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Study on the Transport Characteristics of Floating Garbage in Hori River

STUDY ON THE TRANSPORT CHARACTERISTICS OF FLOATING GARBAGE IN HORI RIVER

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ABSTRACT

In this study, the types and the transport characteristics of floating garbage are examined in the Hori River located at the downtown of Nagoya city, Japan. Field observations revealed that more than 70% of floating garbage in the Hori River is natural garbage, which is mainly composed of dead trees and grasses, and much manmade garbage appears in downstream areas. From the investigation for the behaviour of floating garbage around the water area in front of Matsushige Lock Gate, it is found that the presence of this water area prolonged the duration of floating garbage in the Hori River. Moreover, the results of numerical analysis show that the transport characteristics of floating garbage in the water area is influenced by water flow which is affected by density changes due to tidal phenomena in the estuary region of the Hori River.

Keywords: Floating garbage, Hori River, Transport characteristics, Field observation, Numerical simulation

1. INTRODUCTION

Hori River flowing north-to-south through the downtown of Nagoya city, Japan, is a manmade river dug for the purpose of transporting goods and materials during the construction of Nagoya castle about 400 years ago. The water quality of the Hori River deteriorated due to contamination with waste water during a period of rapid economic growth in 1960-1970 similarly to other urban rivers, and the water environment of the Hori River was seriously aggravated, with foul odors and BOD exceeding 50 mg/l. Water quality and the river environment was improved by waste water regulations, sludge dredging, and the construction of sewer systems. Despite such efforts, there is still strong public demand for further improvements of water quality, foul odors and garbage in the river.

In 2006, a project titled the "2006 Collaboration Project for Restoration of the Hori River" was set up with the aim of restoring the water and social environment of the Hori River region, bringing together participants from Industry, public organization, university and citizen in order to discuss ways to improve the water environment of the Hori River and make a good use of that. The project consisted of the following five groups.

Group 1: Making a good use of the Hori River
Group 2: Joint of active association related to the Hori River
Group 3: Water environment
Group 4: Restoration of Charm of the Hori River

Group 5: Environmental Education, Information Broadcasting and PR

The authors participated in Group 3, which conducted assessments of the Hori River's water environment. This group focus on water quality issues that could be evaluated by sensuous index such as odor and garbage in the river. This paper shows knowledge gained about garbage on the Hori River in this group 3, and reports on the types, properties, and transport characteristics of floating garbage in the Hori River. Moreover, effective counter-measure for handling of floating garbage is suggested.

2. CHARACTERISTICS OF FLOATING GARBAGE IN HORI RIVER

2.1 Evaluation methods

In order to understand the types and volumes of floating garbage in the Hori River, floating garbage was collected at the centre part of cross section of Higashi-Tabata bridge (13.1 km from the mouth of the river), Gojo bridge (10.0 km), Hioki bridge (7.9 km), and Goryo bridge (4.4 km). During both the ebb tide and the flood tide the garbage collection was carried out using a net shown in Figure 2 (the net has an entrance with 40 cm tall x 40 cm wide and a 2 mm mesh). The date of observation was spring tide of August 25, 2006. After drying out the garbage retrieved at each bridge, the type and volume of garbage was measured. Moreover, In order to assess any seasonal variation, the same observation was repeated during the spring tide of December 5, 2006 at Hioki Bridge.

2.2 Results of Field Work

Figure 3 shows the total mass of floating garbage at each bridge. From this figure, less garbage was observed in upstream area of the Hori River, and the volume of garbage increased toward downstream area of the river. In particular, exceptionally higher volumes of garbage were observed at the upstream area of Hioki Bridge during the flood tide than during the ebb tide. The transport characteristics of floating garbage in the Hori River caused by the presence of the water area in front of Matsushige

