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A STUDY OF WATER CONDITIONS AT MATSUKAWAURA

By

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The study of the environment for the cultivation of laver at Matsukawaura, previously resulted in a report on the investigation of Asakusa laver with nitrogen content as a main limiting factor of its production, the soruce of this nitrogen coming from ocean water (1, 2). The following report, based on our investigations in 1964, is an investigation as to how the ocean water infiltrates into the bay and what factors there are as obstacles against the infiltration.

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Methods and Results

I) Change of tide level at various stations in the bay:

At the time of the first investigation, the measurements of tide level were made at seven stations shown in Figure 1. Water level at each of these stations was measured at intervals of about 10 or 20 minutes, by erecting a measure two meters long. It was done from 4:30 a.m. August 11 (this the earliest case) and from 6:20 a.m. of the same day (this is the latest) to after 4:00 p.m.. At the second investigation, the measurements were made from about 3:45 p.m. November 24 to 3:00 p.m. of the next day. We note here that because of the impossibility of measurement at night, the evaluation at St. 1 is substituted for the evaluation at the same station in the report of the Public Works Section of Fukushima Prefecture, the measurement of which, we were told, was made by using a tidal indicator. Our measurements at St. 2 and 4 were made by using a two-meter long measure as in our first investigation. The measurements at ST. 3 and 6, were made by using a self tidal level meter made by Hattori Watchmaking Co.. No measurement was done at St. 5, because the result of the first investigation told us that the evaluation at the station was quite the same as that at St. 4. The measurement at St. 6 was not successful, because the apparatus was blown away by strong winds. Therefore, the

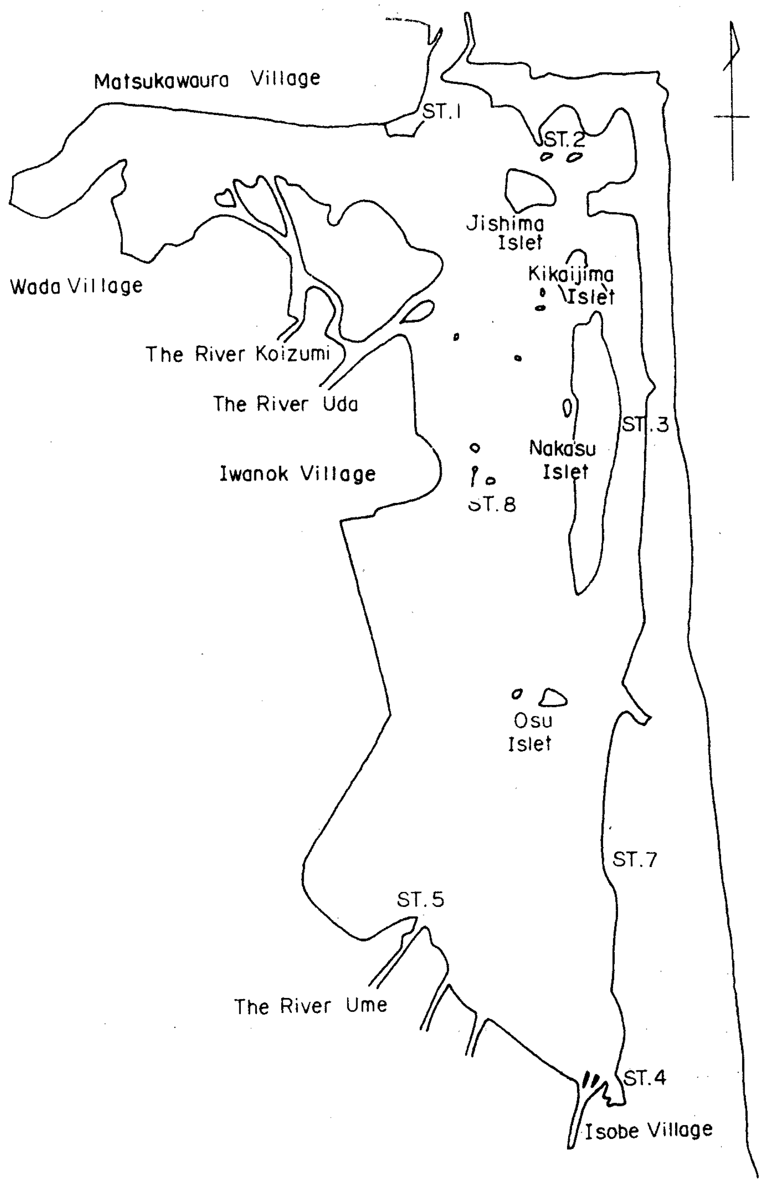

Fig. 1. Stations at Matsukawaura where the measurements of tidal level were made.

second investigation uses only the evaluations at four stations, namely, St. 1, 2, 3 and 4. We arranged our data and we obtained a convertion table of it, by assuming each water level at the highest tide as 0 and by the showing the lowering of the tide at each hour by centi-meters. Table 1 through 7 show the results of the measurements at each station in August, and Table 8 through 11, those in November.

From Table 1 through 7, we can read the time of the highest tide at each station as follows: at St. 2, about 6:40 a.m.; at St. 3, at Nakasu, between 6:40 and 6:50 a.m.; at St. 4, at Isobe, about 6:50 a.m.; and at St. 5, at Umegawa, about 6:50 a.m.. Owing to our delay in arriving at the St. 6, we were unable to reading.

Table 1. The results of the measurements at ST.1 in August

Date	Time	Water temperature C°	Water level −cm	Velosity of current cm/sec	Date	Time	Water temperature °C	Water level −cm	Velocity of current cm/sec
8.11	4:35	24.1			8.11	11:00	27.1	101.1	0.63
	4:40		10.2			11:30	27.4	107.8	0.67
	4:50		5.0			11:45	27.5	112.5	0.71
	5:00	24.2	4.0			12:00	27.8	111.0	0.63
	5:10	24.4	4.9			12:15	27.9	110.3	0.61
	5:20		0.2			12:30	28.0	109.5	0.45
	5:25		0.3			12:45	28.2	110.9	0.45
	5:30		0.1			13:00	28.5	108.3	0.43
	5:40		1.1			13:15	28.7	106.8	0.23
	5:50	24.5	0.2			13:30	28.8	100.1	0.25
	6:00		0.6			13:45	29.1	95.6	0.08
	6:17		1.0			14:00	29.1	88.4	
	6:25		0.2			14:15	29.1	83.7	
	6:40		0.0			14:30	29.1	79.6	
	6:50		5.0			14:45	27.2	72.0	
	7:00		7.1			15:00	26.4	64.3	
	7:15	24.6	13.2			15:30	26.4	54.4	
	7:30		16.4	0.63		16:00	25.8	44.4	
	7:45	24.7	19.5	0.63		16:30	25.4	41.2	
	8:00	24.7	28.2	0.77		17:00	25.3	27.4	
	8:15	24.8	34.2	0.71		17:30	25.1	24.4	
	8:30	24.9	42.0	0.81		18:00	24.8	19.1	
	9:00	25.1	54.6	0.81		18:15	24.7	20.7	
	9:30	25.4	65.8	0.72		18:30	24.6	16.3	
	10:00	25.7	77.5	0.77		18:45	24.5	14.6	
	10:30	26.2	90.1	0.83					

Table 2. The results of the measurements at ST. 2 in August

Date	Time	Water temperature °C	Water level −cm	Date	Time	Water temperature °C	Water level −cm
8.11	5:10		10.0	8.11	9:40	25.1	45.9
	5:25	24.2	7.4		10:00	25.2	52.3
	5:40	24.1	4.9		10:20	25.6	59.3
	5:50	24.0	1.8		10:40	26.5	66.4
	6:10	24.5	1.3		11:00	26.7	72.6
	6:25	24.2	0.3		11:20	27.8	81.5
	6:40	24.5	0		11:40	28.5	83.9
	6:55	24.5	0.9		12:00	28.8	92.0
	7:10	24.5	3.2		12:20		95.3
	7:25	24.5	5.2		12:40		96.3
	7:40	24.5	7.5		13:00		97.1
	7:55	24.5	12.1		13:20		97.0
	8:10	24.5	14.1		13:40		96.3
	8:30	24.5	23.2		14:00		87.5
	8:40	24.6	24.5		14:20		81.9
	9:00	24.6	31.1		14:40		76.3
	9:20	25.0	36.8		15:00		72.6

Table 3. The results of the measurements at ST. 3 in August

Date	Time	Water level -cm	Date	Time	Water level -cm	Date	Time	Water level -cm
8.11	5:20	12.6	8.11	8:30	19.2	8.11	12:50	80.5
	5:30	9.6		8:50	24.5		13:00	82.1
	5:40	7.6		9:00	26.8		13:10	83.5
	5:50	6.3		9:15	30.8		13:20	84.8
	6:00	4.0		9:30	34.6		13:40	87.0
	6:10	2.9		9:45	38.5		13:50	87.2
	6:20	1.1		10:00	41.4		14:00	87.0
	6:30	0.4		10:15	47.2		14:25	83.8
	6:40	0		10:30	49.7		14:40	81.2
	6:50	0		10:45	53.7		14:50	79.7
	7:00	0.7		11:00	56.9		15:00	78.0
	7:10	1.9		11:15	60.8		15:15	74.6
	7:20	3.2		11:30	64.1		15:30	71.5
	7:30	5.5		11:45	68.8		15:45	68.8
	7:40	7.4		12:00	71.7		16:05	65.0
	8:00	11.7		12:10	73.9		16:15	63.9
	8:10	14.6		12:20	75.8		16:45	62.4
	8:20	16.8		12:30	77.5			

Table 4. The results of the measurements at ST. 4 in August

Date	Time	Water temperature °C	Water level -cm	Date	Time	Water temperature °C	Water level -cm
8.11	6:00		5.7	8.11	12:00		59.4
	6:10		3.8		12:10		60.8
	6:20	27.4	2.5		12:20		62.6
	6:30		1.4		12:30		64.0
	6:40		0.6		12:40		65.2
	6:50		0		12:50		66.6
	7:00	27.4	0.6		13:00	32.2	67.6
	7:10		1.1		13:10		68.8
	7:20		3.6		13:20		70.0
	7:30		5.0		13:30		71.6
	7:40		7.1		13:40		72.6
	7:50		9.8		13:50		73.6
	8:00	27.8	12.0		14:00	33.4	74.7
	8:10		14.1		14:10		75.6
	8:20		16.1		14:20		76.6
	8:30		17.6		14:30		77.7
	9:00	28.6	26.4		14:40		78.8
	9:30		33.3		14:50		79.6
	10:00	29.8	39.8		15:00	34.6	80.0
	10:30		45.1		15:10		81.0
	11:00	30.2	50.6		15:20		83.2
	11:30		56.4		15:30		80.8
	11:40	31.6	57.6		15:40		80.6
	11:50		58.1		15:50		80.2
					16:00		77.6

Table 5. The results of the measurements at ST. 5 in August

Date	Time	Water level −cm	Date	Time	Water level −cm	Date	Time	Water level −cm
8.11	6:00	5.3	8.11	9:40	34.9	8.11	13:10	71.5
	6:10	4.0		10:00	39.9		13:20	72.4
	6:20	2.2		10:20	44.3		13:30	73.3
	6:30	6.8		10:40	48.5		13:40	74.9
	6:40	0.3		11:00	52.1		13:50	75.9
	6:50	0		11:20	56.1		14:00	76.7
	7:00	0.6		12:00	61.9		14:20	78.9
	7:20	3.2		12:10	63.1		14:35	80.5
	7:40	7.6		12:20	65.1		15:00	81.9
	8:00	12.0		12:30	66.9		15:15	81.6
	8:20	15.8		12:40	68.1		15:30	79.9
	8:40	20.6		12:50	69.1		15:45	78.1
	9:00	25.2		13:00	70.3			

Table 6. The results of the measurements at ST. 8 in August

Date	Time	Water level −cm	Date	Time	Water level −cm	Date	Time	Water level −cm
8.11	6:20		8.11	9:30	31.0	8.11	13:45	80.0
	7:20	3.2		9:45	34.8		14:00	81.5
	7:30	4.0		10:00	38.8		14:15	82.0
	7:45	6.0		10:15	42.0		14:40	80.0
	7:52	7.0		10:30	45.2		15:00	78.0
	8:00	9.2		10:45	48.5		15:20	72.5
	8:10	11.8		11:00	51.5		15:30	70.0
	8:20	14.2		11:15	54.7		15:45	68.0
	8:30	16.6		11:30	58.0		16:00	65.0
	8:40	19.0		12:00	64.0		16:30	60.0
	8:50	21.3		12:30	69.5		16:45	56.0
	9:00	23.8		13:00	74.5			
	9:15	27.5		13:30	78.5			

Table 7. The results of the measurements at ST. 7 in August

Date	Time	Water level −cm	Date	Time	Water level −cm	Date	Time	Water level −cm
8.11	6:20	1.8	8.11	8:20	16.0	8.11	10:10	41.5
	6:30	1.0		8:30	18.6		10:20	43.5
	6:40	0.3		8:40	20.7		10:30	45.3
	6:50	0		8:50	22.7		10:40	47.2
	7:00	0.3		9:00	25.6		10:50	49.4
	7:10	1.6		9:10	28.2		11:00	51.1
	7:20	3.3		9:20	30.1		11:10	53.1
	7:30	5.0		9:30	32.5		11:20	55.1
	7:40	7.0		9:40	34.8		11:30	56.5
	7:50	9.6		9:50	36.8		11:40	58.2
	8:00	12.0		10:00	39.2		11:50	59.7
	8:10	13.6		10:08	40.8			

Table 8. The results of the measurements at ST. 1 in November

Date	Time	Water level −cm	Date	Time	Water level −cm	Date	Time	Water level −cm
11.24	9:00	25	11.24	17:30	1	11.25	2:00	125
	9:30	24		18:00	0		2:30	124
	10:00	24		18:30	3		3:00	120
	10:30	27		19:00	7		3:30	112
	11:00	32		19:30	15		4:00	101
	11:30	36		20:00	24		4:30	93
	12:00	39		20:30	32		5:00	84
	12:30	35		21:00	41		5:30	73
	13:00	34		21:30	53		6:00	66
	13:30	33		22:00	65		6:30	60
	14:00	30		22:30	76		7:00	50
	14:30	27		23:00	87		7:30	45
	15:00	21		23:30	96		8:00	41
	15:30	15	11.25	0:00	105		8:30	37
	16:00	9		0:30	115		9:00	35
	16:30	7		1:00	122		9:30	35
	17:00	4		1:30	126			

Table 9. The results of the measurements at ST. 2 in November

Date	Time	Water level −cm	Date	Time	Water level −cm	Date	Time	Water level −cm
11.24	15:45	13.0	11.25	0:30	95.0	11.25	8:30	39.0
	16:00	12.0		0:45	98.0		9:00	36.0
	16:15	11.0		1:00	101.0		9:30	35.0
	16:30	9.5		1:15	104.0		10:00	35.0
	16:45	7.5		1:30	106.0		10:15	34.0
	17:00	4.5		1:45	108.5		10:30	34.5
	17:15	3.0		2:00	109.5		10:45	33.5
	17:30	1.5		2:15	109.5		11:00	34.5
	17:45	0.5		2:30	110.0		11:15	35.5
	18:00	0.5		2:45	111.0		11:30	36.5
	18:15	0		3:00	111.0		11:45	39.0
	18:30	1.0		3:15	112.0		12:00	40.5
	18:45	1.5		3:30	112.0		12:15	41.5
	19:00	3.0		3:45	107.5		12:30	42.5
	19:15	6.0		4:00	101.0		13:00	44.0
	19:30	10.0		4:15	98.0		13:15	44.0
	20:00	14.5		4:30	93.0		13:30	45.0
	20:30	22.5		4:45	89.0		13:45	45.5
	21:00	30.0		5:00	85.0		14:00	45.5
	21:30	38.5		5:15	79.0		14:15	43.0
	22:00	48.0		5:30	71.0		14:30	41.5
	22:30	59.0		6:00	66.0		14:45	40.0
	23:00	69.0		6:30	59.5		15:00	39.0
	23:30	78.0		7:00	53.0		15:15	38.5
11.25	0:00	87.0		7:30	47.5		15:30	37.0
	0:15	91.0		8:00	44.0			

