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DEVELOPMENT AND HUMAN SETTLEMENT IN SAGA AND SHIROISHI PLAINS BY RECLAMATION

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ABSTRACT: The paper describes a case study of development of a very unique region in Japan, consisting of the Ariake bay and the Saga plain, which is subjected to about 6 m of tidal fluctuations and had been reclaimed from the sea over a period of centuries. The sequences of land development, reclamations, developments of water systems, dwellings, etc. are traced. The distinct characteristics of hydrology, irrigation and water management and urban drainage are described. Lastly, the serious problem of subsidence due to excessive pumping of ground water mostly for irrigation but also for industrial and domestic use is high-lighted. The human settlements in this region have evolved along unique patterns of designs especially of the water systems and the houses in spite of being subjected to construction on very soft soil, being buffeted by typhoons and subsidence.

INTRODUCTION

The origins of many civilizations can be traced to rivers, deltas and coastal regions of the world. Presently about 80% of the citied or regions with the largest populations are located in these areas. The need to reclaim some of the marginal lands such as the tidal flats has been felt for centuries but mostly in the Netherlands. A recent publication by Johnson (1993) describes the historic development and a very recent urban land restoration of Boston, both of which relate the land (marshy to begin with) with the water (the sea). Most of the central business district and the port area are reclaimed lands. Similar reclamations from the sea have been taking place in many parts of Japan, especially from the Ariake Sea in western Japan, in the island of Kyushu.

LANDSCAPE DEVELOPMENT

The Ariake Sea (bay) is located near the center of Kyushu, the southern most main island of Japanese archipelago (Fig. 1) and surrounded by Fukuoka, Kumamoto, Nagasaki and Saga prefectures. It is enclosed by the Shimabara, Amakusa and Uto peninsulas, forming a large bay with a surface of about 1,700 km^2, a central axis approximately 96 km long, a width of 18 km and an average depth of 20 m. Several rivers flow into the Ariake Sea from the surrounding Sefuri, Tenzan, Tara and Aso-Kuju mountain systems. Weathered materials fom the rocks granite, basalt, andesite and other volcanic rocks are carried continuously by these rivers to the sea. While the heavier materials get deposited in the sea bottom, the finer particles are redeposited by the flood tide gradually forming the tidelands. The greatest tide range of 6 m occurs in the Ariake Sea covering an area of 230 km^2 at spring and 110 km^2 at

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neap tides. Therefore, The most characteristic features of the Ariake Sea are the vast tidelands exposed at low tide.

The Saga and Shiroishi plains are the part of the reclaimed land from the tidal flats of Ariake. Like all Japanese coastal lands, the Saga area also is densely populated but utilized mostly for agriculture. The coast is buffeted by typhoons and strong winds and so protected by sea walls and breakwaters.

LANDSCAPE DEVELOPMENT

The Saga-Shiroishi plain of today is a result originally of natural land formation through alluvial river deposition but mostly through reclamation from the sea. The alluvial plain at the foot of the Sefuri and Tenzan mountains belongs to the Quaternary period. Three major rivers, the Chikugo, the Kase and the Rokkaku, with many smaller rivlets, (the Matsuura, the Shiota, the Ushizu, etc.), creeks and waterways criss-cross (Fig. 2) the plains of Saga and Shiroishi. The Chikugo River has a relatively large amount of discharge and the riverbed is below the ground level, so that the floodwaters return to the river again. The Kase River, on the other hand, has the bed above the ground, thus requiring head–works and creek network for water distribution. The Rokkaku River is also a tidal river that usually has a very small amount of discharge. The tide extends up to 29 km upstream from the Rokkaku river mouth and 14 km from the junction with Ushizu River.

