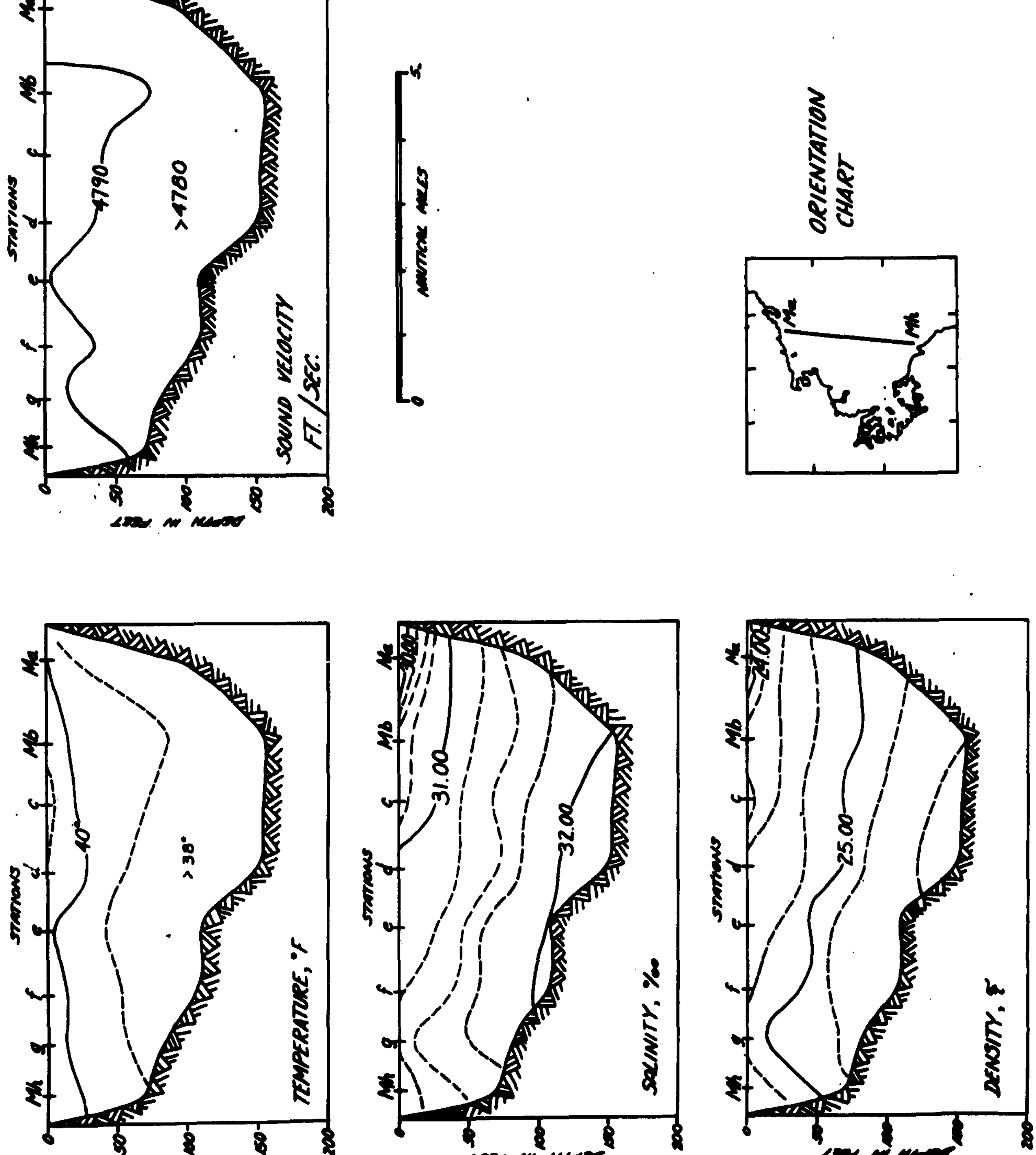

Fig. 4 Distribution of temperature, salinity, density, and sound velocity in the section Minots Light to offing of Gloucester, HAZEL III - Cruise 12, 1 - 4 April 1952.

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In the southern portion off Minots Light, this stratification was less pronounced. The increase in salinity from surface to bottom was less than 1.0 °/oo.