Table 10. The results of the measurements at ST. 3 in November

Date	Time	Water level −cm	Date	Time	Water level −cm	Date	Time	Water level −cm
11.24	15:10	26.0	11.24	23:30	53.0	11.25	8:00	61.0
	15:30	23.0	11.25	0:00	59.5		8:30	56.0
	16:00	17.0		0:30	65.5		9:00	51.0
	16:30	13.0		1:00	71.0		9:30	45.5
	17:00	8.0		1:30	78.0		10:00	43.0
	17:30	5.0		2:00	83.0		10:30	39.0
	18:00	1.0		2:30	87.5		11:00	37.0
	18:30	0		3:00	91.5		11:30	35.5
	19:00	1.0		3:30	95.5		12:00	36.0
	19:30	5.0		4:00	96.5		12:30	39.0
	20:00	10.0		4:30	95.5		13:00	41.0
	20:30	15.5		5:00	91.0		13:30	43.0
	21:00	21.0		5:30	87.0		14:00	44.0
	21:30	26.0		6:00	81.0		14:30	45.5
	22:00	33.0		6:30	76.0		15:00	45.5
	22:30	40.0		7:00	71.0			
	23:00	46.0		7:30	66.0			

Table 11. The results of the measurements at ST. 4 in November

Date	Time	Water temperature °C	Water level −cm	Date	Time	Water temperature °C	Water level −cm
11.24	16:40	8.0	9.0	11.25	3:00	5.9	82.0
	17:00	8.0	7.0		3:30	5.5	84.5
	17:30	7.5	3.0		4:00	4.8	85.0
	18:00	7.3	1.0		4:30	4.8	85.5
	18:30	6.7	0		5:00	5.0	87.0
	19:00	6.2	3.5		5:30	5.0	87.5
	19:30	7.0	6.5		6:00	5.5	85.0
	20:00	6.3	12.5		6:30	5.5	
	20:30	6.3	18.0		7:00	5.0	79.5
	21:00	6.3	23.0		7:30	4.2	73.2
	21:30	6.3	27.5		8:00	4.0	65.5
	22:00	6.3	33.8		8:30	4.0	58.0
	22:30	6.3	40.3		9:00	4.2	52.0
	23:00	6.3	46.5		9:30	4.3	45.0
	23:30	6.3	51.0		10:00	4.5	41.0
11.25	0:00	6.3	57.5		10:30	5.0	36.0
	0:15		60.0		11:00	5.0	34.0
	0:30	6.3	62.5		11:30	5.2	34.0
	0:45		65.0		12:00	5.2	35.5
	1:00	6.2	68.8		12:30	5.3	38.1
	1:15	5.9	70.0		13:00	5.5	39.8
	1:30	5.9	71.3		13:30	5.6	42.0
	2:00	5.9	75.5		14:00	5.5	43.6
	2:30	5.9	80.0		14:30	6.2	44.0
					15:00	6.2	42.6

From our findings, however, it can safely stated that at every station the highest tide comes at a time between 6:40 and 6:50 a.m.. As for the time of the lowest tide, which is shown in the same tables, we find the lowest tide at 11:45 a.m. at St. 1; at 1:00 p.m. at St. 2; at 2:15. p.m. at St. 6. Thus the further the distance from the mouth of the bay, the later the lowest tide comes. Even in the second investigation, we got quite the same results about the time of high and low tide. The time of the highest tide of all the stations is almost equal but the time of the lowest was recorded to come later in accordance with the distance from the mouth. This delay in time should be considered to be attributed to resistance of water current, which happens when high tide ebbs out of the bay.

The differences of the tide level between the highest and the lowest in order from St. 1 to St. 6 as follows: 112.5 cm, 97 cm, 87.2 cm, 83.2 cm, 81.9 cm and 82.0 cm. From these we can see that the further from the mouth, the less the difference is. This is the same tendency as in the case of the time of the highest and lowest tide. This phenomenon also should be attributed to the resistance of current at each station.

Here, we had better note that in order to figure out the changes in time of water level, we know, it is necessary to measure what is the standard level at each station, but this work requirer the management of apparatus on such a large a scale that it is impossible for us at present though important and fundamental for our investigations. From the fact that the time of the highest tide at every station on the morning of August 11 was between 6:40 and 6:50 a.m., we have drawn a hypothesis that the time of the highest tide at every station can be regarded as the same. On this hypothesis that is, on assuming the tide levels at all the stations should be the same and work as a standard, we constructed Figure 2.

The tide condition at Ishinomaki Harber on August 11 found the highest tide at 5:20 a.m. with a tidal level of 63.0cm, and the lowest tide, at 11:57 a.m. at –56.0cm. In our second investigation, we chose the days when a tidal condition was supposed to resemble the condition of the first investigation, but later it turned out to be the days which had a comparatively larger difference in tide level than in August; for on November 24, the highest tide was at 5:24 p.m. with a tidal level of 57 cm, and the lowest tide was at 1:13 a.m. of the next day, November 25, with the level of –27 cm. Therefore, in August the difference of the tide level is counted to be 119cm, while in November it is 129 cm. On the other hand, the difference of the tide level at the mouth of Matsukawaura was recorded 112.5 cm in August 11 and 126.0 cm in November 24. From all of these we can judge that the differences between both of the above-mentioned places show a similar tendency. The time of the highest tide at Matsukawaura in August 11 was 6:40 a.m., which was 1 hour and 30 minutes later than that at Ishinomaki Harber. And on November 24 the time of th highest tide at the former was 6: 00 p.m., which was 36 minutes later than that at the latter.

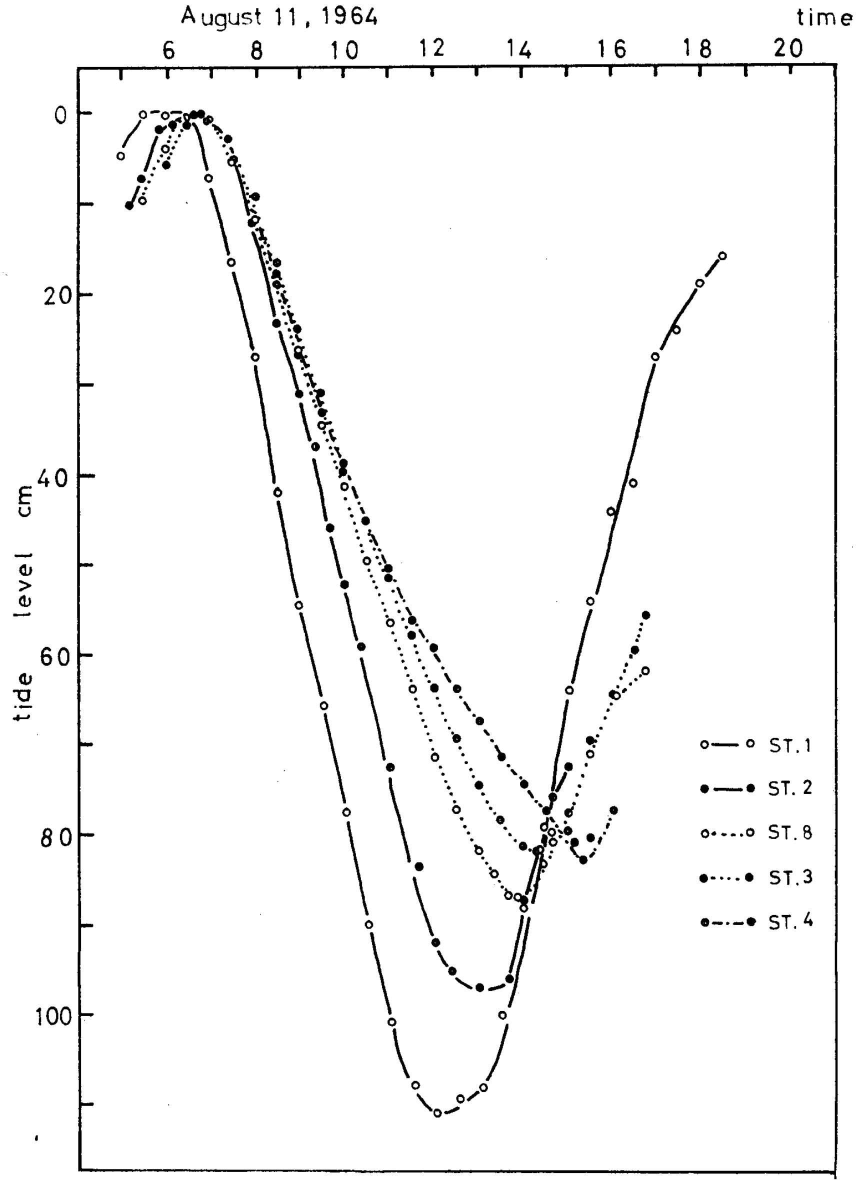

Fig. 2. Measurement of tide level at each station of Matsukawaura.

The delayes of time of the highest tide measured in November were as follows: 6:00 p.m. at St. 1; 6:15 p.m. at St. 2; 6:30 p.m. at St. 3; 6:30 p.m., at St. 4. Compared with those in August, the delay was larger; the largest, 30 minutes. As to the lowest tide in November 25, we recorded it at 1:30 a.m. at St. 1; 3:25 a.m. at St. 2; 4:00 a.m. at St. 3; 5:30 a.m. at St. 4. These show that the lowest tide comes later in accordance with the distance from the mouth of the bay. This result showed the same tendency as that in August; the latest dealy was 4 hours.

The same similarity is seen in the difference of a tide level. They become smaller in accordance with the distance from the mouth; that is, 126 cm, 96.5 cm and 87.5 cm, respectively from St. 1 to St. 4. Here again we can draw the same hypothesis

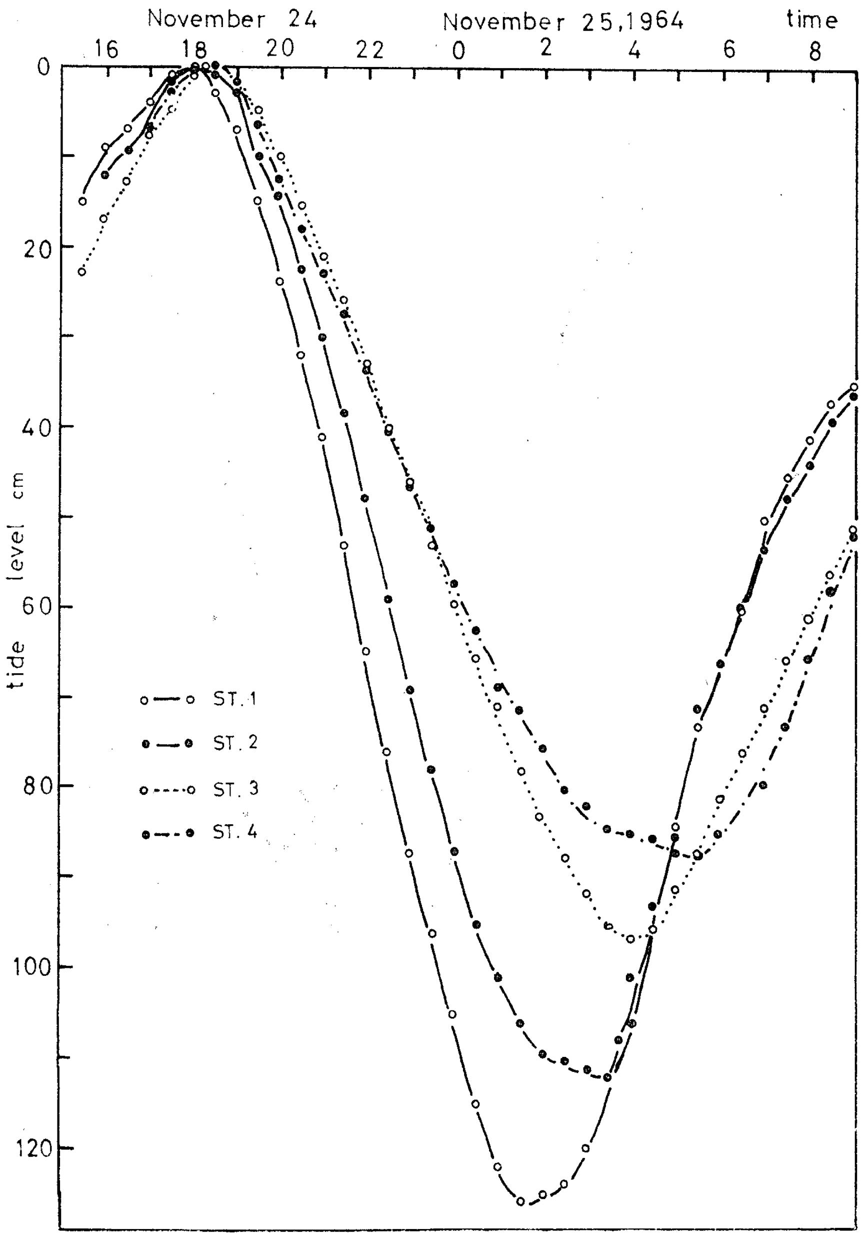

Fig. 3. Measurement of tide level at each station of Matsukawaura.

as in the case of August. In Figure 3, we show the differences of the tide level at each station.

ii) **Water quality**:

As we have already mentioned, this examination consists of six measurements: water temperature, chlorinity, dissolved oxygen, ammonium nitrogen, inorganic phosphate and silicate. All the measurements were made with the standard methods. Table 12 and 13 show our results of all the measurements.