Fig. 1 Location of Saga-Shiroishi plain in Kyushu, Japan

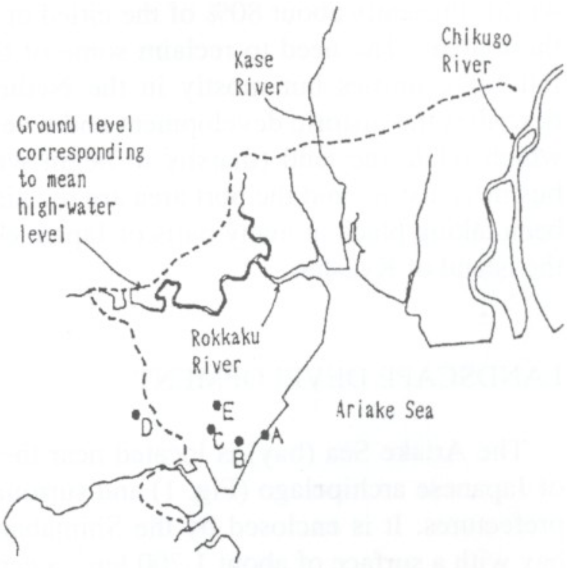

Fig. 2 The river systems

The eastern part of the plain was created mainly through deposition of sediments that had been carried down along the Chikugo and Kase Rivers. The western part was formed with the deposits of Rokkaku and Shiota rivers. In addition, two other rivers, the Hayatsue and the Hattae, also play an important role in serving and shaping this region both in terms of water resources and also in landscape development.

RECLAMATIONS

The original coastline of the Ariake Sea is believed to be a contour line lying in the foothills at an elevation of 5 m above the present sea level and about 20 to 25 km inland from the existing coastline. The series of reclamations in the plains are depicted in Fig. 3. While some reclamations were believed to be prehistoric, history records them from c.800 AD. The oldest dated reclamation is from the Kamakura period (1185-1333 AD). Simple reclamations with bank construction continued through the age of Civil Wars (1482 to 1558 AD). Remarkable technological progress was achieved during the Edo era (1600 to 1867 AD) when stone was used to build coastal dikes and reclaim large areas of land. Lands have been created throughout the Meiji Period (1862 to 1912 AD) and continue to be created even during the present time with the land for the new Saga airport (to be opened in 1998) being the latest.

The Saga plain is approximately 60,000 ha in extent and occupies nearly a quarter of the Chikushi Plain, a land developed along the northern coastal areas of the Ariake Sea. Four main dykes have been built before 1800 AD. The construction of the dykes was initated by the local inhabitants and supported by the Government by exempting them from the land taxes. The comparative locations and elevations of the dikes built with respect to one of the major structures, the Saga Prefectural office, are depicted in Fig. 4. Also shown are the tidal fluctuations, which vary from a high +3.84 m to a low –2.89 m. The high tides are accentuated further by the typhoons that strike annually during July to September causing severe damage to the plains of Saga and Shiroishi.

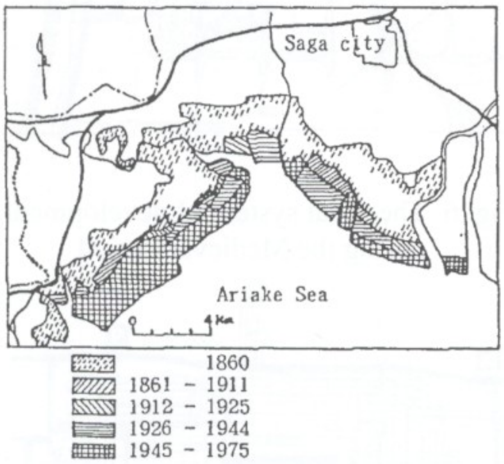

Fig. 3 Reclamations in Saga-Shiroishi plains over the centuries

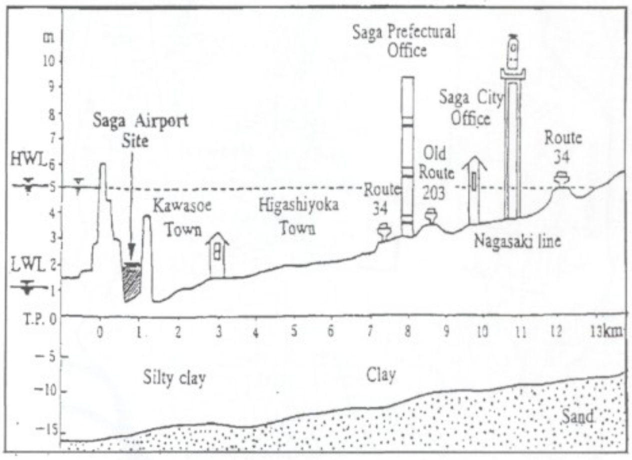

Fig. 4 Comparative elevations of tides, dikes and Saga plain

During the process of reclamation, gullies were left unchanged and the creeks got formed (Fig. 5), giving the Saga plain a unique aerial panoramic view. There are two forms of the creeks, the natural and the artificial ones. The latter are dug out around living areas firstly to drain groundwater and later to store rainwater. The ground water level in this area is very close to the ground level. So, for constructing a human settlement, a ditch is dug and the water level lowered, earlier by bailing but presently by pumping. The excavated soil is dried out and mixed with quick lime to form a relatively strong material out of which the dwelling are constructed. It is also used to raise the elevation of the ground. Subsequently, the ditches get transformed in to creeks and are utilized to store rainwater as Saga plain, which has a small catchment area, suffers with water shortages otherwise. However, they are not navigable as in some other parts of the world. The creeks of Saga plain occupy about 1,800 ha, i.e. about 7%