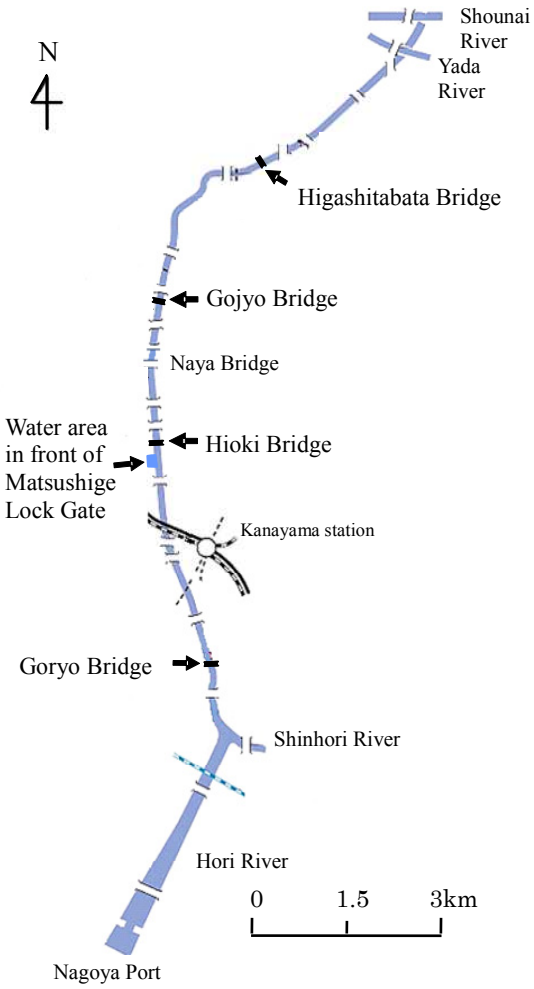

Figure 1 Location of observation

Figure 2 Net for garbage collection

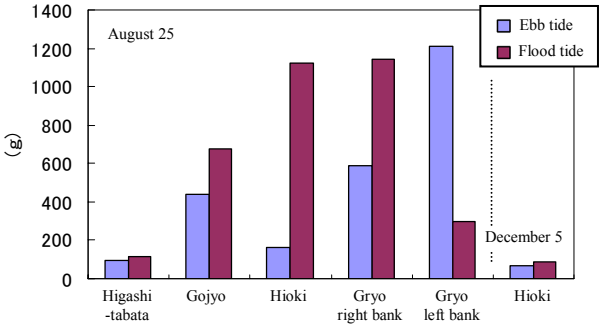

Figure 3 Total mass of floating garbage

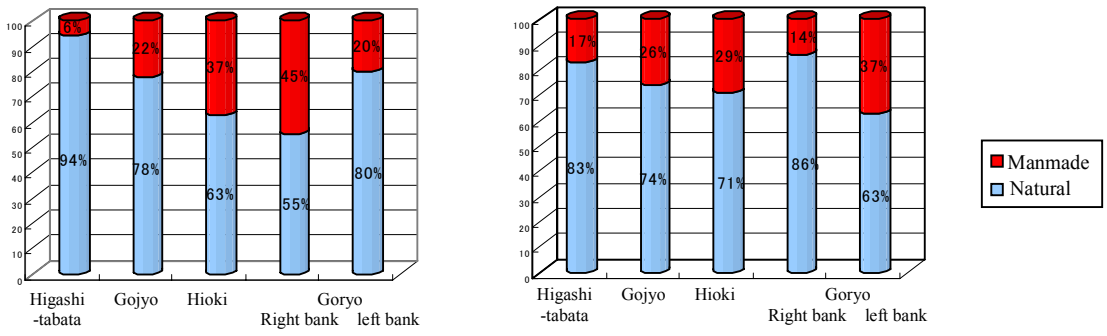

Figure 4 Volume ratio of manmade and natural garbage

Lock Gate, which will be explained in subsequent sections. In addition, a large difference was observed in the amount of garbage collected at Hioki Bridge on August 25, 2006 and December 5, 2006. This difference is affected by rainfall of 33.5 mm per day on August 22 (maximum hourly rainfall: 17.5 mm).

The garbage was categorized into natural one such as leaves, and manmade one such as plastic bags. Figure 4 shows the volume ratio of natural and manmade garbage at each bridge during ebb tide and flood tide. From Figure 4, it is found that the volume of natural garbage is more than that of manmade garbage (averaging more than 70%), and the ratio of manmade garbage increases at downstream area of the Hori River. Furthermore, it was noticed that natural garbage was primarily composed of materials from outside the river such as fallen leaves and dead wood. The manmade garbage was composed of a number of plastic bags, and a number of discarded cigarette butts increased in downstream area. There was much vegetation surrounding the upstream area of the Hori River, while a large number of men were passing along the downstream area of the river, hence these situations of the Hori River are related to the observation results of floating garbage. The floating garbage in the Hori River are repeatedly transported to upstream and downstream by tidal flow, and flowed down gradually toward Nagoya Port in which the Hori River terminates. The results of this investigation clarified the transport characteristics of garbage in the Hori River. Additionally, the high volume of natural garbage such as dead leaves indicates that measures to control floating vegetation such as levee management and weed removal could help to improve the water environment of the Hori River.