Table 12. Data of the measurements of water quality in August

Station	Water temperature °C	Cl ‰	Dissolved oxygen %	Dissolved oxygen cc/L	NH_4-N γ/L	PO_4-P γ/L	Si mg/L	Loss weight of iron plate mg
St. S-1	30.4	11.22	77.0	3.82	1330.3	Trace	8.61	45.5
St. S-2	29.0	15.76	84.9	4.06	128.0	Trace	6.30	62.1
St. S-3	28.6	15.92	85.0	4.69	93.5	Trace	6.11	164.7
St. S-4	28.2	16.77	79.2	3.80	96.5	Trace	5.74	
St. S-5	26.9	17.08	88.1	4.30	32.0	Trace	2.60	130.8
St. S-6	26.2	17.04	99.4	4.92	0	Trace	2.61	
St. S-7	24.9	17.36	86.3	4.36	15.0	Trace	1.74	
St. S-8	28.1	15.55	70.8	3.45	128.0	Trace	5.60	
St. S-9	27.9	15.67	90.0	4.40	114.3	Trace	5.80	
St. S-10	27.8	15.85	82.4	4.03	123.0	Trace	6.51	
St. S-11	27.4	15.72	68.6	3.38	113.4	Trace	6.09	
St. S-12	27.8	16.62	90.7	4.39	107.0	Trace	2.79	
St. S-13	28.4	16.49	92.9	4.46	80.0	Trace	5.39	166.0
St. S-14	27.0	16.84	99.6	4.88	20.0	Trace	2.61	219.9
St. S-15	28.4	16.77	87.9	4.20	143.0	Trace	7.90	42.6
St. S-16	28.8	15.88	95.0	4.56	104.0	Trace	7.00	
St. S-17	27.6	16.76	88.2	4.28	89.5	Trace	4.51	
St. S-18	28.0	16.92	107.1	5.14	52.0	Trace	3.65	
St. S-19	29.3	17.09	110.9	5.19	50.0	Trace	2.61	227.8
St. S-20	26.8	17.01	93.7	4.60	20.0	Trace	3.04	202.5
St. S-21	26.8	17.13	96.7	4.74	0	Trace	2.77	249.7
St. S-22								253.1

Table 13. Data of the measurements of water quality in November

Station	Water temperature °C	Cl ‰	Dissolved oxygen %	Dissolved oxygen cc/L	NH_4-N γ/L	PO_4-P γ/L	Si mg/L	Loss weight of iron plate mg
ST.W-1	4.9	14.21	89.0	6.85	392	74.3	1.23	79.3
ST.W-2	5.6	16.07	87.6	6.44	264	58.5	0.93	103.6
ST.W-3	7.2	17.02	92.2	6.47	162	54.5	0.85	91.9
ST.W-4	10.4	18.06	92.7	5.99	100	64.5	0.59	107.5
ST.W-5	11.5	18.23	94.4	5.96	154	54.5	0.54	132.0
ST.W-6	11.8	18.31	98.6	6.18	115	58.5	0.53	115.3
ST.W-7	5.8	16.34	90.5	6.60	385	132.5	1.13	19.7
ST.W-8	6.7	16.84	94.2	6.70	255	54.8	1.06	87.1
ST.W-9	9.8	18.21	94.0	6.13	130	113.0	0.61	34.5
ST.W-10	10.5	17.34	94.0	6.13	200	39.0	0.69	87.1
ST.W-11	10.5	18.09	97.0	6.22	128	48.5	0.64	46.3
ST.W-12	10.0	17.73	95.1	6.22	115	29.0	0.70	191.9
ST.W-13	10.7	17.31	98.2	6.38	225	64.5	0.83	166.3
ST.W-14	6.1	16.05	93.8	6.82	224	93.6	1.02	88.7
ST.W-15	12.4	18.25	103.5	6.42	215	60.2	0.55	92.2
ST.W-16	11.5	18.00	101.6	6.43	215	66.3	0.58	58.9
ST.W-17	11.5	18.19	101.4	6.39	110	64.5	0.71	133.1
ST.W-18	11.7	18.43	101.4	6.36	200	39.0	0.57	151.5
ST.W-19	11.7	18.28			155	35.0	0.60	

a) *Water temperature*:

Our examination of water temperature consists of observations of its change in a day at each station and of its distribution all over the bay. The observation of the change of water temperature was made in parallel with the measurement of tide change. The changes of water temperature at different times at the place of the mouth in August are shown in Table 1, Figure 4. That is, the water temperature from 5:00 a.m. to 8:00 a.m. is constant at 24°C or so, but after that it gradually rises up to the highest of 29°C at 2:30 p.m., and then comes to fall rapidly to 25°C at 5:00 p.m. and to 24.5°C at 6:30 p.m.. The last temperature is almost equal to that at 5:00 a.m..

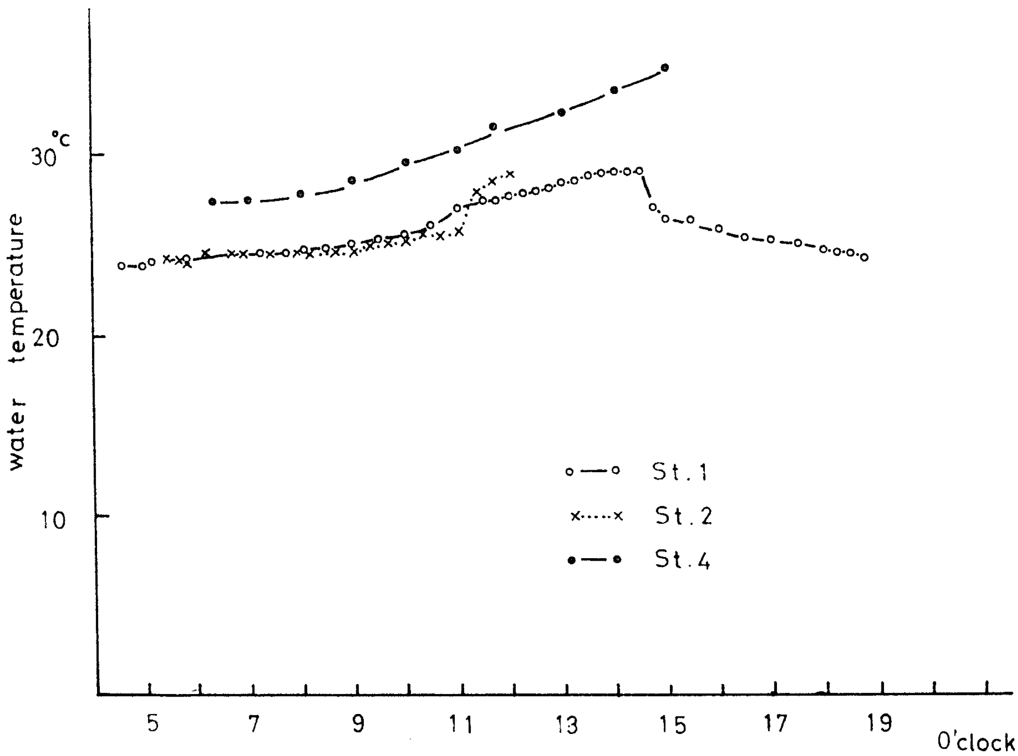

Fig. 4. Diurnal changes of water temperature in August 11.

At the mouth, at 4:35 a.m., it stood between 24.1 and 24.5°C. In our consideration, this means that the temperature of 24.1°C-24.5°C is that of the ocean water, because the time of 4:35a.m. is a time approaching high tide. And at 6:40 a.m. the tide reached its highest. After 6:40 a.m. the tide begins to ebb, that is the water in the bay, which is warm, begins to go out to the ocean. This causes the water temperature at the mouth to rise higher. If we assume 27.4°C, a water temperature at Isobe at 7:00 a.m. to be the temperature of the water proper in the bay, and if we boldly neglect a heat exchange with atomosphere, then the water temperature at the place where the ocean water and the bay water are mixed 50% could be calculated to be about 26°C. Hence, we consider that a great deal of

Fig. 5. The plane distribution of water in August.

the bay water will not go out until 10:00 a.m.. This is supported by the fact that just at 10:00 a.m. water temperature rises with considerable rapidity, and that it is after 10:00 a.m. that a great quantity of the bay water goes out of the bay, but from 11:45 a.m., that is the time of the highest tide, to 2:30 p.m., the water temperature does not fall. According to our observation, the upper water in this period flows toward the mouth of the bay. As Table 1 shows, the upper water, flowing at a speed of 83—67 cm/sec till the time of the highest tide, gradually slows down in current speed to 43 cm/sec at 1:00 p.m. and to 8.3 cm/sec at 1:45 p.m., and at last the speed becomes too slow to measure. From the time of the highest tide to 2:30 p.m. the upper water flows out into the ocean and at the same time the water coming into the bay from the ocean runs lower along the bottom of the bay.

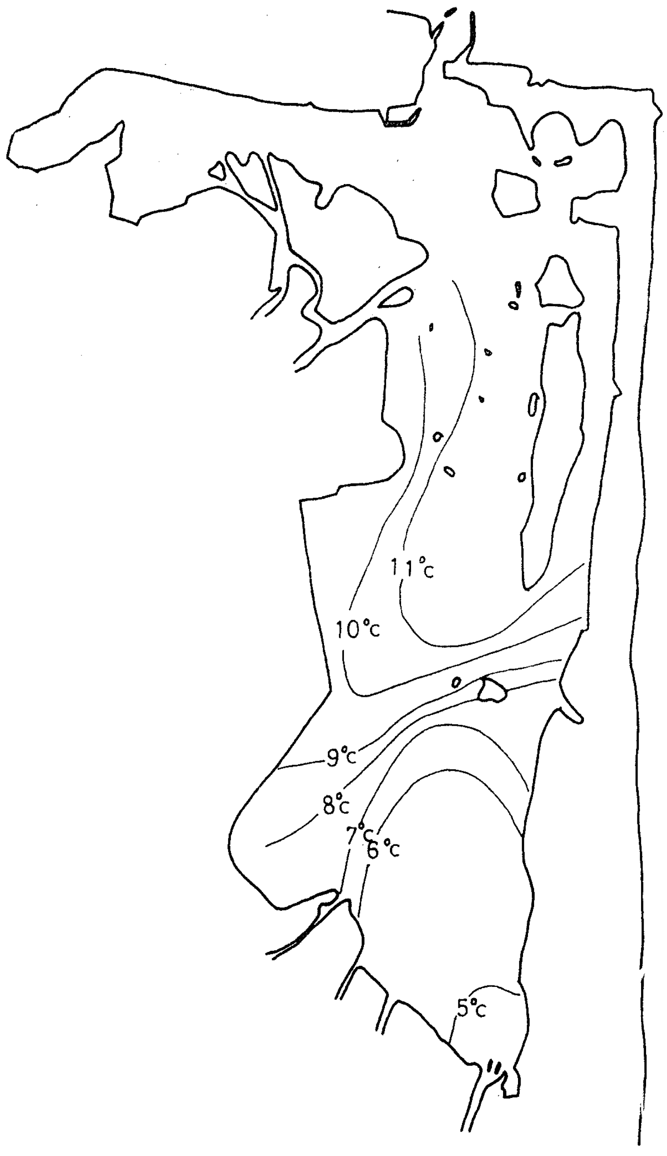

Fig. 6. The plane distribution of water temperature in November.

The variation of water temperature at St. 2 also supports this inference. As shown by the graphic line of water temperature at St. 2, it rises from 26.5°C to 28.0°C just after 11:00 a.m.. This means that the ocean water which has infiltrated on flow tide into the bay remains there until that time. On the other hand, at Isobe, the water temperature was 27.5°C at 6:00 a.m.. It rises in accordance as the sun goes higher and reaches to 35°C at 3:00 p.m.. This phenomena, we conclude, is due to the affection of the radiant heat of the sun.

Judging from these variations of water temperature, we can say that the span of time of the affection of the ocean water upon the water temperature of the upper water at the mouth is 5 hours a day at most.

This means that during summer season, such a duration of time naturally be

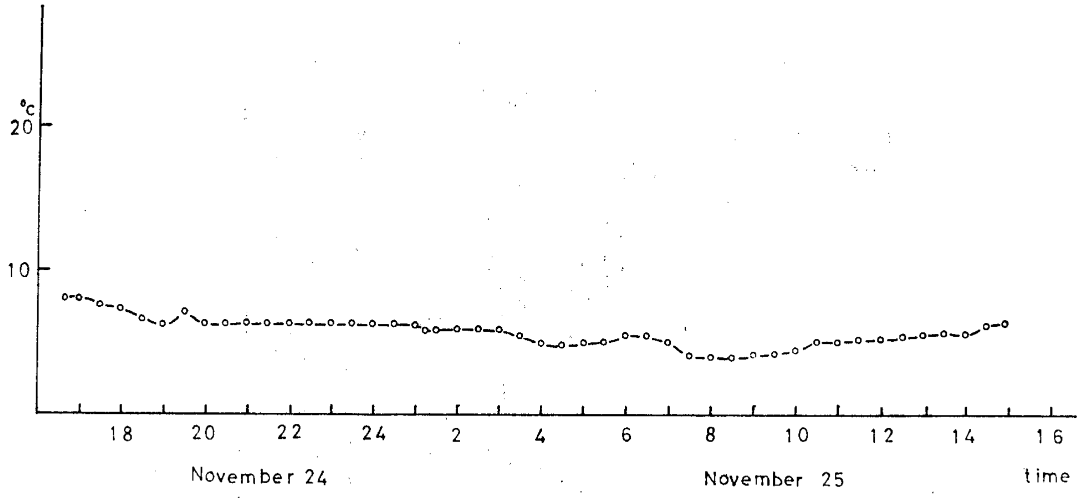

Fig. 7. The change of the surface water temperature at Isobe.

comes shorter at the lower part of the water. In this case, we boldly suggest that it is less than one hour before and after the time of the highest tide. This is equally true the water temperature at St. 2, that is, at Jishima; the upper water here is affected for less than 5 hours a day. At this station, there seems to be little difference between the upper and the lower.

Next, we shall go to Table 12, Figure 5, namely to the plane distribution of water temperature. These measurements were made on the morning of August 12, the day following our examination of tide level. Since the time of our measurements differs at each station, the isothermal line only indicates a general trend. However, we can see in it how main current of the bay water flows out to the ocean. (See Figure 5) As we can see in the figure, there is a water zone of more than 28°C at the place south of Nakasu, and one of 30°C at Isobe. If we compare these two temperatures with those measured at the same places on the previous day, we may say that they are equivalent to the conditions at about 11:00 a.m., or should we say that they show the conditions just before low tide. The water at St. 2 has not yet been affected by the bay water, or it might be better to say that the time at which it is affected by the bay water is delayed in comparision with the time at mouth; the current of St. 18—St. 19–St. 21 — St. 22 tends to be strong, whereas the current of St. 5 —St. 6— St. 7.— The east side of Jishima— St. 22, is oppressed.

The water temperature at each station was measured on the morning of November 25. Therefore, the data in Figure 6 present the conditions just a little before the highest tide, which is quite the reverse in the case of August. (See Figure 6) The temperature of the ocean water at that time was inferred to be about 11.7°C, while the diurnal changes of the water temperature at Isobe, as is shown in Figure 7, varied between 8.4°C and 4.0°C; its lowest was recorded at 8:00 a.m.. The temperature of 4.9 °C at St. W. 1 was measured about 10:30 p.m. on November 25.

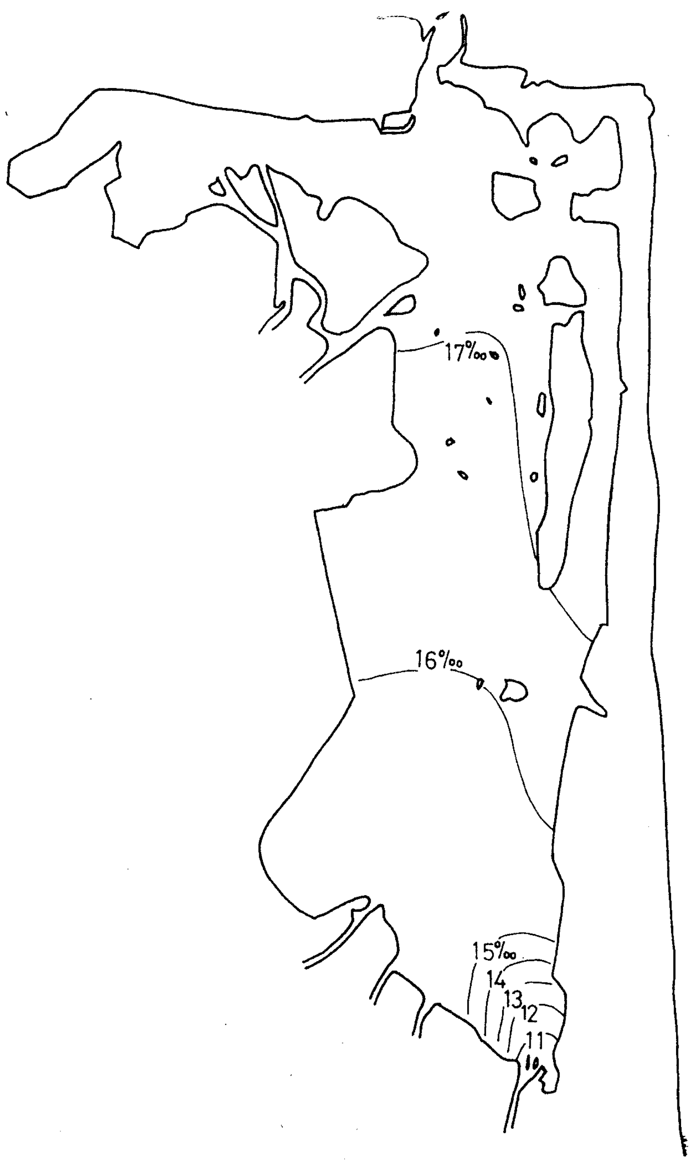

Fig. 8. The distribution of chlorinity in August.