of the total paddy field area. The total volume of the creeks is 25 Mm^3, accounting for approximately 8% of the volume of water required for irrigation. Most of the creeks in Saga plain are used for water storage while those in Shiroishi exist as channels for drainage.

DEVELOPMENTS OF WATER SYSTEMS

The developments of the water systems, i.e. the creeks, the ditches and lately the drains, formed an integral part of the development of the land and the human settlements. Fig. 5 depicts the patterns of the creeks and the drains in the Saga area. This mosaic has been developed over a period of 13 to 14 centuries. Three distinct phases, the ancient, the medieval and the recent to modern, have been identified. In the north (top of Fig. 5) at the foothills of the Sefuri Mountain, the natural creeks, which carry the runoff water from the slopes, extend from the north to the south as they have been extended down as the land was being reclaimed in the ancient period (7th to 8th centuries).

Fig. 5 Mosaic of creeks in Saga

Fig. 6 The moat system of development during the Medieval Period

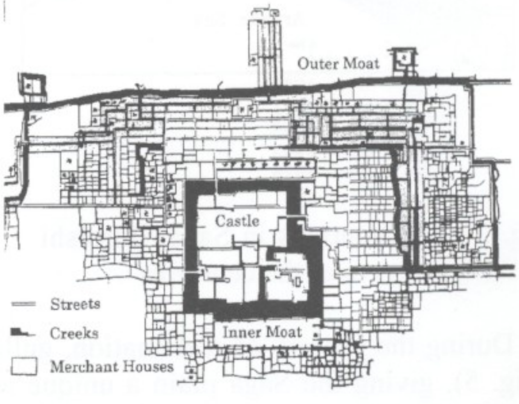

Fig. 7 The creek systems in the castle township

During the medieval period, i.e. the 13th to 15th centuries, interestingly the moat system was developed (the middle part of Fig. 5). Each settlement surrounded itself with a moat, which probably served as a protection from invaders as well as water storage system for agriculture and daily living. A typical example (Fig. 6) of this type of settlement is the Naotori Mura (settlement) in the Chiyoda cho (suburb). The series of the moats got interconnected eventually. Small-scale reclamations took place during the Edo era (17th to 19th centuries) and once again the north to south lineal pattern of creeks and ditches have been built. This period witnessed the emergence of the feudal system and the development of the castle township (Fig. 7). Both the moat and the grid systems of creeks, canals and ditches have been built in and around the castle. While the castle had a wider inner moat for protection, a second line of defense had an outer moat that extended from the east to the west through a long northern corridor. The Southern boundary did not pose any threat as it was being reclaimed continuously from the sea.