Density (sigma-t) followed the salinity pattern more closely than the temperature pattern. As with the salinity, the lowest densities were at the surface just south of Gloucester and the greatest at depths greater than one hundred feet in the central portion of this section. The extremes were 23.6 σ_t and 25.5 σ_t, giving a range of 1.9 σ_t units between surface and bottom. Stratification in the southern part was less intense, the increase from surface to bottom being only 0.6 σ_t units.

Sound velocity reflected the above conditions and showed the beginning of a vertical gradient. Velocities tended to decrease slightly with depth introducing the summer conditions where downward refraction is to be expected. The range in velocities between the surface and bottom was slight at the time, however, the extreme being found at Station Mc where the difference was only 18 feet per second. As with the salinity, values decreased near the surface in the northern part of this section near Gloucester.

In general, all the four properties studied showed distinct changes from the homogeneous conditions that had been found a month earlier to the more complex stratification characteristics of the summer months. Temperatures had increased by more than 3°F. and showed the beginnings of a negative gradient with depth. Salinity values were less at the surface, but uniformly increased with depth. Densities were lower by about 1 unit of σ_t than those of the previous month, but began to show a vertical gradient increasing with depth. Sound velocity paralleled these patterns.

In the section from Boston Inner Harbor through North Channel to the longitude of Boston Light Vessel (Fig. 5), the beginning of the negative temperature gradient characteristic of the summer months was apparent. The warmest water appeared at high water at the surface in the Inner Harbor immediately south of the mouth of the Charles River where a reading of 44.8°F. was obtained. Temperatures in this area decreased by 4°F. in the first thirty feet, below which lay a virtually isothermal layer of less than 40°F. Observations made in the Inner Harbor at low water revealed a similar negative gradient, though less intense, the maximum surface temperature being 42.9°F. Again, values decreased to less than 40°F. below twenty feet. From Reserve Channel eastward, the vertical gradient was less pronounced though still apparent except at Stations Bk and Bl at the seaward end of North Channel where differences of only 0.7°F. and 0.3°F., respectively, were found.

The salinity pattern was very similar to that of temperature, the strongest gradient appearing at high water in the Inner

