Mbay city's eco-hydraulic concept leads to sustainable water supply and management

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Abstract. Mbay City is a lowland city flanked by rows of mountains and agricultural rice fields. This barren mountain range causes rainwater mostly flow towards the urban lowlands, as flood. The city of Mbay which consists of 3 different regional groups, namely mountains-lowlands-rice fields, encourages a sustainable water supply and management with an eco-hydraulic concept. First, it is necessary to understand the terms eco-hydraulics, sustainable water management and sustainable water supply as well. Furthermore, we can find the right innovation to handle the three distinctive areas of the different Mbay cities. Mountain areas need water conservation that applies ecological concepts, while urban plains need hydraulic handling to drain flood water from the city, and rice fields also need ecological handling so that rice fields are protected from overflowing sea water when high tide occurs. Finally, it can be said that the integrated handling of ecology and hydraulics concepts has made the city of Mbay able to manage and supply water in a sustainable manner.

Keywords: eco-hydraulic, sustainable water management, sustainable water supply

1. Introduction

Mbay City is a lowland city flanked by rows of mountains and agricultural rice fields. This barren mountain range causes rainwater mostly flow towards the urban lowlands, as flood. Floods and puddles, which are quite extensive and long in each rainy season are caused by several factors include[1]:

1. Physically, soil types in urban plains are naturally sedimentary soil types, that have low water infiltration. Surface ground-flat conditions and sparse vegetation along catchment area, namely a row of barren mountains, causes erosion and floods every year (Figure 1).
2. Geomorphology of the Mbay plains is a delta resulting from very flat and deep alluvial soil deposits on some locations make it difficult to flow water by gravity (Figure 2).
3. Lack of maintenance of existing drainage by related agencies or low awareness community to participate in maintaining drainage conditions in their environment (Figure 3).
4. The urban development has led in the land use change, the bare land into built-up area (buildings, roads and other facilities), that make surface and temporary water catchment areas decreasing.
5. Paddy fields apart from being burdened by water and garbage discharges from settlements, and also burdened by sea water intrusion to the rice fields during high tide (Figure 4).

Figure 1. Barren mountains and urban plains (google earth)

Figure 2. Flat and deep alluvial soil deposits (google earth)

Figure 3. Low awareness community to their environments (google earth)

Figure 4. Paddy fields burdened city drainage and intrusion of sea water (google earth)

This problem encourages the application of the right eco-hydraulic concept in water management, thereby ensuring a sustainable water supply.

2. Eco-hydraulic concept

Several literatures related to eco-hydraulics are usually associated with flood management in rivers to improved river banks [2] or eco-hydraulic analysis in flood management in rivers [3]. The eco-hydraulic concept is also used as an effort to overcome erosion that affects coastal areas [4]. From the web page of eco-hydraulic, it has been provided diverse perspectives on what is meant by the term “Eco-hydraulics”[5]. Prof. Sung-Uk Choi from Yonsei University, explain that eco-hydraulics is a study, which attempts to understand ecosystem structure and functions using physical methods, while Dr. Chris Katopodis, explain that eco-hydraulics is the inter-and trans-disciplinary field broadly characterized by the eco-hydraulic trilogy: (1) movements, abilities and passage of aquatic organisms; (2) e-flows, by which it means environmental, ecological or instream flow regimes for aquatic flora and fauna; and (3) restoration of aquatic habitats and ecosystems. Prof. Markus Noack from Hochschule Karlsruhe – Technik und Wirtschaft, explain that eco-hydraulics is a term that developed over time, startin the beginning was focus purely on the coupling of hydraulics with biota, then attempts to bridge the gaps between engineers and biologists/ecologist, until nowadays, the term “eco-hydraulics” is used as a synonym including all interactions between abiotic and biota in fluvial systems, including many different sub-disciplines. Dr. Valerie Ouellet, from University of Birmingham said that eco-hydraulics aims to unravel the links between stream/river ecology (fish physiology and habitat) and the hydrodynamics or related abiotic factor (water temperature). It also needs to look at other variables like the influence of stream geomorphology, local and regional climate, anthropic activities, riparian vegetation, etc., so it is truly an interdisciplinary science.
Prof. Paul Kemp University of Southampton, provided a definition eco-hydraulics is the synthesis of ecology and hydraulics, and as a discipline exists at the interface of the two [6]. This definition can be broadened more generally to include other disciplines that are related to aquatic biology (physiology, population dynamics, and evolution), engineering (fluid mechanics and hydrodynamics), and other physical sciences (geomorphology and hydrology).