Provided that the temperature of the bay water is about 7°C, temperature of about 10°C is considered to be the temperature of an equal mixture of ocean and bay water. From this, we think we can conclude that even at the highest tide, that is at time when the affection of the ocean water upon the bay water is greatest, the ocean water hardly exerts any great influence upon the inner area.

b) *Chlorinity*:

Figure 8 shows the distribution of chlority in August. This distribution is quite similar to that of water temperature in tendency or shape. Taking Figure 5 into consideration, and assuming the inner area other than Osu as the bay water area, we can possibly induce that, in so far as Matsukawaura is concerned, the bay water contains Cl 16 ‰. Provided that the ocean water is Cl 18.4 ‰, the chlorinity

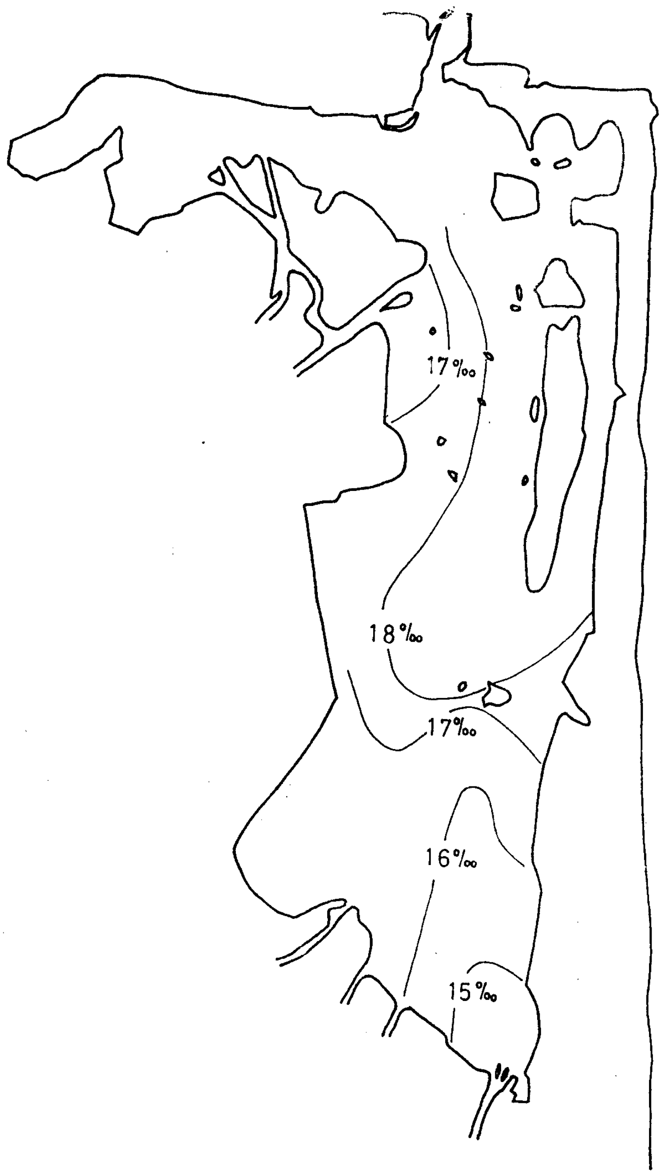

Fig. 9. The distribution of chlorinity in November.

17.2 ‰ means the 1/2 mixed water of the ocean and the bay water. When we see the distribution of water temperature in August, holding this inference in mind, the temperature of the half mixed water comes to be about 25°C or 26°C. This shows that our inference here almost corresponds with that which we mentioned before.

Figure 9 shows the distribution of chlorinity in Novemer. If we take 17.2 ‰ as a limitation, Osu is situated on that point. This also accords with our inference concerning the water temperature.

In order to ascertain these inferences, we inquired then into the relation between chlorinity and water temperature. In so doing, we excluded from the data in August the results of our measurement at the inner area of Osu, because it should be regarded as belonging to the bay water proper, and because it can possibly be

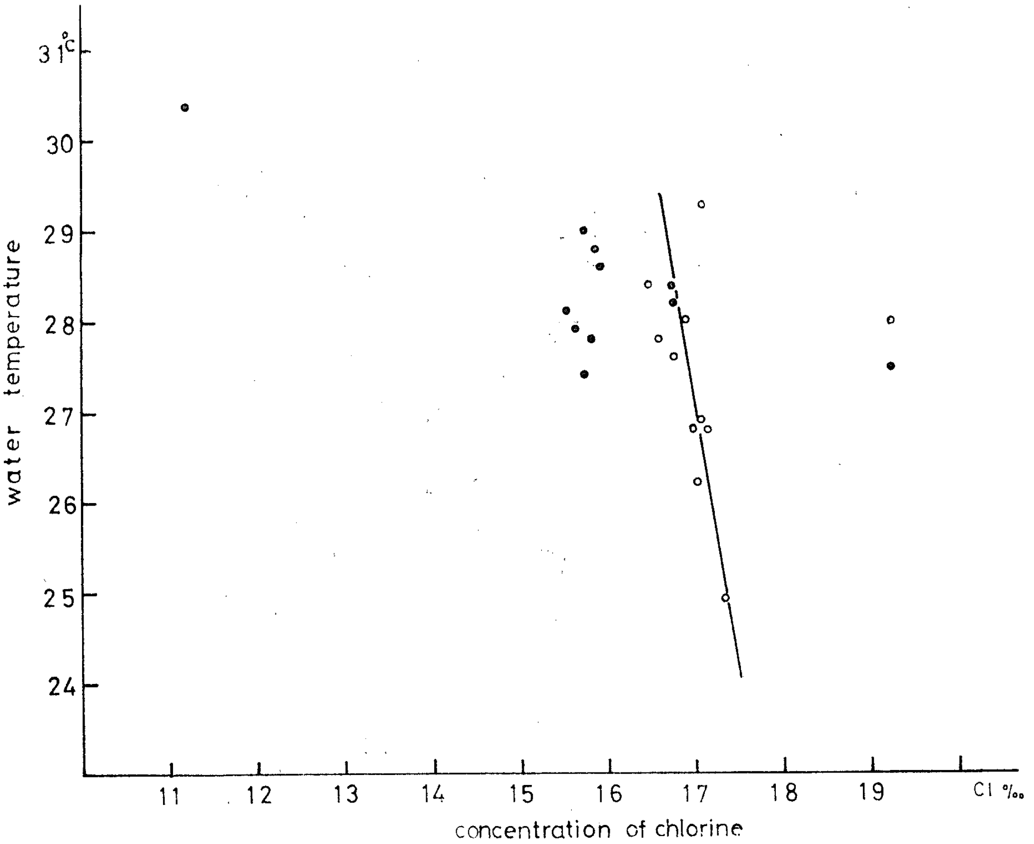

Fig. 10. The relation between chlorinity and water temperature in August.

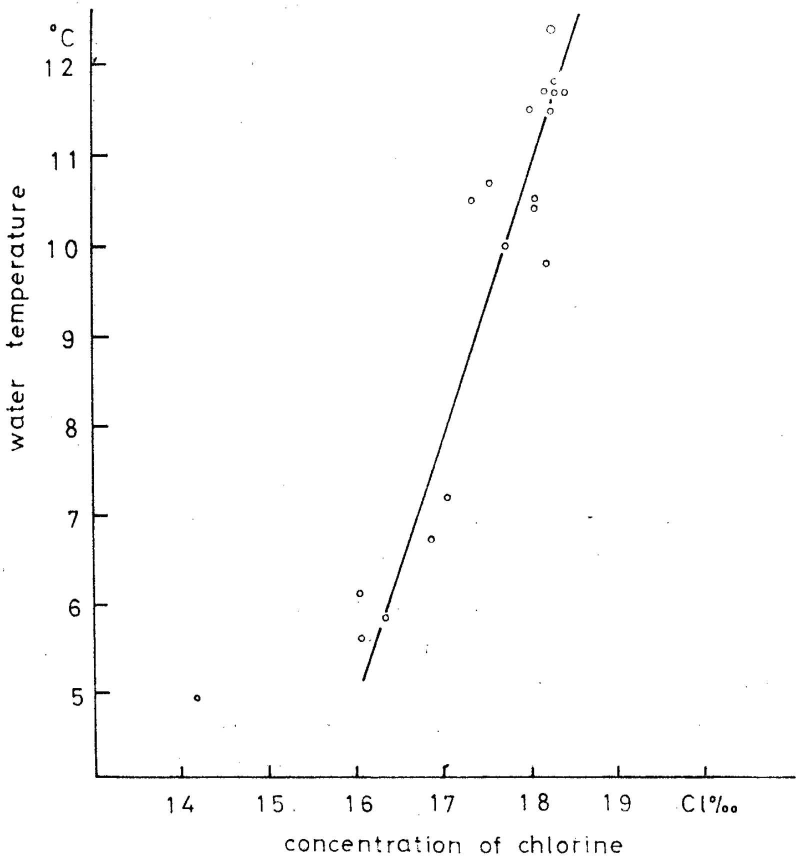

Fig. 11. The relation between chlorinity and water temperature in November.

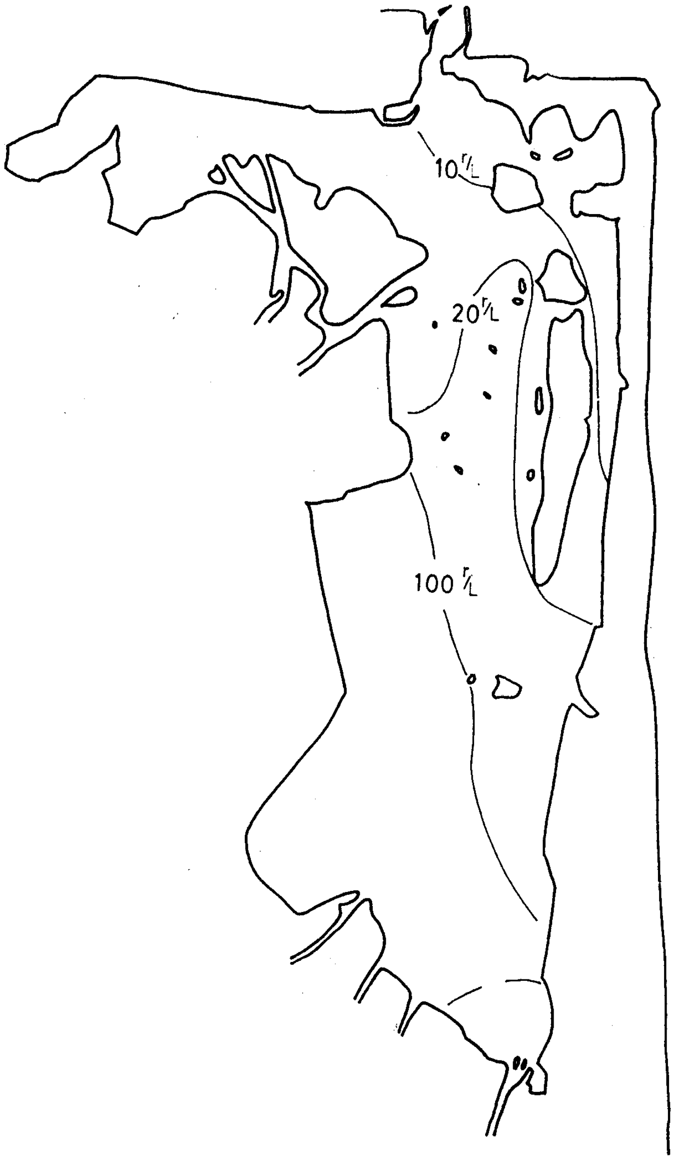

Fig. 12. The distribution of NH_4-N concentration in August.

affected a great deal by the river water of the Kusakaishi-gawa and the Umegawa. Figure 10 is of this inquiry, and Figure 11 shows the relation between chlorinity and water temperature, though the data of St. W. 1 are put aside for the same reason as we mentioned above. In either case, a close relation can be seen between the chlorinity and the water temperature. According to our measurements, the minimum chlorinity is about 17.25 ‰, which happens where the water temperature is 25,5°C (in case of August) and 8.5°C (in November). These figures are approximate to the evaluations in our above-mentioned inferences.

c) *Concentration of ammonium nitrogen and inorganic phosphate*:

Figure 12 shows the distribution of ammonium nitrogen in August. Figure 13, of that in November. In August, the concentration of ammonium nitrogen varies in

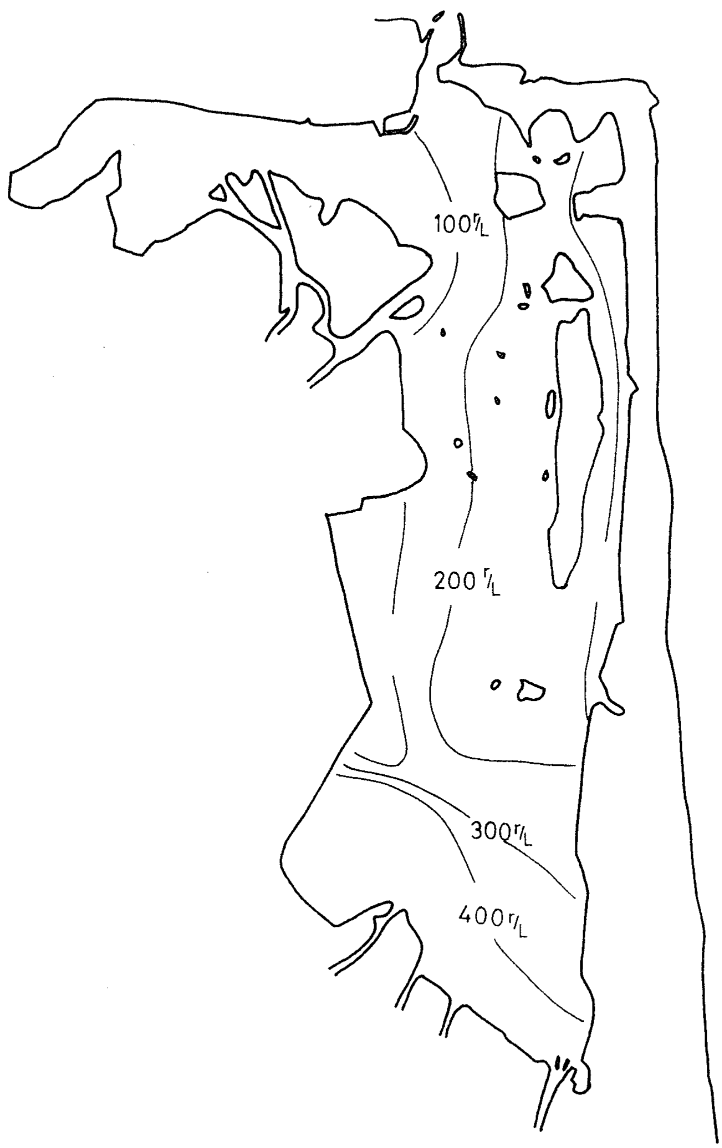

Fig. 13. The distribution of NH_4-N concentration in November.

the range from 1331 to 110 γ/l, whereas in November, from 455 to 110 γ/l. It is clear that the range is wider in August than in November. Generally speaking, the distribution, in each case, has a close relation to that of water temperature.