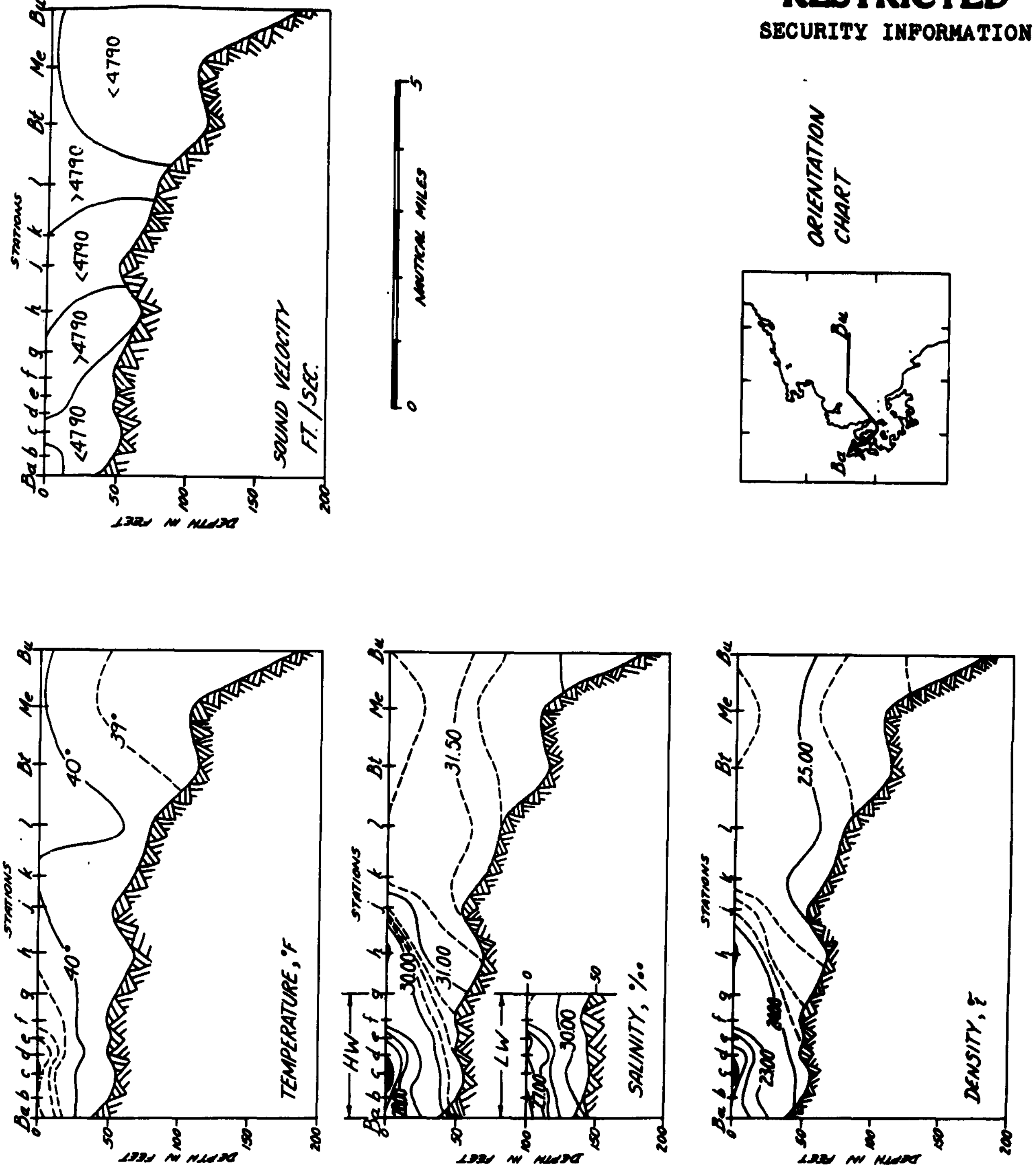

Fig. 5 Distribution of temperature, salinity, density, and sound velocity in the section Chelsea River to longitude of Boston Light Vessel, HAZEL III - Cruise 12, 1 - 4 April 1952.

Harbor. Off the mouth of the Charles River, values rose from a minimum of 20.7 $^{o}/oo$ at the surface to 30.3 $^{o}/oo$ near the bottom. Another pocket of low salinity appeared off Deer Island where a value of 28.5 $^{o}/oo$ was obtained at the surface. From Deer Island seaward the positive gradient was apparent though less pronounced than in the Inner Harbor.

Density corresponded closely to the salinity structure, exhibiting a pronounced vertical gradient. The lowest density, 16.2 σ_t, was found to be at the surface near the mouth of the Charles River at high water, where values increased to 21.0 σ_t at eight feet and to greater than 24.0 σ_t near the bottom. Another pocket of lesser density was found at the surface off Deer Island where a value of 22.6 σ_t was derived. From Deer Island to the east, density continued to increase with depth, greater than 25.0 σ_t being found below fifty feet.

Throughout this entire section the extremes of sound velocity differed only by eighteen feet per second, the highest being 4,799 feet per second at the surface in Mystic River, and the lowest 4,781 feet per second in a pocket of relatively fresh water on the surface near the mouth of the Charles River. Generally, there was a slight decrease in velocity with depth except for the two areas of low salinity off the Charles River and off Deer Island where velocity increased slightly with depth.

The general trends throughout this section were, again, toward more definite stratification of the properties studied, vertical gradients appearing for the first time since Cruise 8 in November 1951 (WHOI Reference No. 52-19). Temperatures had risen by more than 8°F. at the surface and by more than 3°F. at the bottom in the Inner Harbor since the end of February (WHOI Reference No. 52-43). An over-all increase of 3°F. prevailed elsewhere in this section; salinity and density showed positive gradients; sound velocity increased in the Inner Harbor by as much as forty feet per second, while in North Channel and eastward the increase was twenty feet per second.