There were many floating carcasses of rats in the river on August 25 2006. It is thought that rats can not escape from the sudden increase of storm water in the pipe of combined sewer system during the rainfall on August 22, 2006. The floating of animal carcasses in the river for prolonged periods is big problem. Countermeasures should be discussed to prevent and quickly remove animal carcasses caused by storm runoff.

It might seem odd treatment to consider natural things such as leaves and branches as garbage. Dead vegetation was settling on the river bottom and contributes to sludge formation. The sludge affects the foul odors and deterioration of water quality of the river. From these reasons, natural things such as dead leaves and branches in the Hori River are treated as natural garbage in this study.

3. TRANSPORT CHARACTERISTICS OF FLOATING GABAGE

3.1 Floating garbage below Hioki Bridge

Garbage entering into the Hori River moves according to the tides, and was often presence in the river for a long time. This study examined the transport of floating garbage in the river. During tide from 8:00 to 18:00 on November 9, 2006 and during spring tide from 8:30 to 18:00 on December 5, 2006, the location of visible garbage appearing below Hioki Bridge was surveyed. Figure 5 shows the state of garbage at the river side and Figure 6 shows a sample of the survey results. Diamonds in Figure 6 show pieces of manmade garbage, while circles show natural garbage, with time in the downward direction. From this Figure, it can be seen that there is less garbage during low tide. As shown in Figure 5, it is thought that the number of floating garbage decreases because it settles on the side beds of the river in low water level. When the water level rises in flood tide, the garbage is returned to the surface of the Hori River and the garbage is repeatedly transported. During the ebb tide, a large amount of garbage travels downward along the sides of the river, particularly along the right embankment. On the other hand, the garbage is spread out in the centre part of water surface of the river during flood tide. These features on transport of floating garbage were observed on both November 9, 2006 and December 5, 2006. Furthermore, a large number of floating garbage travels upward during flood tide more than that during ebb tide. This result for mass of floating garbage is related to presence of the water area in front of Matsushige Lock Gate located at downstream from Hioki Bridge as shown in Figure 1. In order to investigate the impact of this water area on the transport of floating garbage, observation of the behaviour of floating garbage was executed on November 9 and December 5, 2006. The results and their discussion are under mentioned.