As to inorganic phosphate, only a trace of it was found in August, which seems to mean that almost all the inorganic phosphate is consumed. However, in November, it was recorded from 132.5 to 29.0 γ/l. Although we have not shown the figure of this distribution, we can safely say that its highest evaluation appears at the bay bottom.

The distribution of concentration of silicate is shown in Figure 14 and 15. The shapes of both distributions resemble that of water temperature.

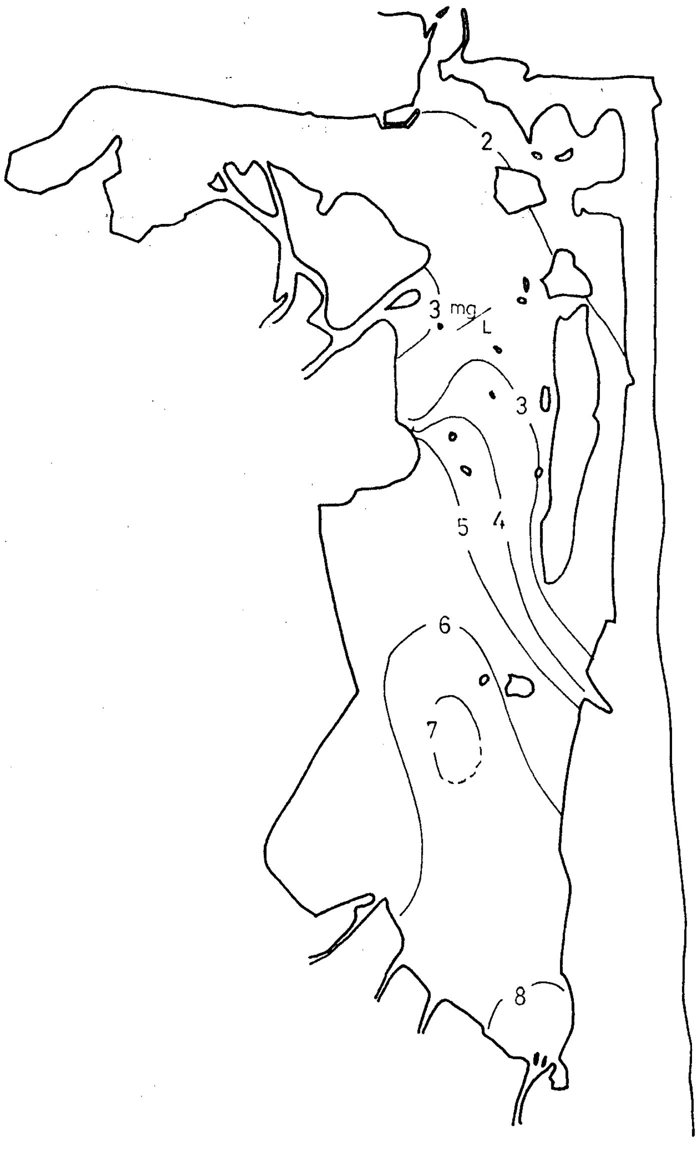

Fig. 14. The distribution of SiO_2 concentration in August.

d) *Concentration of dissolved oxygen*:

We also have not shown the distribution of dissolved oxygen. However, it may be safely stated that in summer the evaluation of its is low at the bay bottom and that it becomes higher at stations to closer the mouth. In winter, this is somewhat divierse. These tendencies are due to the large inclination of water temperature in the bay, to which we have referred.

As to the saturation value of oxygen, we report that at shallows west of Nakasu the water contains a concentration of dissolved oxygen above the saturation value, both in summer and in winter; but at the bay bottom it invariably contains a small quantity.

Inferring from the condition of the bay water, there seems to be some materials

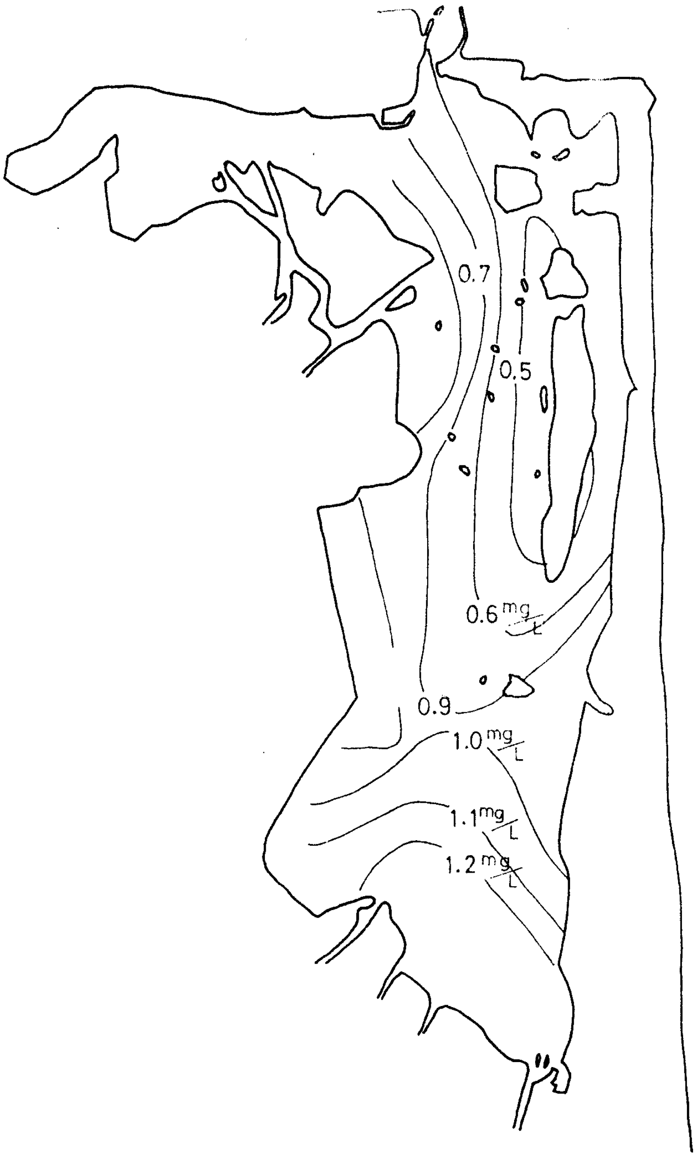

Fig. 15. The distribution of SiO_2 concentration in November.

which consume iodine in it, so that they affect the measurement by Winkler's Method. This is the reason why the concentration of dissolved oxygen is always low at the bay bottom.

iii) **Loss in weight of iron plate**:

Matsudaira and Hamada[3] have already reported that the measurement of a loss of weight of iron plate is one of the methods quite serviceable for the measurement of water quantity in current. Therefore, based on this idea, we measured the loss.

The method we employed is as follows: first of all, we polished with emery cloth a cold extended steel plate, 50 mm 100 mm and about 37–35 g, made by Yahata

Fig. 16. The 100 mg line of loss wight of iron plate in November.

Iron Manufacturing Co. and weighed it on a scale with a sensitivity of 0.1 mg. After it hung in the sea water for 24 hours, we picked it out, and rubbed off the rust from its surface with clothe and then dried it in a decicator and weighed it. In this weighing, we determined the loss of quantity (mg). In August, we had not so many stations for this examination which made it in difficult to show the "isoloss lines", but we could report that in the zone between the line stretching from Kikaijima to the point of Iwanoko and the mouth of the bay the quantity of loss was more than 200 mg, and that at the point of Isobe, that is, at the bay bottom, it was constantly less than 100 mg. Figure 16 shows the line of 100 mg loss in November. In this season, as laver beds have been put in water, resistance becomes greater, (of which we shall make a detailed explanations in discussing the resistance ratio in current which can be calculated from the evaluations of different tide levels) but on the contrary, we can say, the loss quantity is comparatively small in general. When we compare the loss weight in August and that in November, measured at the same station, we get the following results: if the loss weight in August should be estimated as 1, then the loss in November will be between 0.58 and 0.99. From this, we conclude that the loss weight in November is comparatively small, though, we must note, one exception was observed at the station of Isobe.

The shape of the line of 100mg loss tells us that the integration of current is the largest in two streams: a stream running in the east of Nakasu and a stream twoard the mouth along Iwanoko Village. The region west in Nakasu is so shallow that the water of the bay bottom appears to the naked eye to flow evenly in a wide current between Iwanoko and Nakasu, from the time of high tide to that of low, but as tide ebbs, the stream of the western side of Nakasu weakens rapidly, while the stream running in the east to Iwanoko Village does not. This might be considered to be the factor which makes the integration of current so large.

It has been juged in the report about the measurement at Mangokuura that the water with a loss weight of less than 100mg is poor for the cultivation of laver.

iv) **Resistance in each current of the bay**:

We have already mentioned that the tide change at each station is due to the resistance in current. However, for the purpose of improving a water change in the bay, we must necessarily show this resistance in terms of quantity by employing some available method. It would have been proper, therefore, to make some experiment with a large scale, using a model. But as this kind of experiment would have required much time and expence, we have decided to make a series of experiments

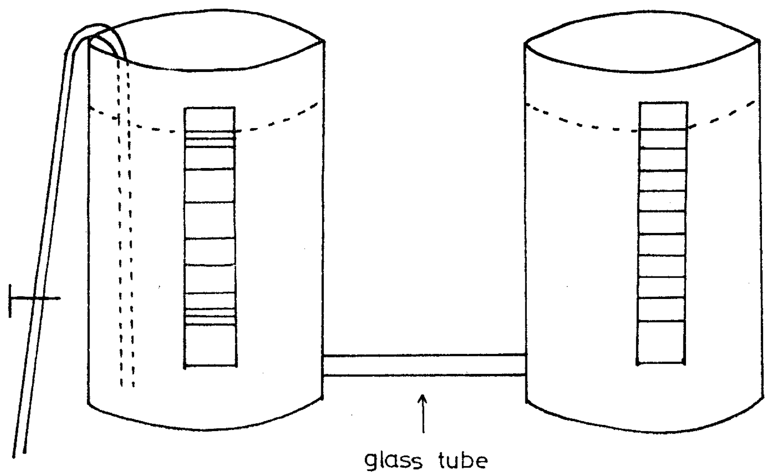

Fig. 17. Apparatus for determining the changes of water level by the resistance of glass tube.

Table 14. The results of the model experiment, based on the data in August

Glass tube (cm)	Radius 0.195	0.195	0.195	0.144	0.144	0.144	0.144	0.103	0.103	0.103	0.095	0.095	0.095
Water level (cm)	Length 20	15	10	20	15	10	5	20	15	10	20	15	10
Minutes													
2	0.1	0.15	0.1	0.1	0.0	0.05	0.1	0.05	0.0	0.1	0.05	0.0	0.0
4	0.7	0.5	0.7	0.3	0.2	0.32	0.6	0.1	0.1	0.2	0.05	0.05	0.1
6	1.5	1.3	1.7	0.7	0.6	0.85	1.3	0.15	0.2	0.4	0.15	0.15	0.2
8	2.4	2.3	2.7	1.1	1.1	1.55	2.0	0.35	0.4	0.65	0.25	0.25	0.5
10	3.5	3.2	3.9	1.6	1.85	2.46	2.8	0.6	0.65	0.9	0.5	0.45	0.75
12	4.5	4.5	5.0	2.4	2.5	3.27	3.7	0.8	0.9	1.2	0.65	0.7	1.1
14	5.6	5.6	6.2	3.1	3.3	4.3	4.6	1.1	1.3	1.6	0.9	0.95	1.45
16	6.4	6.6	7.4	3.8	4.1	5.25	5.5	1.3	1.65	2.0	1.2	1.2	1.85
18	7.8	7.8	8.5	4.9	5.0	6.1	6.4	1.65	2.0	2.4	1.45	1.5	2.3
20	8.9	8.9	9.7	5.5	5.9	7.1	7.4	2.0	2.5	2.85	1.8	1.9	2.65
22	9.8	9.7	10.4	6.4	6.7	8.0	8.3	2.35	2.9	3.3	2.0	2.2	3.1
24	10.3	10.4	10.95	7.1	7.5	8.7	9.1	2.65	2.3	3.8	2.55	2.6	3.5
26	10.5	10.6	10.85	7.7	8.0	9.2	9.6	2.95	3.7	4.15	2.7	2.9	4.05
28	10.5	10.3	10.6	8.1	8.4	9.4	9.9	3.25	4.05	4.5	2.9	3.1	4.3
30	10.2	9.9	10.1	8.4	8.6	9.15	9.7	3.55	4.4	4.85	3.1	3.4	4.6
32	9.5	9.2	9.2	8.3	8.5	8.6	9.3	3.7	4.6	5.05	3.3	3.5	4.9
34	8.6	8.3	8.3	8.1	8.3	8.05	8.8	3.9	4.7	5.15	3.45	3.7	4.95
36	6.6	7.3	7.2	7.7	7.9	7.28	8.1	3.95	4.8	5.2	3.55	3.8	5.0
38	5.6	6.2	6.0	7.4	7.3	6.55	8.15	4.0	4.8	5.15	3.5	3.85	4.95
40	4.5	5.1	5.0	6.6	6.5	5.55	6.3	4.0	4.65	5.1	3.45	3.85	4.9
42	3.3	3.9	3.9	6.2	5.8	4.63	5.2	3.95	4.50	4.95	3.4	3.75	4.8
44	2.3	2.8	2.6	5.4	5.0	3.75	4.2	3.9	4.3	4.5	3.35	3.65	4.6
46	1.4	1.7	1.5	4.8	4.2	3.0	3.3	3.75	4.1	4.45	3.3	3.55	4.35
48	0.4	1.0	0.8	4.2	3.5	2.65	2.4	3.6	3.95	4.15	3.2	3.45	4.1
50	1.0	0.6	0.75	3.8	2.9	2.55	1.9	3.5	3.80	3.9	3.2	3.3	3.85
52	1.15	0.9	0.9	3.6	2.5	2.8	1.6	3.4	3.6	3.7	3.2	2.15	2.65
54		1.5	1.8	3.55	2.45	3.3	1.9	3.35	3.5	3.65	3.2	3.1	3.55
56				3.8	2.7		2.5	3.4	3.45	3.65		3.1	3.6
58				4.1				3.45	3.45	3.75		3.15	3.6
60									3.5			3.2	3.8

which could be made easily at present. In fact, through them we have obtained an average resistance ratio, calculating from the various evaluations of different tide levels.