Dr. Xiaodong QU, China Institute of Water Resources and Hydropower Research, explain that eco-hydraulics still is not a well-known discipline in China, although it had been used to reduce effects of the dam construction, control the movements of contaminants in the water, and manipulate the habitat restoration of aquatic organisms for the purposes of ecosystems protection and restoration. He cited the most widely used definition of eco-hydraulics in China and try to conclude several quotes from them:

1. The ecohydrology mostly focused on the studies of flow regime at the macroscopic perspective, while eco-hydraulics focused on the studies of flow speed, fluidic characteristics, water depth, water temperature, water quality (contaminant, nutrients, pH, dissolved oxygen, etc.) and sediment (concentration of sediment, substrates) etc.

2. The eco-hydraulics studied the relationships among the hydraulic characteristics, flow, river (stream) and ecosystems for the purposes of restorations of rivers and wetlands.

3. Eco-hydraulics is the interdisciplinary between ecology and hydraulics. The eco-hydraulics studies the relations between flow and aquatic community in the stream, which described the living environment of aquatic organisms and flow condition and could support the living environments.

4. Eco-hydraulics is a developing and new interdisciplinary science that study the inner-relationships between hydraulics and aquatic ecosystems dynamics, the effects of variations of hydraulics on the balance of aquatic ecosystems and biodiversity and also the effects of ecosystems successions on hydraulic regimes. Science recently, mention that eco-hydraulic study including hydromechanics, biology, ecology, environmental sciences and engineering sciences, and also the movement rules of aquatic organisms in the water, and their controlling techniques related with mechanics.

5. Eco-hydraulics is an interdisciplinary including hydraulics, biology, and ecology. Mainly studies related mechanisms of effects of hydraulic condition on aquatic ecosystems and hydraulic controlling techniques for the purposes of sustaining the aquatic ecosystem health. Eco-hydraulics also studies the effects of variations of hydraulic condition on the biogeochemical processes and community composition, habitat distribution and ecosystem functions and the effects of succession of ecosystem on hydraulic regimes.

Eco-hydraulics is one of these emerging fields of research that has drawn together biologists, ecologists, fluvial geomorphologists, sedimentologic hydrologists, hydraulic and river engineers and water resource managers to address fundamental research questions that will advance science and key management issues to sustain both natural ecosystems and the demands placed on them by contemporary society [7].

3. Methodology

The steps taken to find the eco-hydraulic concept in the city of Mbay in managing water that causes disasters can be useful as a source of raw water, as shown in Figure 5. The first step: an overview is needed to explain the general description of the Mbay city. Zoning needs to be done to distinguish the characteristics of each regional zone. The second step: it is necessary to understand the terms of eco-hydraulics, sustainable water management and sustainable water supply as well. Furthermore, it can be found the right innovation to handle the distinctive areas of the different Mbay cities or specific Mbay
city area. Then, it can be explored to find problem solving for the specific Mbay area to lead the sustainable water supply and management, especially for the specific Mbay city area.

4. Mbay city’s eco-hydraulic concept.

In general, the city of Mbay can be divided into 3 zoning, namely mountain areas, lowlands city, and rice fields area (Figure 6).

The basis for the zoning area is the topographic and geomorphological characteristics of the Mbay city, which can be categorized into 3 areas:

1. The barren mountain area, located in the upstream or southern part of the Mbay city, which consists of quaternary and tertiary hills. These quaternary hills are composed of old volcanic rocks, which consist of pumice tuff, sandy tuff, lava andesite, breccias and agglomerates. This area is largely bush forest areas, moor and grasslands, and a small part are settlements. On Tertiary hills have form that make up the landscape from the Kiro Formation in the form of lava andesite, breccia, sandy tuff; and the Nangapanda Formation in the form of sandstone, rocklime with a marl lens. This area is generally overgrown with reeds with nuggetsrock on the surface.