Attendant Precipitation and Stream Flow

Precipitation and stream flow for New England are available from Geological Survey Water Bulletin for March 1952. Precipitation averaged about 94 per cent of normal in Massachusetts, 3.64 inches. In general, at the close of the month streams were discharging at about two to three times the rate of discharge found at the beginning of the month, but runoff was still somewhat below normal for this time of year. The runoff of representative rivers averaged 99 per cent of normal, 3.05 inches. Ground water levels showed a slight net increase. Water levels were in general above average in Middlesex County, reaching an all-time high for the twelve years of record.

Net change in month: plus 1.45 feet
Net change in year: plus 0.39 feet
Departure from March average: plus 1.16 feet

Flushing Time of Boston Inner Harbor

In the preceding reports on the flushing time of Boston Inner Harbor, the computations have been dependent upon the calculated fresh water content of the harbor and an assumed runoff of 300 square miles. This assumed runoff has been based on the concurrent total monthly runoff of the four representative rivers in the New England district. Admittedly, it would have been far better to use the concurrent runoff from the tributary watershed. Only the Charles River is gaged but the data postcedent to the 1949-50 water year is not presently available. As soon as this data does become available it will be forwarded to us and we shall apply it to the Boston flushing problem. In the meantime, the nearest river, geographically to the Charles River, for which we have monthly runoff figures for the last 21 months is the Wading River gaged at Norton, Massachusetts. The runoffs per square mile from the watersheds of the Charles and Wading Rivers over a period of 14 years are strikingly similar. Inasmuch as the watersheds are also similar, as regard rainfall, geology, and topography, we have computed the runoffs for a 300 square mile watershed on the basis of the Wading River data. The appropriate fresh water volumes and flushing times for the several series of observations made in Boston Inner Harbor are listed in Table I. The flushing time is plotted against the reciprocal of the runoff in Figure 6. These data very decidedly suggest that the flushing rate is dependent upon the runoff; that when the runoff is large the flushing time is short, when the runoff is small the flushing time is long. The so calculated flushing times vary from about two to sixteen days, averaging to date about five days. It is obvious, from the graph, that we need more data from the months of small runoff; namely, July, August, September, and October. Inasmuch as the mean annual runoff (Charles and Wading Rivers) is 1.6 second feet per square mile, the mean flushing time for Boston Inner Harbor as estimated from Figure 6 is 3.5 days.