We took two cylindrical receptacles of clear vinyl chloride, 21 cm across and 30 cm tall, and to their bottoms attached glass tubes of various diameter and various lengths. (Figure 17) Then, we jointed the receptacles to them. As it is well known, the varieties of diameter and length of the glass tubes bring changes of flux. Hence, we calculated an evaluation of resistance from the diameters and lengthes. Filling the two receptacles with water to an equal level and making the water in one of the two receptacles flow out, the water level of the other becomes gradually lower; that is to say, the difference between the two levels of the water becomes greater in proportion as resistance of the glass tube increases. By making use of this phenomenon, we inquired how the water level varies and what relations there are

Table 15. The results of the model experiment, based on the data in November

Glass tube (cm)	Radius 0.195	0.195	0.144	0.144	0.144	0.144	0.144	0.103	0.103
Water level (cm)	Length 20	30	5	10	15	20	30	10	15
Minutes									
2	0.1	0.1	0.15	0	0	0	0.1	0.1	0
4	0.4	0.3	0.45	0.2	0.2	0.1	0.2	0.2	0.1
6	0.8	0.7	0.8	0.4	0.5	0.3	0.3	0.3	0.15
8	1.5	1.25	1.25	0.85	0.8	0.6	0.55	0.4	0.25
10	2.1	1.8	1.9	1.4	1.2	1.0	0.85	0.6	0.4
12	3.0	2.4	2.5	2.0	1.8	1.4	1.2	0.8	0.6
14	3.9	3.25	3.3	2.65	2.5	2.1	1.7	1.1	0.8
16	4.8	4.1	4.1	3.5	3.1	2.7	2.2	1.4	1.2
18	5.8	5.1	5.0	4.45	3.9	3.4	2.8	1.8	1.55
20	6.9	6.1	6.0	5.4	4.7	4.15	3.5	2.2	1.9
22	7.9	7.1	6.95	6.3	5.6	5.0	4.2	2.65	2.4
24	8.9	8.1	7.9	7.3	6.4	5.8	4.9	3.1	2.8
26	9.9	9.1	8.8	8.25	7.3	6.6	5.6	3.6	3.3
28	10.85	10.1	9.75	9.2	8.2	7.4	6.35	4.1	3.7
30	11.65	10.8	10.6	10.0	9.0	8.2	7.1	4.55	4.2
32	12.1	11.4	11.3	10.7	9.6	8.9	7.8	5.0	4.8
34	12.2	11.8	11.75	11.2	10.2	9.4	8.35	5.5	5.2
36	12.2	11.95	11.95	11.45	10.8	9.9	8.85	5.9	5.55
38	11.9	11.85	11.8	11.4	10.9	10.15	9.3	6.25	5.85
40	11.3	11.4	11.4	11.3	10.9	10.2	9.4	6.5	6.15
42	10.6	10.9	10.8	10.8	10.7	10.15	9.45	6.75	6.35
44	9.7	10.25	10.2	10.2	10.4	9.95	9.4	6.9	6.5
46	8.9	9.5	9.5	9.55	9.9	9.55		7.0	6.6
48	8.1	8.65	8.7	8.8	9.25	9.1		6.95	6.6
50	7.3	8.15	8.0	8.05	8.7	8.65		6.9	6.55
52	6.5	7.1	7.2	7.35	8.0	8.15		6.8	6.5
54	5.7	6.4	6.5	6.65	7.35	7.55		6.7	6.45
56	5.0	5.7	5.8	5.95	6.8	6.95		6.6	6.35
58	4.5	5.1	5.2	5.3	6.2	6.45		6.4	6.2
60	4.05	4.6	4.7	4.8	5.7	5.95		6.2	6.0
62	3.8	4.2	4.25	4.4	5.2	5.5		6.0	5.85

between different levels of water and resistance, provided that we change a water level in one receptacle, just as the tide level at the mouth of the bay changes.

When we made our experiments, we reduced the different evaluations of the real tide level (that is, 111 cm in August, 126 cm in November) to 1/10, and the real time to 1/15 for the sake of a diagram. And we poured water into and out of one of the receptacles in accordance with the real phenomenon, and at the same time we recorded how the water level of the other goes up and down at intervals of two minutes. Table 14 shows the results of our experiments, based on the data in August, and Table 15, in November. Figures 18 and 19 are diagrams of the results, respectively.

As is clearly shown in the figures, the changes of the water levels, obtained through our experiments, that is, by using various lengths of glass tubes with the same diameter, proves to be quite similar to the changes of the real tide

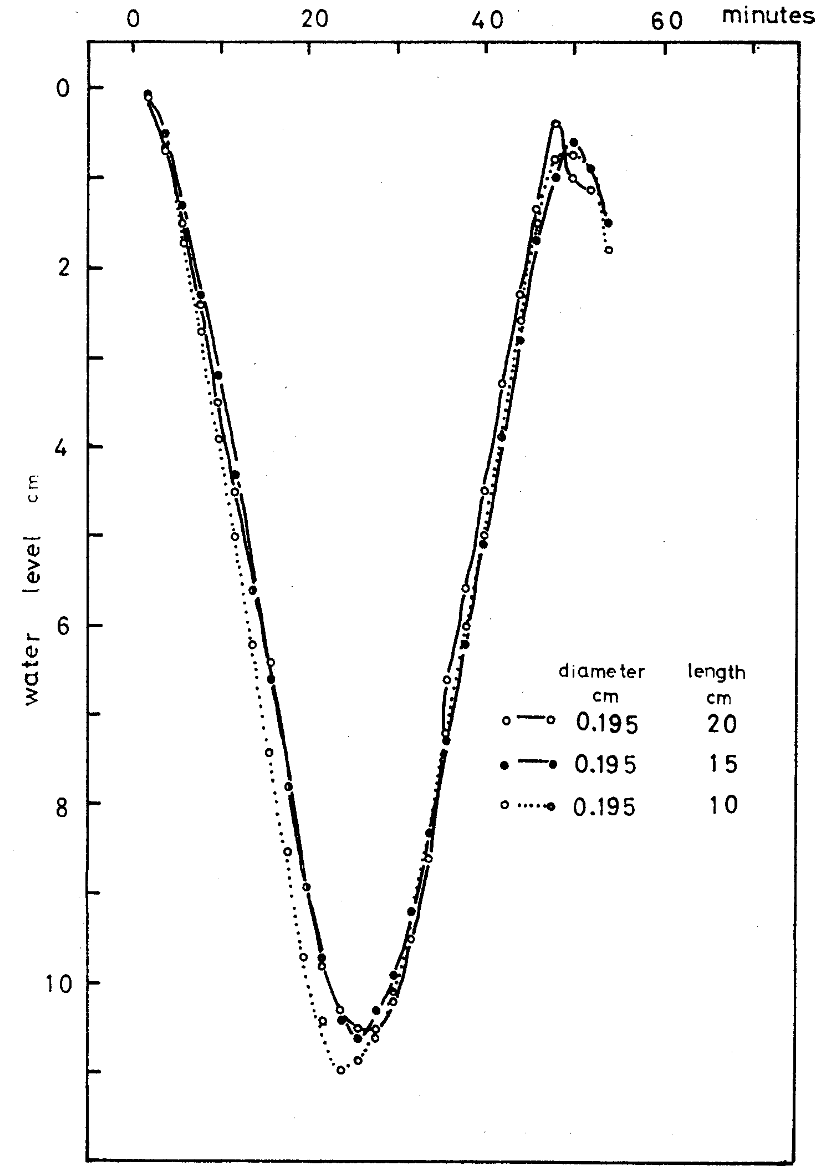

Fig. 18(I). Changes of water level by changing the glass tube.

levels measured at Matsukawaura. (See Figure 2 and 3) It is obvious from this that the longer a tube is, the more the time delays when the water level reaches its lowest point, and the upper the level of water rises.

Hereupon, regarding the difference between the lowest level in the standard change and the lowest level in each case of our experiments as a difference of water level, we examined the interrelations between this difference and the diameter and the length of a glass tube. Hagen and Poiseuille formularize the following, when they made an experimental examination about the relation between the flux running through a tube and decrease of pressure:

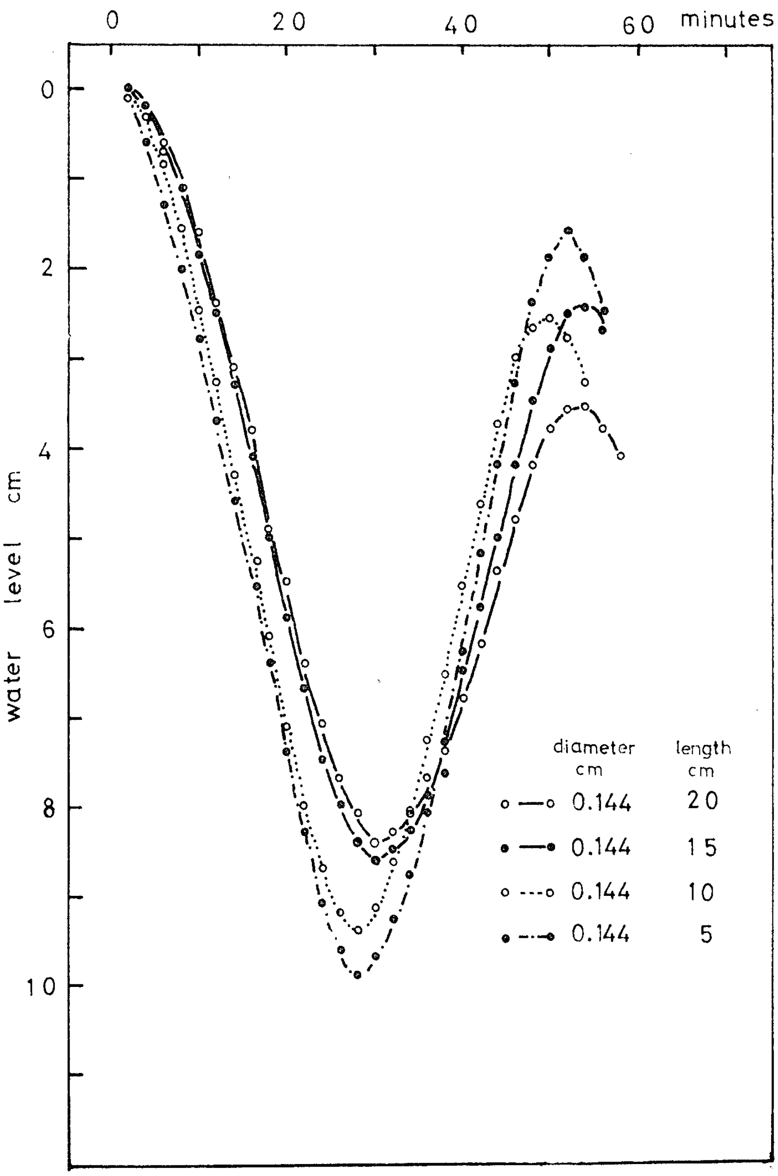

Fig. 18(II). Changes of water level by changing the length of the glass tube.

$$Q=\frac{\pi r^4}{8\mu}\times\frac{\Delta P}{l}$$

Q: flux r: radius μ: viscosity coefficient

l: length Δp: decrease of pressure in L

From this, we can know that the resistance of tube and flux are in inverse proportion. Therefore, in our experiments, we took it for granted that the resistance is in inverse proporition to a radius raised to the fourth power and that it is in direct proportion to the length of a tube, and regarded l/r^4 as resistance 'R' for convenience's sake of calculation. Table 16(a) shows the relation between this resistance and the difference of water level in August, and Table 16, that in

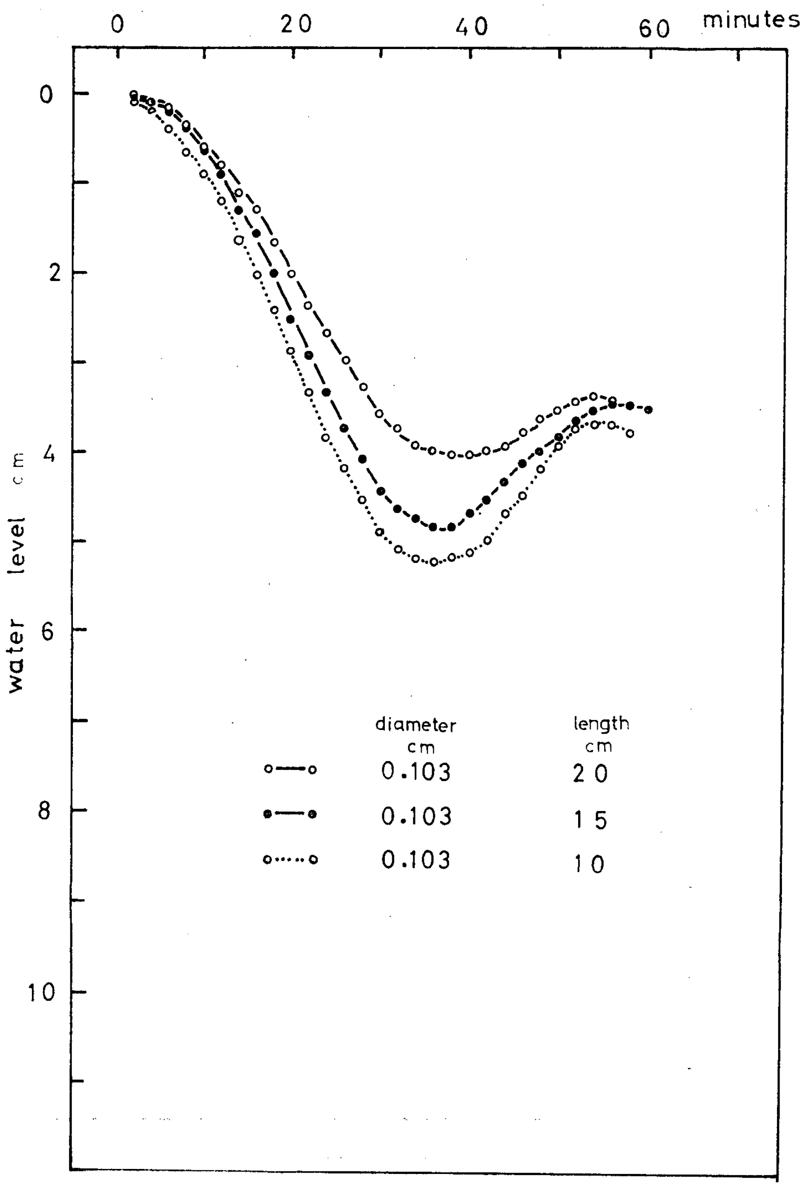

Fig. 18(III). Changes of water level by changing the length of the glass tube.

November. Evaluations in the both, when shown in a logarithmic diagram, make a rectilinear figure. (Figure 20, in August; Figure 21, in November)

The following formulae show the correlation between this resistance R and the difference of water level P, acquired by the method of least squares.

$$P \text{ (in August)} = 1.005 \times 10^{-4} \times R^{0.2173} \quad (1)$$

$$P \text{ (in November)} = 6.763 \times 10^{-4} \times R^{0.1745} \quad (2)$$

Table 17(a) shows the changes of the water level in the receptacles, when glass tubes with different resistance are connected parallel, which are measured at intervals of two minutes, based on the natural change in November. Table 17 (b) shows the changes, when those glass tubes are connected series. Read the

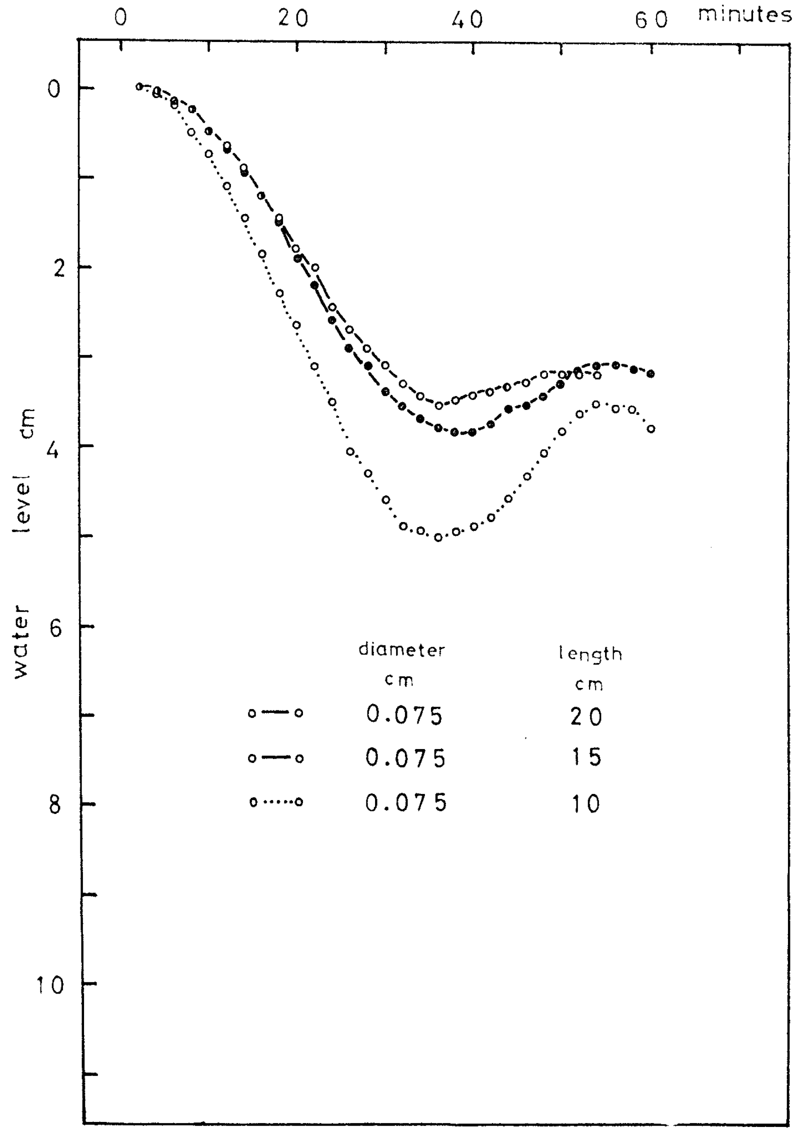

Fig. 18(IV). Changes of water level by changing the length of the glass tube.

differences of the lowest level of water in the experiments against the standard lowest water level as we have mentioned. Calculate a total resistance from $R=R_1+R_2$, in the case of series connection and from $1/R=1/R_1+1/R_2$ in the case of parallel connection, referring to each resistance in Table 17 (b). And compute the differences of calculated water level from formula (2) and compare them with those in the experiments. Results are shown in Table 18 (a), which is concerning the series connection, and Table 18 (b), concerning the parallel. Both the cases closely resemble each other. From this we have come to conclude that resistance R which we want here can be reckoned by the same formula as in electric resistance R.