Figure 5 States at the river side

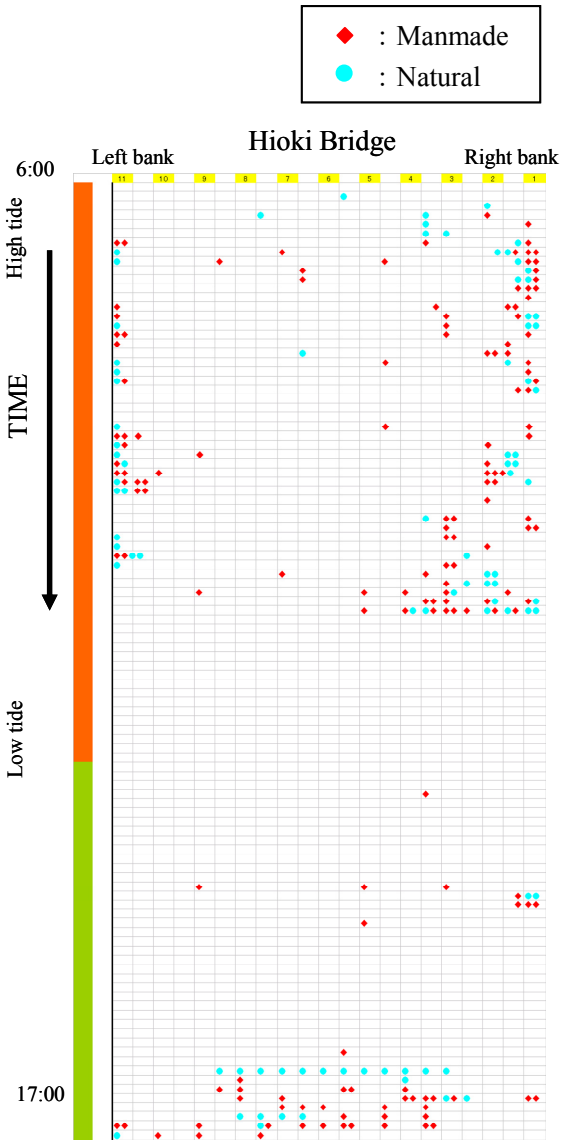

Figure 6 Location of floating garbage at Hioki bridge

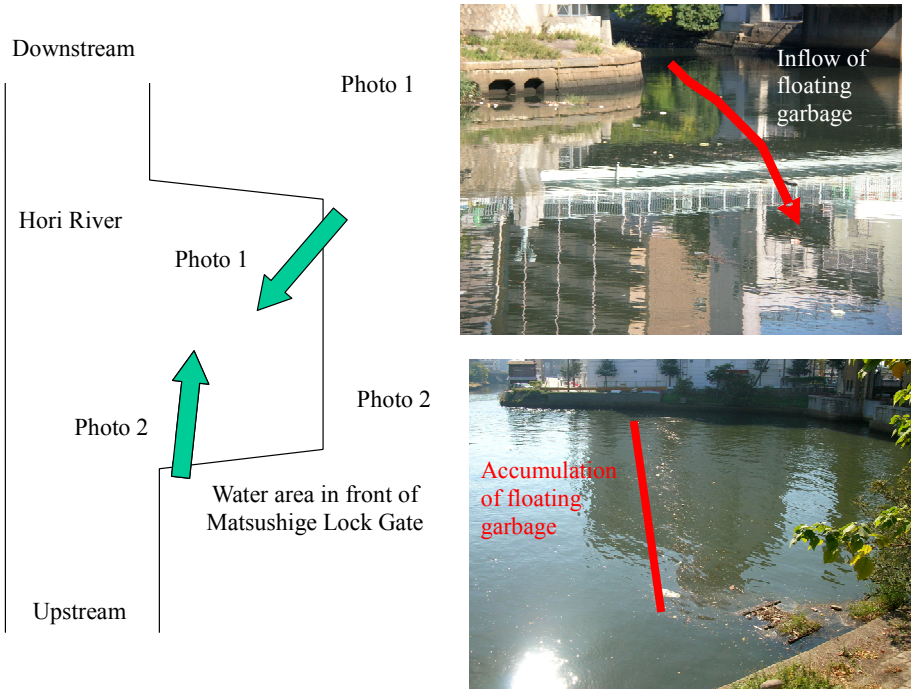

Figure 7 Distribution of floating garbage in the water area in front of Matsushige Lock Gate

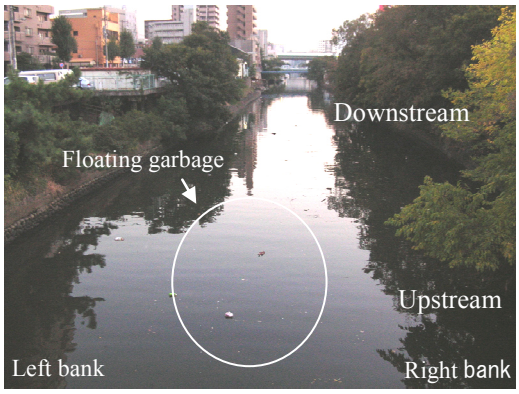

Figure 8 States of floating garbage in the downstream direction from Hioki Bridge