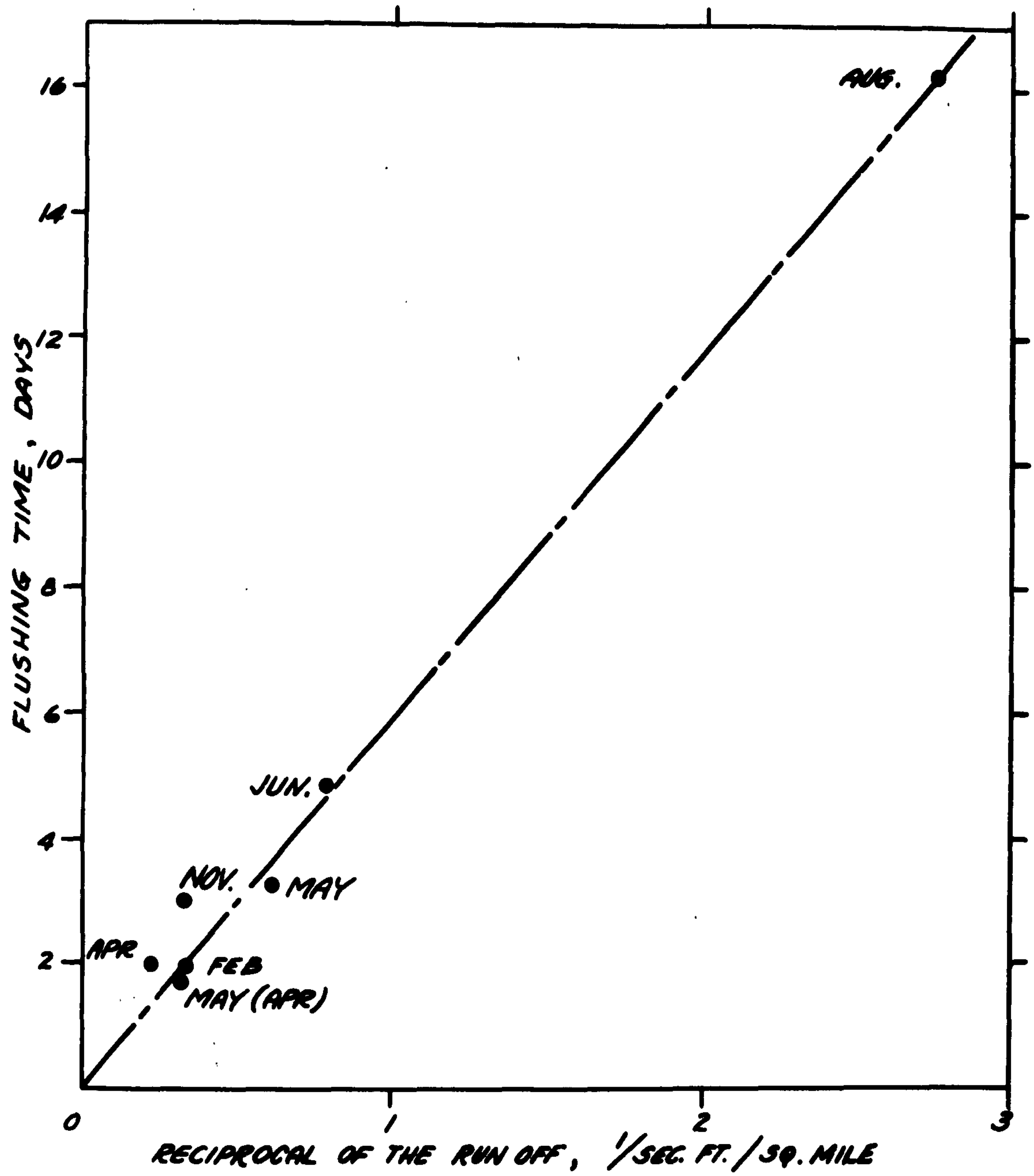

Fig. 6 Flushing time of Boston Inner Harbor versus calculated runoff of 300 square miles watershed.

Table I

Summary of Flushing Data, Boston Inner Harbor

Date 1951		River Water in Hbr. x 10^6 cu.ft.	%	Runoff (Wading R.) sec.ft/sq.mi.	Runoff/day from 300 sq.mi. area x 10^6 cu.ft.	Flushing Time Days
5 May		133.7	5.6	3.10 (Apr.)	80.4 (Apr.)	1.66
				1.62 (May)	42.0 (May)	3.18
26 June		159.6	6.7	1.27	32.9	4.85
23 Aug.		153.1	6.5	0.364	9.45	16.2
24 Nov.		232.8	9.8	3.00	77.8	3.0
1952						
28 Feb.	HW	154.0	5.6	2.95	76.5	2.02
	LW	149.5	7.5	2.95	76.5	1.96
1 Apr.	HW	259.5	9.4	4.49	117.0	2.22
	LW	192.4	10.1	4.49	117.0	1.65

Transparency

During the first week in April, the visibility with a white Secchi disc ranged from 4.5 feet in the Mystic River to 10 feet in President Roads and 30 - 39 feet offshore. The black disc could be seen to approximately one-third these depths.

The change in transparency as observed from time to time during the past year at three stations in the Boston area, is illustrated in Table II. The relatively low transparency values in May are due to the presence of abundant plankton. During the summer and autumn, the transparency improved to a maximum in November prior to the onset of winter. Northeast storms which stir up the mud and silt in the shallow waters cause the sharp reduction in transparency noted in early March. With the cessation of winter storms, the particulate matter settles out to produce maximum transparency in April prior to the blooming of plankton in late April and May.

Table II

Summary of Secchi Disc Observations at Three Stations in the Boston Area

Date	Station* Bg	Bk	Mc
5 May '51	4.5'	9'	17'
22 June '51	6.0'	10'	28'
23 August '51	9.0'	9.0'	27'
24 November '51	9.9'	17.8'	25'
1 March '52	3.0'	3.5'	12'
28 March '52	-	9'	21'
3 April '52	10.8'	25.8'	36.5'

* Bg at western end of President Roads
Bk at northern end of North Channel
Mc one mile north of Boston Light Vessel

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