Upon these examinations, we made reduction of the differences of tide level at each station in Matsukawaura into 1/10 and time into 1/15, and adopted

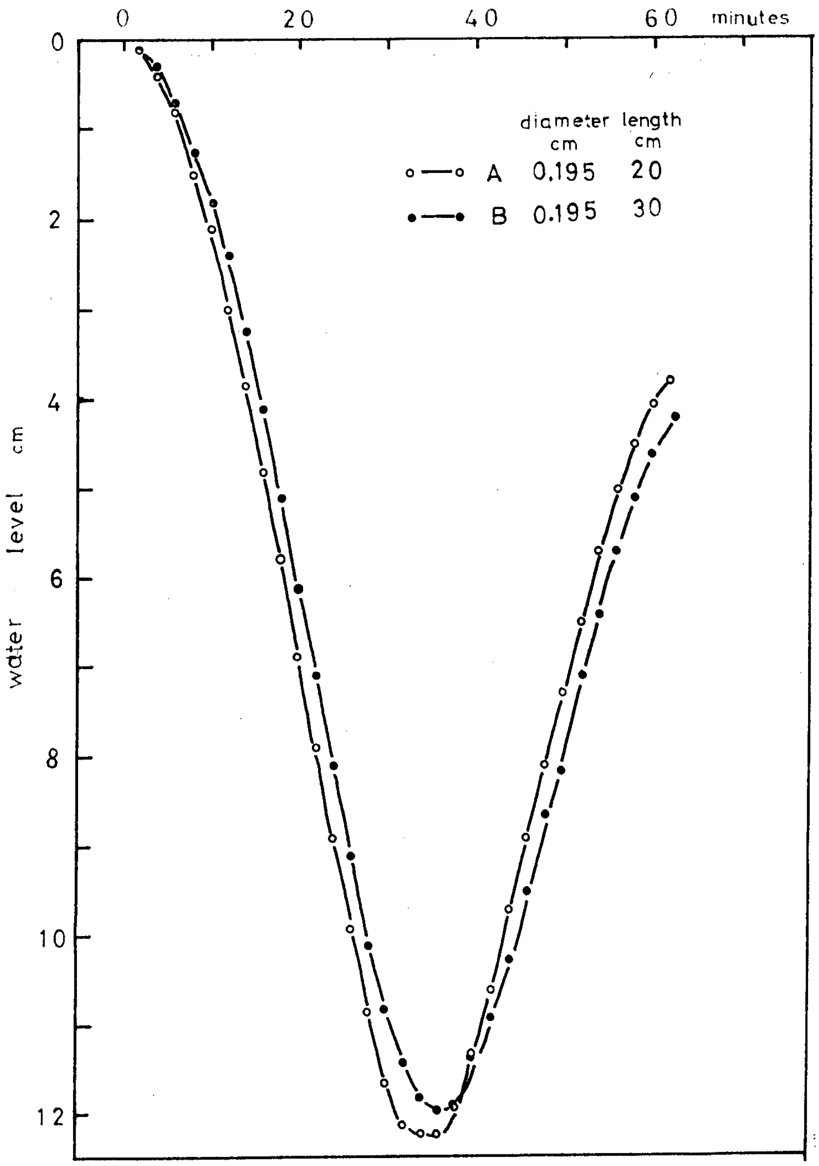

Fig. 19(I). Changes of water by changing the length of the glass tube.

them in our consideration. We replaced resistance in currents from the mouth of the bay to each station with resistance in the glass tubes, by using Formula (1) in case of August, and by using Formula (2) in case of November, and called it the evaluation of resistance ratio. The results are shown in Table 19 (a) and (b). Since a total resistance in a series connection is the sum of the resistance at each station, the resistance between the mouth and St. 2, between St. 2 and St. 3, between St. 3 and St. 4, between the mouth and St. 6 can be calculated by the substraction of each resistance between them.

Next, we obtained radius ratio by measuring the real distance between the stations and by dividing resistance ratio by the distance, and then by calculating

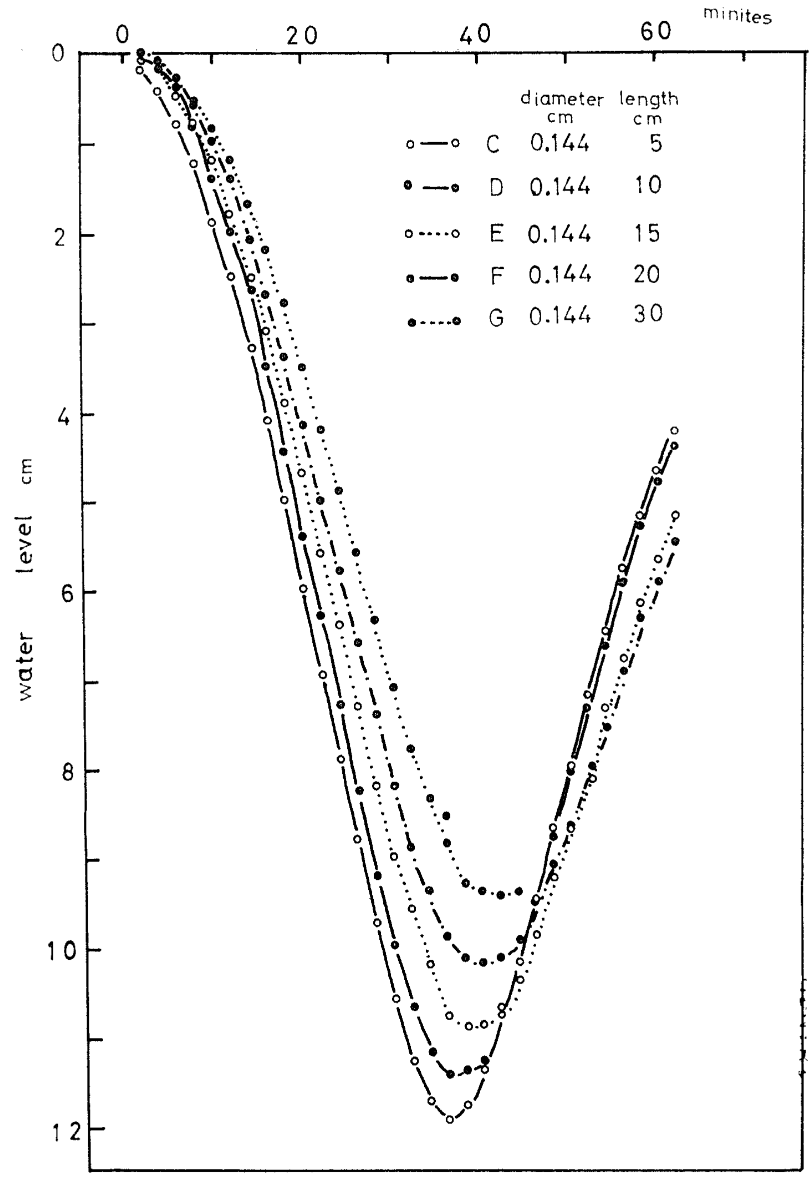

Fig. 19(II). Changes of water level by changing the length of the glass tube.

fourth root of quotient. Table 20(a) and (b) show the radius ratio calculated in this way. We noted there the radius ratios which were evaulated from section square of the currents between the stations in a map we got this by making an average of five or six measurements and by extracting the square root from the average.

If we compare (a) and (b), resistance in (b) is larger. Provided that resistance between Nakasu and Isobe is I, resistance between Jishima and Nakasu will be 0.7 (in August) and 1.1 (in November), and resistance between the mouth and Jishima, 1.5 (in August) and 1.35 (in November). From this, we can see that among these three regions resistance between Jishima and Nakasu increases consider-

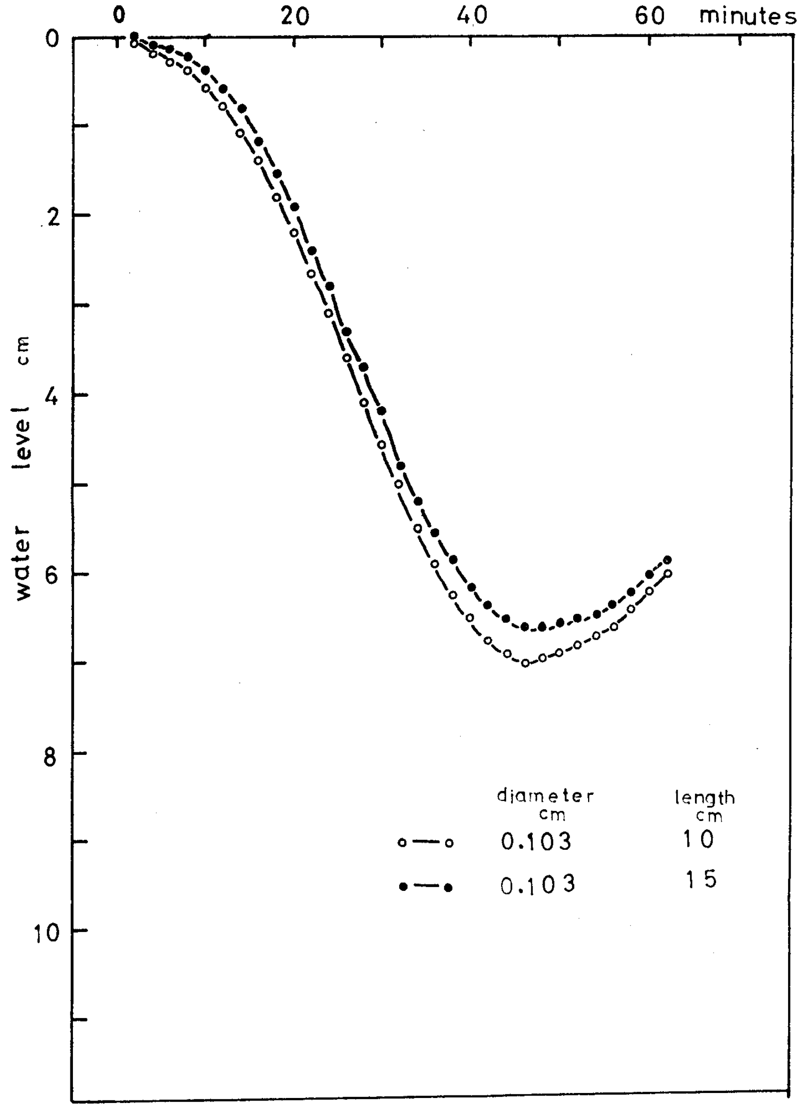

Fig. 19(III). Changes of water level by changing the length of the glass tube.

ably more than the other two, both in August and in November. The reason of this phenomenon is not clear, but we can assume that it might be the same reason as in the case of the loss of weight of iron plate. That is to say, in regard with resistance, it increases 1.4–2.3 times; in regard with flux, it decreased 0.43–0.77, for resistance and flux are in inverse proportion. And with the loss of weight of iron plate, it decreases approximately 0.58–0.99 in November.

When we compare the radius ratio calculated from the difference of tide level at each station with that calculated from section square of the currents, at two zones, namely between Jishima and Nakasu, and between Nakasu and Isobe, we find they are proportional in August, a time when resistance is comparatively small, but on the contrary, the zone between the mouth and Jishima has a wide difference between the two radius ratios, and at the same time the latter has a much larger resistance.

Table 16. The relation between the resistance of the glass tube and the difference of water level

Radius cm	Length cm	Difference of water level cm	Resistance value
0.195	10	0.2	6.9×10^3
	15	0.5	10.37×10^3
	20	0.6	13.8×10^3
0.144	5	1.4	11.6×10^3
	10	1.7	23.25×10^3
	15	2.5	34.88×10^3
	20	2.7	46.5×10^3
0.103	10	5.9	88.8×10^3
	15	6.3	123.3×10^3
	20	7.1	177.69×10^3

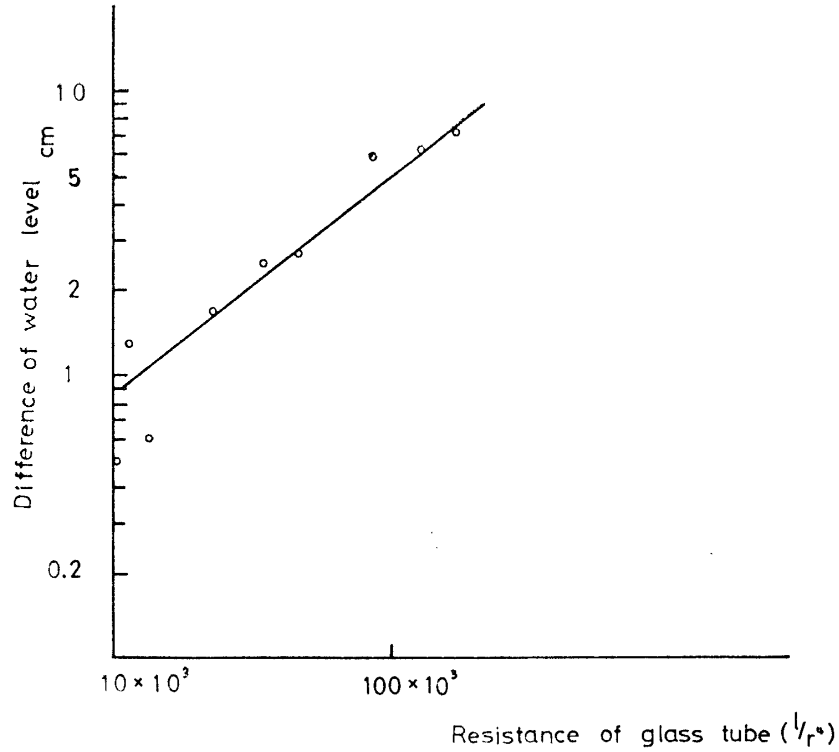

Fig. 20. The relation between the resistance R and the difference of water level in August.