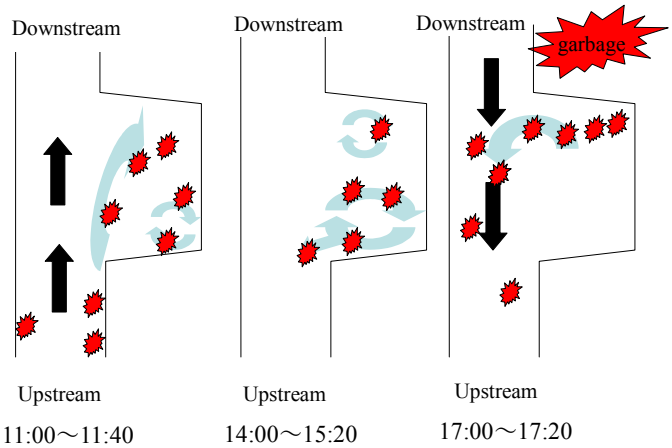

Figure 9 Sketch of transport of floating garbage

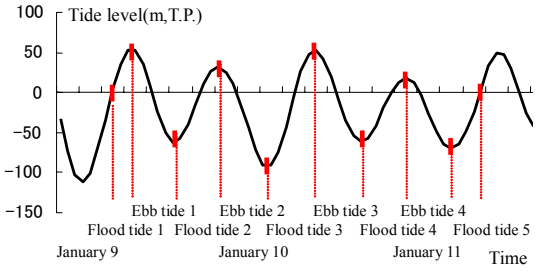

Figure 10 Tide level at Nagoya Port

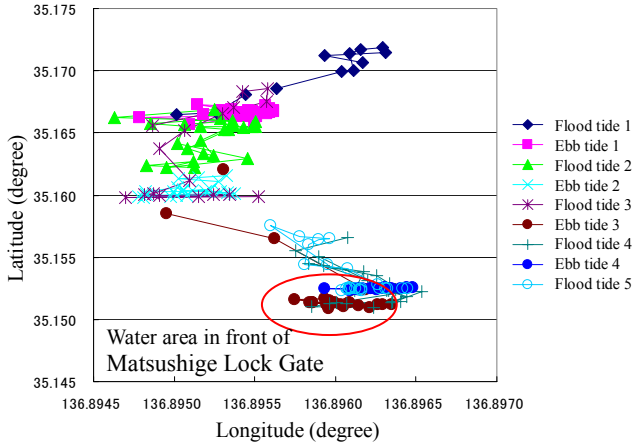

Figure 11 Transport trajectory of dummy garbage

3.2 Garbage transport in the water area in front of Matsushige Lock Gate

The water area in front of the Matsushige Lock Gate was used to store boats when the lock was in operation. Figure 7 shows the distribution of floating garbage observed on November 9, 2006. It is found in Figure 7 that garbage enters into there and accumulates gradually during the ebb tide. Figure 8 shows the states of the floating garbage in the downstream direction from Hioki Bridge during the flood tide. From this figure, it is found that garbage flows up from the water area in front of the Matsushige lock Gate toward upstream and spreads out in the centre part of the Hori River. Figure 9 shows the sketch of the transport of floating garbage in the water area in front of Matsushige Lock Gate. During the ebb tide, garbage entering into there from the right side of the river was observed, but no garbage was observed to outflow from there to downstream during the observation period. The collected garbage in the water area outflows from there toward upstream of the Hori River during the flood tide, particularly at 17:00. This behaviour of the garbage is linked to the large volumes of garbage observed at Hioki Bridge during this time. Moreover, similar feature on transport of floating garbage was observed on December 8, 2006. Consequently, some of the garbage in the Hori River circulates between midstream of the Hori River and the water area in front of Matsushige Lock Gate, and this water area may contribute to long-term floating of the garbage in the Hori River.

3.3 Garbage transport survey using GPS

In order to ascertain the transport characteristics of floating garbage in the Hori River, a dummy piece of garbage mounted with a GPS unit was released into the river. The recording time for the position of the dummy garbage is every 15 minutes. The observation period was from 6:00 January 9 to 10:00 January 11, 2007, and the release of the dummy garbage was started at Naya Bridge. The dummy garbage was collected at Hioki Bridge at 10:00 on January 11 2007. Figure 10 shows the tide level of Nagoya Port, and Figure 11 shows the transport trajectory of the dummy garbage during the observation period. As shown in Figure 11, the dummy garbage gradually moved to the southerly direction from flood tide 1 to flood tide 3. From ebb tide 3 to flood tide 5, the garbage moved in the same region. Matsushige Lock Gate is located at the southern edge of this movement. From these results, it was confirmed the water area in front of the Matsushige Lock Gate strongly influences the transport characteristics of floating garbage in the Hori River.

Considering the feature of floating garbage in the Hori River above mentioned, the catching of the garbage prior to being released from the water area during flood tide is an effective countermeasure for removal of the garbage. If a moveable type fence will be placed at the mouth of the water area in front of Matsushige Lock Gate and opened when garbage starts to enter into the water area and also closed when the garbage starts to outflow from the water area, this system may be very effective facility for garbage control on the Hori River.