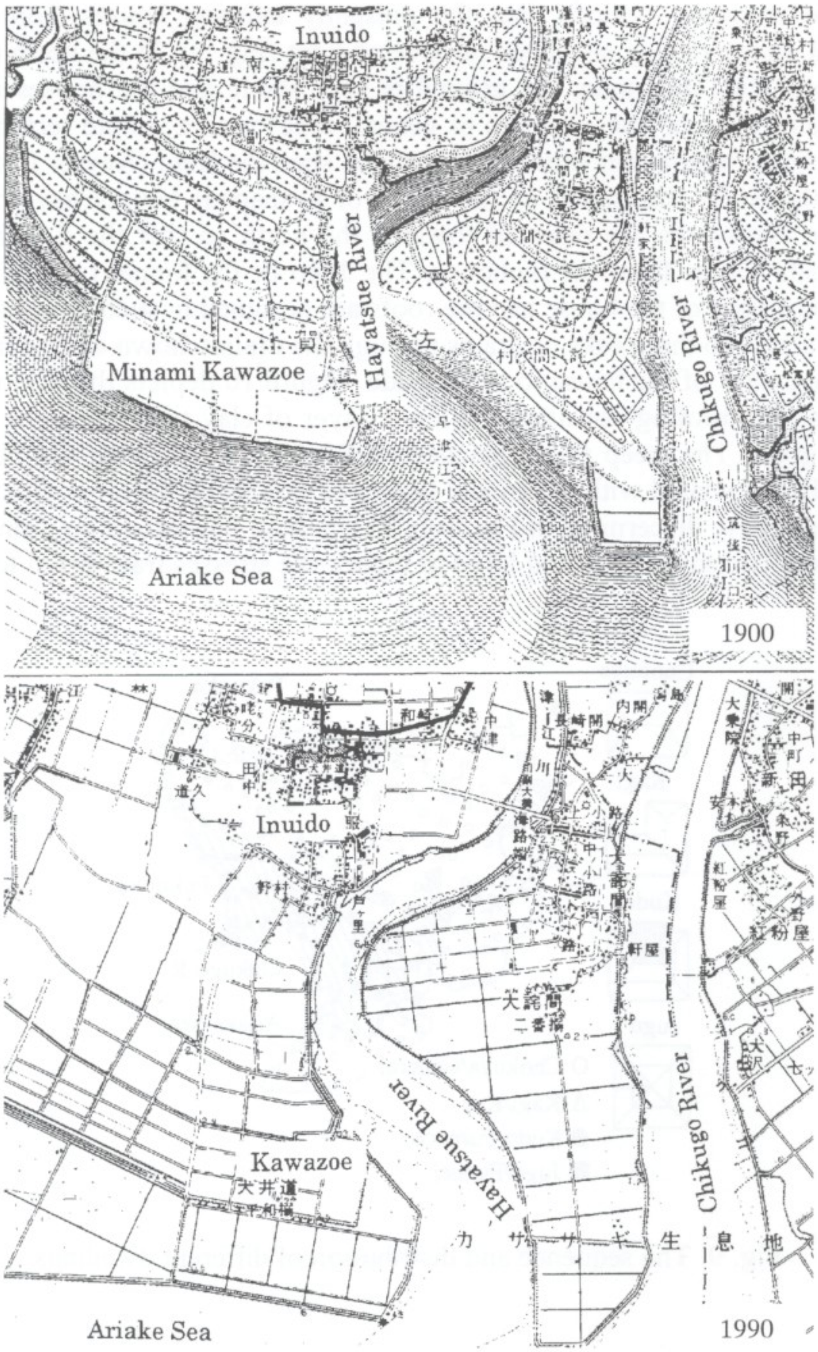

Fig. 8 The new town Kawazoe developed during 1900 to 1979

Reclamations and the development have been on a much larger scale during the Meiji and Showa eras (19th and 20th centuries) during which the ditches and the drains have been built in the east to the west direction as well forming a grid pattern (the Southern part of the area, i.e. the lower portion of Fig. 5). Figure 8 illustrates the development of a new town, Kawazoe, during 1900 to 1979 (late Meiji to Showa periods). The intricate drainage patterns can be clearly seen.

DEVELOPMENT OF DWELLINGS

No historical record seems to be available about the types of houses built during the ancient and the medieval periods. But the presently existing houses from the Meiji era onwards exhibit an interesting sequence of development (Fig. 9). In the north of Saga city, at the foot hills of Sefuri mountain, the ground is very stable and the houses are of the type locally known as Chokuya (the common or general type) with a simple rectangular plan and sloping roofs. In the middle part of the town, can be seen the Kagi (Key or L-shaped) houses. Subsequently, the Kudo (translated as fire place or C-shaped) houses have been built. The openings or the courtyards are oriented towards the north so that the full frontal face can withstand the gale forces from the typhoons. The Jugo or the funnel type of houses are the most recent. The layout of the house and the roofs are designed in such a way as to collect the rainwater and carry it to the creeks or drains through the drain (shown as discontinuous line in Fig. 9) from the center of the house to the outside. Figure 10 depicts the Kudo and the Jyogo types of houses. The roofing consists of a lower layer of clay tiles while the upper one is a thick patch of grass. The steep thick thatched roof helps in protecting the house from high intensity rainfalls associated with the annual typhoons that strike the area. The funnel shape of the inner roof is clearly discernible in Fig. 10b. Since these houses are built on soft reclaimed ground, the layout had to be wide and large to reduce the stresses transferred to the weak sub-soils.