In our consideration, this is due to the fact that at the ebb of tide a stream running from the zone between Nakasu and Iwanoko to the mouth of the bay is stronger than the others, of which we have already mentioned in relating a distribution of the chlorinity. We presume that this depends on a stream from Wada district which works as an oppressive power against the stream running east to Nakasu. (As to the stream from Wada district, we have no measurement at this time.)

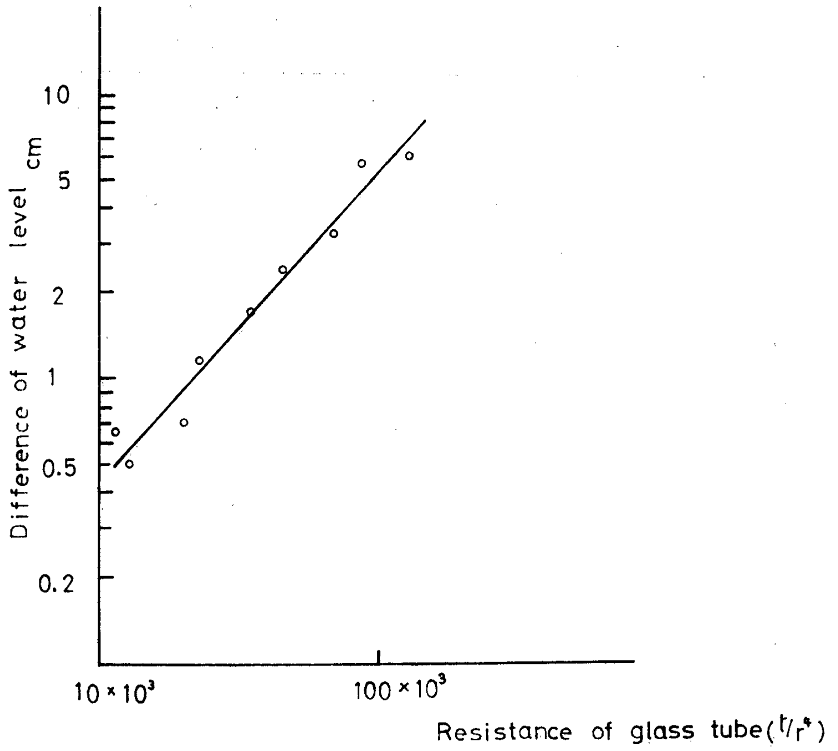

Fig. 21. The relation between the resistance R and the difference of water level in November.

Conclusion

When we examine minutely all the data of our investigations of the year, we see several problems awaiting a solution for our main subject. Needless to say, our investigations were done in a limited time and our data tells us only the conditions of the two definite days, August 11 Nobember 25. Therefore, it is almost beyond our considerations about the conditions when the ocean tide changes unexpectedly, or when strong winds blow from some unusual directions, or when a great amount of water comes into the bay from the rivers around. Thus we base our problems on the data itself.

It is best for our purpose to diveide Matsukawaura into four areas. The demarcation lines for the areas are not readily evident, but it seems the divisions as in Figure 22.

Region A has almost all dead water of a special quality. We may call this water the 'inner bay water'. Even when the lowest tide comes in some of this inner bay water, about 210,000 tons will not flow because the bottom of this area is in the shape of a large depression. Owing to the water stagnation, the water temperature of this area rises more than 30°C in summer. And since this water is always mixed with fresh water from the many small rivers around, it contains little salt; namely it is less than 17.2‰ chlorinity. At ebb tide, some of this water goes out to the ocean through Regions B, C and D, but some of it spreads all over the

Table 17(a). Changes of the water level, when glass tubes with different resistance are connected parallel

Resistance		R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
	Radius (cm)	0.195	0.144	0.195	0.103	0.144	0.103	0.195	0.144	0.195	0.144
	Length (cm)	10	20	10	10	5	10	10	10	10	15
Time (min.)											
2		0.1		0		0		0.1		0.1	
4		0.2		0.1		0.15		0.3		0.2	
6		0.45		0.2		0.25		0.6		0.4	
8		0.7		0.3		0.4		1.0		0.8	
10		1.15		0.5		0.55		1.55		1.2	
12		1.6		0.75		0.75		2.1		1.55	
14		2.15		1.0		1.05		2.8		2.2	
16		2.8		1.2		1.4		3.5		2.9	
18		3.35		1.7		1.75		4.35		3.7	
20		4.2		2.0		2.15		5.2		4.45	
22		4.95		2.45		2.55		6.2		5.3	
24		5.8		2.9		3.0		7.0		6.0	
26		6.55		3.3		3.45		7.9		6.85	
28		7.3		3.8		3.95		8.85		7.8	
30		8.1		4.3		4.45		9.8		8.4	
32		8.8		4.8		4.9		10.3		9.15	
34		9.4		5.2		5.35		10.8		9.75	
36		9.85		5.6		5.75		11.2		10.2	
38		10.15		5.95		6.15		11.3		10.5	
40		10.25		6.2		6.4		10.8		10.5	
42		10.15		6.45		6.6		10.25		10.3	
44		9.9		6.6		6.75		10.0		10.0	
46		9.6		6.7		6.8		9.6		9.55	
48		9.2		6.75		6.8		8.9		9.0	
50		8.7		6.7		6.75		8.3		8.5	
52		8.2		6.6		6.65		7.6		7.9	

surface of the bay. At the flow, most of this water is forced to return to where it was because of ocean tide. The route of current is so wide that it has little resistance; it flows slowly. In winter the water of this area shows the lowest water temperature of all areas. Through all the seasons and in all areas it shows the greatest quantity of ammonum nitrogen. From this, we can infer that the water here has some reducing materials in it.

Region B is a place which is covered over by the inner bay water of Region A at the lowest tide, and which is strongly affected by the ocean water at the highest tide. The linear stretching zone from Iwanoko to Nakasu is shallow; the inner part of it forms a depression with a capacity of some 50,000 tons of water. This depression is connected with that of Region A, so that the water facing in wards to the bay bottom is some what stagnant. The water west to Nakasu is shallow and the time influenced by the inner bay water for a little more than half a day.

Region C, just like Region B, is affected by both the ocean water and the inner bay water; the former influence being much greater. It goes without saying that

Table 17(b). Changes of the water level, when the glass tubes are connected series

Resistance		R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
	Radius (cm)	0.144	0.103	0.144	0.103	0.144	0.103	0.144	0.103	0.144	0.103
	Length (cm)	15	15	20	20	30	30	15	30	10	10
Time (min.)											
2		0.1		0.05		0.05		0.05		0	
4		0.25		0.2		0.2		0.2		0.25	
6		0.6				0.35		0.5		0.55	
8		1.0				0.6		0.9		1.05	
10		1.5		1.2		0.95		1.4		1.65	
12		2.1		1.7		1.4		2.0		2.35	
14		2.7		2.35		1.9		2.55		3.15	
16		3.6		3.05		2.5		3.2		3.95	
18		4.4		3.85		3.15		4.1		5.0	
20		5.3		4.7		3.9		5.0		6.0	
22		6.3		5.6		4.6		5.85		6.95	
24		7.2		6.4		5.4		6.7		7.85	
26		8.2		7.3		6.2		7.65		8.85	
28		9.0		8.2		7.0		8.6		9.7	
30		9.8		8.95		7.8		9.35		10.65	
32		10.25		9.7		8.5		10.0		11.25	
34		11.0		10.25		9.0		10.55		11.65	
36		11.3		10.5		9.45		10.9		11.7	
38		11.35		10.8		9.75		11.1		11.65	
40		11.25		10.75		9.9		11.0			
42						9.85					

the nearer to the bay bottom, the greater the affection of the inner bay water will be. Although we regard the area west to Nakasu and the area east of it as belonging to Region C, they seem different in character. The flux of this region is much stronger than that of Region B (The loss of weight of the iron plate is more than 100 mg.) Therefore, in our consideration, Region C is the most suitable for the cultivation of laver. And it is worth noticing that the nearer to the mouth of the bay it is, the less the affection of the inner bay water will be. The water of this region always changes itself with the ocean water in so great a degree that it can work as a culture pond with a good current. When the tide ebbs, streams coming from the bay bottom turn against each other and whirl at the neighbourhood of the demarcation between Region C and D, so that the resistance of current increases most there. This means that the mouth of the bay is too narrow.

Region D has always the ocean water at its bottom. The surface water flows on its surface for less than 10 hours a day. After the time of the highest tide, it goes out of the bay, whereas the ocean water has invaded into its lower part. The inner bay water which once goes out of the bay hardly returns to the bay, in so far as our present investigations are concerned.

Laver production at Matsukawaura is carried on chiefly in Region C with only a little produce in Region B, and none in A. There is an oppinion that the produc-

Table 18. Total resistance, when two glass

(a) Series connection

R_1			R_2		
Radius (cm)	Length (cm)	Resistance	Radius (cm)	Length (cm)	Resistance
0.144	5	11.6×10^3	0.103	10	88.8×10^3
0.195	10	6.9×10^3	0.144	10	23.25×10^3
0.195	10	6.9×10^3	0.144	15	34.88×10^3
0.195	10	6.9×10^3	0.144	20	46.5×10^3
0.195	10	6.9×10^3	0.103	10	88.8×10^3

(b) Parallel connection

R_1			R_2		
Radius (cm)	Length (cm)	Resistance	Radius (cm)	Length (cm)	Resistance
0.144	15	34.88×10^3	0.103	15	133.3×10^3
0.144	20	46.5×10^3	0.103	25	177.0×10^3
0.144	30	69.7×10^3	0.103	30	266.6×10^3
0.144	15	34.88×10^3	0.103	30	266.6×10^3
0.144	10	23.25×10^3	0.103	10	88.8×10^3

Table 19. Evaluation of resistance ratio between each station

(a) August

Station	Difference of Water level	Resistance ratio	Length (cm)
ST.-2	1.6	22.5×10^3	88.8×10^3
ST.-3	2.35	37.0×10^3	211.0×10^3
ST.-4	3.05	52.0×10^3	516.5×10^3
ST.-8	2.95	49.5×10^3	200.0×10^3

(b) Nobember

Station	Difference of water level	Resistance ratio	Length (cm)
ST.-2	1.5	31.0×10^3	88.8×10^3
ST.-3	2.8	55.0×10^3	211.0×10^3
ST.-4	3.8	73.0×10^3	516.5×10^3

tion of laver is supported only by ocean water. But here we raise a question. In our consideration, the actual state of the laver production could be considered as follows: the inner bay water which contains a large amount of nutrition is diluted tubes are connected series or parallel

R	Difference of water level (cm)	Calculated difference of water level (cm)	Difference
100.4 × 10^3	5.8	5.6	+0.2
30.15 × 10^3	1.3	1.5	−0.2
41.78 × 10^3	2.1	2.5	−0.4
53.4 × 10^3	2.35	2.65	−0.3
95.7 × 10^3	5.85	5.15	+0.7
			0

R	Difference of water level (cm)	Calculated difference of water level (cm)	Difference
27.7 × 10^2	1.25	1.32	−0.07
36.85 × 10^3	1.80	1.80	0
55.25 × 10^3	2.70	2.80	−0.1
30.84 × 10^3	1.50	1.57	−0.07
18.43 × 10^3	0.80	0.83	−0.03
			−0.27

Table 20. Evaulation of radius ratio between each station

(a) August

Station	Resistance ratio	Length (cm)	Radius ratio	Mean Section area
ST.-1~ST.-2	22.5×10^3	88.8×10^3	1.4	40401
ST.-2~ST.-3	10.5×10^3	122.2×10^3	1.75	7215
ST.-3~ST.-4	15.0×10^3	305.5×10^3	2.35	10958
ST.-1~ST.-8	49.5×10^3	200.0×10^3	1.44	

(b) November

Station	Resistance ratio	Length (cm)	Radius ratio	
ST.-1~ST.-2	31.0×10^3	88.8×10^3	1.30	
ST.-2~ST.-3	24.0×10^3	122.2×10^3	1.50	
ST.-3~ST.-4	23.0×10^3	305.5×10^3	1.90	

to some extent, to work as a manure for laver, and when it is diluted and stirred, the harmful factors for its production such as reducing materials in the water decrease markedly.

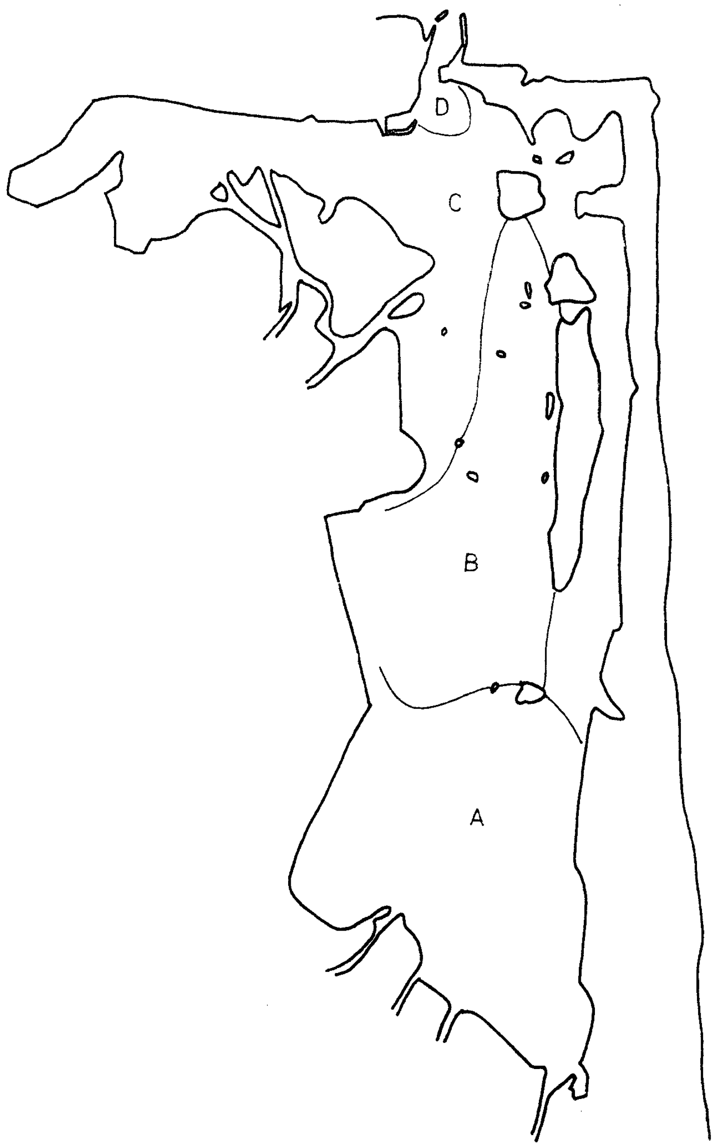

Fig. 22. Four charactaristic areas of Matsukawaura.

In the near future, when these points are investigated more fully and when a method for laver production or a mechanism of laver cultivation is studied much more in detail, a more suitable plan will be divised for its cultivation and production.

We are told that the plan at present is to make a stream by digging the rocks at the shallow places near the points of Iwanoko for the promation of good discharge of the dead water in the inner bay. But seeing that the neighbourhood of the demarcation between Region C and D is a place where resistance is greatest and that the region of Iwanoko, has a very little resistance digging would result only in inducing the 260,000 tons of water in the depressions of Region A and B to flow to the other parts of Region B and C. In effect, it gives almost no change to the total quantity of the ocean water which enters the bay.

So far we have made rather bold inferences, but we believe such inferences give some suggestions for the improvement for the cultivation of laver. However, we must add, it is quite necessary in future to go into the sources of nutrition for the laver production.

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