2. A residential plain area located in the middle of the Mbay city area, with rock the constituents of the landscape are generally in the form of loose material, namely alluvium and coastal sediment.

3. The area of rice fields located in the downstream or north of Mbay city, which is coastal areas, with constituent rocks the same as residential plains, in the form of material off, namely alluvium and coastal deposits.
Apart from the above, the division of zoning/handling areas is also based on the land-use function, which can also be categorized into 3 areas (Figure 7):

1. A hilly area in the upstream or southern part of the city, which is mostly in the form of thicket forest, the grass is bare and barren, so it is easy to erode when it rains.
2. A residential plain area in the middle of the city which is an urban and central area government activities, which often occur inundation or flooding due to water surface runoff rain from hilly areas.
3. The area of rice fields in the north or downstream on the coast, which mostly consists of wetland rice-fields with technical irrigation and few settlements. In this area, seawater intrusion has started due to the loss of protection beaches in the form of mangrove forests.

4.1. Management of upstream/hilly areas
To overcome the problem of erosion and large surface runoff in the upstream area in the form of the hills are bare and barren, so an approach method used that slows down the surface runoff and conservation efforts by increasing the vegetation in the hills. The water trap series system can be implemented in this area to slow down runoff and sink the water into the ground so that it become as groundwater recharge (Figure 8). As for the way the vegetation is applied with the fish scale hole system applied to this upstream area (Figure 9). This system allows water to infiltrate the soil through the holes made, so that it can provide water availability for the plants planted in these holes, besides the availability of water is also expected from the water trap series system applied. These ecology and hydraulic, eco-hydraulic, action give the available water to meet the raw water requirement, and lead the supply and management water sustainability.

4.2. Central area/plains settlement management
To solve the problem of residential plains in the central region which is an area urban and central government activities, which waterlogging or flooding occurs frequently due to runoff surface of rainwater from hilly areas, so the handling is simultaneous between treatments the upstream area is
hilly and the middle area is handled with the concept of eco-drainage. Handling of the central area or settlement plains is carried out using 2 approaches:

1. A physical engineering approach, namely the hydraulic structures approach in the form of a drainage network. These network support by retention ponds/city’s lake of an area concept, as well as rainwater harvesting structures on a household scale (Figure 10).

2. Non-physical approach in the form of local policies/regulations.

![Figure 10. Several kinds of city lake / retention pond constructions](image)

The hydraulic action cope the inundated water in the lowland city, and also give the available water for other option, so also leads the supply and management water sustainability.

4.3. Handling of downstream/rice fields and beaches

To overcome the frequent problems of rice fields in the downstream coastal and coastal areas experiencing seawater interference, the handling is simultaneous between the handling of the upstream area in the form of hills and handling in the central area with the concept of eco-drainage, as well as handling in the area downstream with a fish skeleton long storage system or a fishbone-shaped storage system. This reservoir is intended to control the return flow of sea water when there is a tidal wave, so that this water does not interfere with the irrigation system in rice-fields. Storage construction fishbone is described as in Figure 11. This construction is applied accordingly with the conditions of the materials available in the field.

![Figure 11. The construction of the reservoir extends the fishbone concept](image)

The rice fields are protected from disturbance of the entry of sea water into the rice fields by constructing a channel that can also function as a long-storage from the effects of sea water flow into the rice fields due to the influence of rising tides, and the construction of storage ponds can also function as brackish fish farming. These lead the supply and management water sustainability.

5. Conclusion and recommendation

From the tree option handling in upstream/hilly areas, centre area/plain settlement management, and downstream/rice fields and beaches, lead the supply and management water sustainability. Finally, it
can be said that the integrated handling of ecology and hydraulics (eco-hydraulic) concepts has made the city of Mbay able to manage and supply water in a sustainable manner.

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