Fig. 9 The sequence and distribution of different dwellings

HYDROLOGY

Hydrological and environmental characteristics in lowland areas are very different from other regions. Most lowlands are located in the deltas or downstream parts of river basins, which receive runoffs from the whole watersheds prior to discharging into the seas. The hydrological regime in a lowland river system is influenced by watershed characteristics as well as the tidal phenomena. The drainage capacities of lowlands are poor due to their flatness and flooding is a common occurrence whenever there is heavy rainfall in the catchment areas or a storm surges in the tidal inlets due to typhoons. Flooding is a common feature during the rainy season as most of the annual rainfall is concentrated to within a 6 to 8 week period. The most recent disaster that befell the Saga-Shiroishi region was during June 29 and July 2, 1990, when more than 500 mm of rain fell in a period of 6 days.

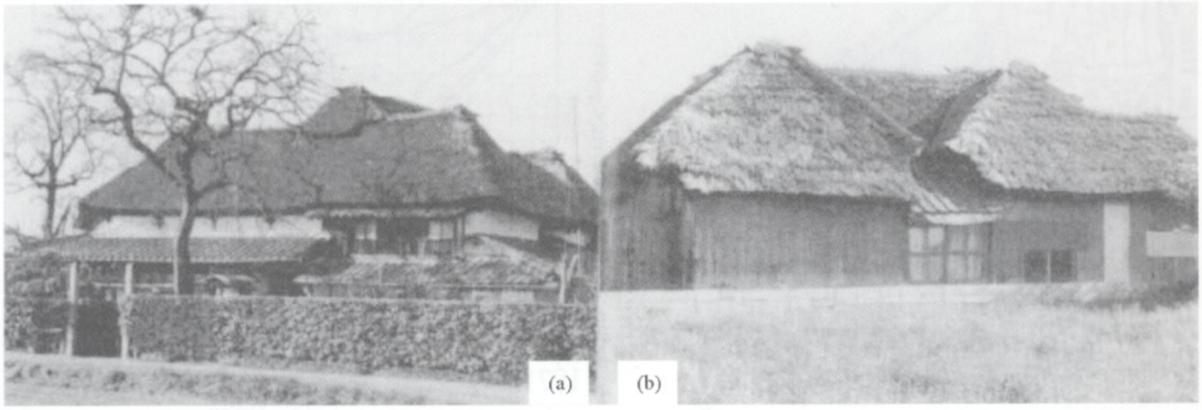

Fig. 10 The Kudo (a) and Jyogo (b) types of houses (Source: Saga no Minka 1981)

IRRIGATION AND WATER MANAGEMENT

A system of water management has been evolving in this region since c. 1500 because of increasing demand on river waters for ever expanding paddy cultivation on reclaimed land. Several irrigation projects were executed by Hyogo Narutomi (1560-1634), a great civil engineer from the Edo era, who was retained by the Saga clan. The Hazama canal, the Dainichi weir and the Nagaike pond were built by him. In addition, a cross levee was built in the middle of Ushizu river for flood control. At present about 40 to 46% of the land is being used for paddy cultivation. Of late, fruits and vegetable cultivation, and livestock breeding are also being practiced.

Because of the inadequate supplies from river waters, ponds are required for irrigation. The Yakigome pond with a storage capacity of 1 million cubic meters built in 1800 AD, is probably the oldest. The recent Asahi reservoir built in 1959 has a capacity of 1.3 Mm^3. At present over 50 irrigation ponds have a storage capacity of 5 Mm^3. Pumping of groundwater started from about 1940 AD but the quantity of water pumped has significantly increased from 1955 onwards causing serious ground subsidence problems especially in the Shiroishi plain. The number of deep tube wells is in excess of 150 and the pumping capacity exceeds 300,000 m^3/day. In drought years, more than 20 million tons of water is pumped out annually.

URBAN DRAINAGE

Rivers in lowlands, particularly those in Saga and Shiroishi areas are basically tidal ones. As a result, drainage from the land becomes a major problem as the water level in the river is affected by the tides. Of the two alternative drainage systems, the channel and the network, the latter is preferred, since it functions as a balancing reservoir for peak flood storage and then discharges the water over a period of time or through pumping with relatively low capacity pumps. The drainage network for central Saga (Fig. 11) is a typical example of the urban design to handle floodwaters from rainfall intensities of as much as 60 mm/hour that occur during the typhoon season.