3.4 Numerical analysis of transport characteristics of floating garbage transport

A 3-dimensional numerical calculation considering with density changes was performed to clarify the factor affecting to the transport characteristics of floating garbage in the water area in front of the Matsushige Lock Gate. The governing equations in the analysis model are continuity equation, momentum equation, conservation equation for salinity and equation for the state of density, which are expressed by Cartesian coordinate system. In the momentum equation of vertical axis, hydrostatic pressure is assumed. Moreover, the analysis region between 4.4km and 13.6km from the mouth of the Hori River was assumed as a straight line.

Figure 12 shows the analysis region. In this figure, the Y axis is displayed at 10 times the size of the X axis. 0.5 m mesh was placed in the vertical direction, with the mesh adjusted

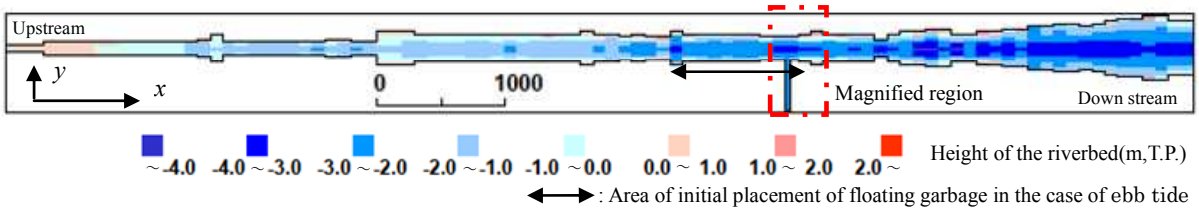

Figure 12 Analysis region

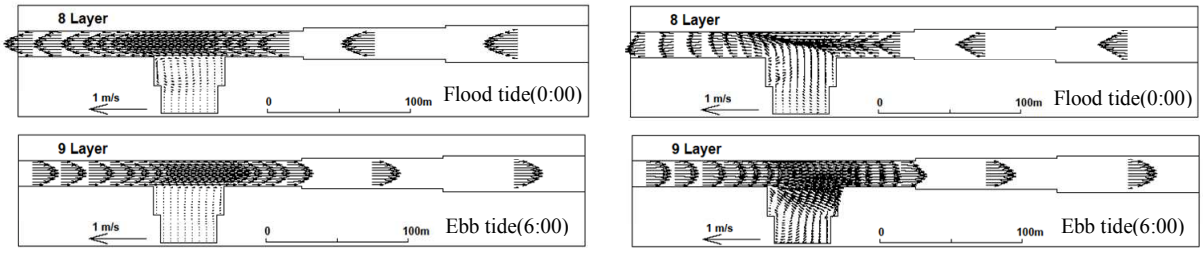

Figure 13 Distribution of water velocity at surface layer

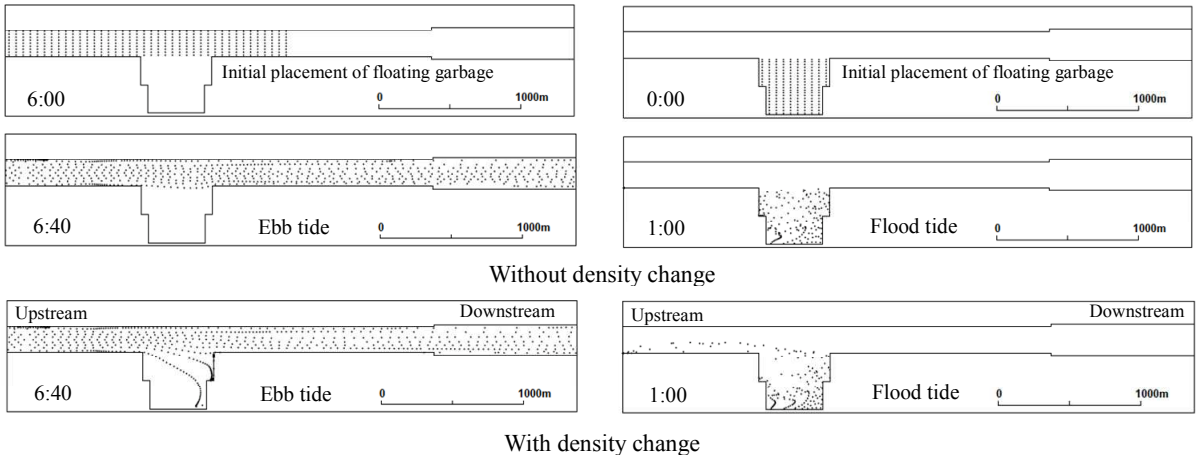

Figure 14 Movement of floating garbage in Hori River

according to water level. The upstream boundary conditions were set at 0.3 m^3/s freshwater flow, and tidal variation was set at 1.0 meter amplitude on a 12 hour cycle at the downstream boundary. An initial salinity value was set by use of the data recorded at 6:00 on August 25, 2006 at the four bridges described in section 2-1. Water temperature was kept constant at 28.8ºC, and salinity at the downstream boundary was set at 10.7 psu in the surface layer, 19.4 psu in the middle layer, and 22.7 psu in the bottom layer. Though the analysis period was four days and 12 hours, finally one cycle data of analysis results are used for the examination. In addition, movement of floating garbage was calculated with the Lagrange method by using flow velocity at the surface layer.

Figure 13 shows the distribution of surface water velocity during flood tide and ebb tide in the magnified region of Figure 12, with and without density change. The time of zero in the figure corresponds to the time after four days since the calculation start. From this figure, it is clear that water velocity inflowing into and outflowing from the water area in front of Matsushige Lock Gate is vague in the case of no density change. On the other hand, in the case of density change, water flows into the there from the Hori River during ebb tide,

and outflows from there to the Hori River during flood tide. During flood tide, density in the Hori River near the Matsushige Lock Gate quickly increases more than that in the water area in front of Matsushige Lock Gate. As this density change creates the density current, the water at the mouth of the water area in front of Matsushige Lock Gate inflows to the water area at the bottom layer. On the other hand, the water at the mouth outflows to the Hori River in the surface layer. During ebb tide, opposite density change in the case of flood tide is occurred in these water areas. Because density in the Hori