Fig. 11 Urban drainage pattern in Saga

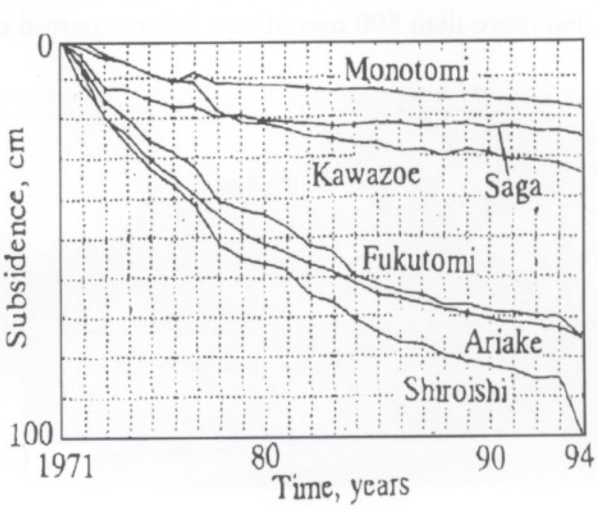

Fig. 12 Subsidence in Saga-Shiroishi plain

SPECIAL PROBLEMS – SUBSIDENCE

The development of lowlands is often more difficult and costly than the developments of upland flood plains. In lowlands, not only are embankments needed to protect the areas from periodic flooding by the sea and/or rivers, but also the quality of water creates problems as brackish water may affect the crops. In addition, land subsidence due to excessive groundwater extraction and the sea level rise due to global warming cause greater impact on lowland areas that on the other regions.

The Saga-Shiroishi plain is one of the significant land subsidence areas in Japan. Subsidence has begun in 1958 with the development of deep tube wells and utilization of groundwater for agriculture and became a serious problem since 1971 from when systematic observations of ground levels (Fig. 12) are available. The rate of subsidence has been 4.0 to7.0 cm per year resulting in an accumulated subsidence of more than 1.0 m in the Shiroishi area. The area of subsidence in the Saga prefecture is about 320 km^2, i.e. about 46% of the total area. The rate of subsidence increases sharply in the drought years. For example, in 1994, Shiroishi town had a subsidence of 14 cm. With the construction of dams and reservoirs and restrictions of groundwater use, the subsidence in the Saga area could be arrested. However, it continues in the Shiroishi area due to continuous use of groundwater for agriculture and domestic uses.

The damages caused by subsidence have been categorized into direct and indirect ones. The former consist of damages to constructed facilities such as buildings, roads, bridges, culverts, etc. Buildings supported on deep (pile) foundations get 'apparently' uplifted from the ground creating gaps especially near the entrances to them. Some failures of piles due to down drag have also been reported. Gas, water and drainage pipes get broken. Roads become bumpy near pile-supported bridges due to large uneven settlements of the approaches. Some other examples of direct damages are the obstructions to the flow in the rivers, irrigation and drainage canals and sewerage systems, and the facilities for pumping water. The most significant indirect damage is the enlargement of the 'below the sea level' land area which then gets subjected to increased flooding, high tides and ponding of water during heavy rains.

CONCLUSION

The paper describes a case study of development of a very unique region in Japan, which is subjected to about 6 m of tidal fluctuations and had been reclaimed from the sea over a period of centuries. In addition, the land is underlain by a very soft and sensitive clay and has been subsiding due to withdrawal of groundwater. The region has many distinctly different features such as soils, climates, society and technology. The sequences of developments of the landscape, the water systems and the dwellings have been described. The human settlements in this region have evolved unique patterns of designs especially of the water systems and the houses in spite of being subjected to construction on very soft soil, being buffeted by typhoons and subsidence.

REFERENCES

Johnson, C.R. (1993). Urban land restoration on the water's edge: Case studies in Boston. Ekistics, 360(360/361): 176-182.

Koga, K., Araki, H. and Liengcharernsit, W. (1994). Hydrological and environmental characteristics. In: Miura, N., Madhav, M.R. and Koga, K. (Editors) Lowlands – Developments and Management, A.A. Balkema, Netherlands: 41-63.

Watanabe, K. (1994). Irrigation and drainage in Saga Plain. In: Miura, N., Madhav, M. R. and Koga, K. (Editors) Lowlands – Development and Management, A. A. Balkema, Netherlands: 403-411.

Watanabe, K. and Ogushi, K. (1990). Damage resulting from heavy rainfall in July 1990. Int. Seminar on Geotechnical and Water Problems in Lowland, Saga: 1-9.