River quickly decreases more than that in the water area in front of Matsushige Lock Gate during ebb tide, the water at the mouth outflows to the Hori River in the bottom layer due to density current. On the other hand, the water at the mouth inflows to the water area in front of Matsushige Lock Gate in the surface layer. Figure 14 shows the movement of floating garbage during flood tide and ebb tide both with and without density change. Floating garbage was placed in the water area in front of Matsushige Lock Gate at 0 hour in the case of flood tide, and it placed in the area indicated in Figure 12 at 6 hours in the case of ebb tide, as initial condition. As shown in Figure 14, there is a very small amount of garbage that enters into or leaves from the water area in front of Matsushige Lock Gate when there is no density change. However, in the presence of a density change, garbage at the right side of the river enters into the water area during ebb tide, and garbage is released into the river from the downstream side of the water area during flood tide. Transport characteristics of floating garbage obtained by numerical simulation in the water area in front of Matsushige Lock Gate, especially feature of entering and releasing of floating garbage are similar to observation results. Consequently, it is confirmed surface flows in the water area in front of the Matsushige Lock Gate caused by water density change have a significant impact to transport characteristics of floating garbage in the Hori River.

4. CONCLUSION

The results of this study are summarized as follows:

1) Approximately 70% of floating garbage was natural garbage and many materials of natural garbage were from outside the river such as dead trees and plants. Manmade garbage was frequently observed in downstream region of the Hori River.
2) Floating garbage observed at Hiokii bridge flowed downward along the river edges during ebb tides, and especially, a large volume of garbage was observed on the right embankment. During flood tide, the garbage is spread out in the centre part of water surface of the river.
3) The water area in front of Matsushige Lock Gate is effected the transport feature of floating garbage observed at Hioki bridge. During ebb tides, floating garbage at the right side of the river entered into the water area, then the collected garbage in the water area outflowed to the Hori River during flood tides.
4) When a dummy piece of garbage mounted with a GPS unit was released into the river, it was found to circulate between the midstream portion of the Hori River and the water area in front of Matsushige Lock Gate.
5) The floating garbage remains present for longer periods in the Hori River due to the transport characteristics.
6) Numerical analysis revealed the transport characteristics of floating garbage in the water area in front of Matsushige Lock Gate is significantly influenced by water density change.
7) The hydraulic properties in the water area in front of Matsushige Lock Gate to collect floating garbage can provide an effective measures for garbage control in the Hori River.