Physics and Chemistry of the Earth 33 (2008) 695–700

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Eco-hydrology of the Pangani River downstream of Nyumba ya Mungu reservoir, Tanzania

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ARTICLE INFO

Available online 10 July 2008

Keywords:
Flow duration curve
Hydraulic parameters
Microhabitat
Ecohydrology
Physical habitat

ABSTRACT

Eco-hydrological studies are highly emphasized worldwide at the moment especially where hydraulic structures such as dams are concerned, mainly focusing on benefiting both humans and existing ecosystem for the present and future generations. The study at Pangani basin was aimed at assessing the sufficiency and the amount of flow reaching the downstream area of the Pangani River for maintenance of ecosystem. Fish species were considered as the indicators for ecosystem health.

Flow duration curves (FDC) and hydrographs were developed by using the collected historical daily flow data and used for assessing the flow variation before and after Nyumba ya Mungu (NYM) dam construction. The results showed that there is no seasonality and that for most part of the year the flow is within 20–40 m^3/s. From the comparison it was found that there is 42.7% decrease in Q_5, 2.1% decrease in Q_{95}, 38.9% increase in Q_{75}, 23.4% increase in Q_{50} and decrease of percentage exceedence of 50 m^3/s by 61.5%. Physical habitat simulation model (PHABSIM) was used for hydraulic simulation incorporating geometric and flow data collected in the field. From the simulations minimum flow for habitat protection is about 15 m^3/s and for flood formation flows should be greater than 50 m^3/s. Thus the required reservoir outflow for sustainable water resources management at the NYM should follow the above specifications.

1. Introduction

Eco-hydrology defines new approaches to freshwater protection, restoration and management, thus one increases opportunities for ecosystems maintenance. Eco-hydrological studies on river systems have two main purposes: first, they are used to develop an understanding of the relationship between the various parts of a river ecosystem (channel, wetlands and floodplains, banks, groundwater, estuary; and their plants and animals (the biota)) and flow; and secondly, they are used to advise management on how flows can be manipulated for offstream purposes whilst holding changes to the river within acceptable limits (King, 2007). Recently there is an increasing number of countries such as South Africa which have engaged in eco-hydrological studies successfully within Africa, but in Tanzania it is still a new concept being applied recently in some rivers. In the Pangani basin as a result of the Nyumba ya Mungu (NYM) dam construction in mid 60s a number of researchers such as (MoW, 1996; PBWO/IUCN, 2007) have commented on the effects to the aquatic ecosystem as well as the environment downstream. Hence the rising need for this eco-hydrological study which is done by determining flow variation assessments before and after the dam construction, and also hydrological and hydraulic features of Kirua swamp area, in order to know the sufficiency of the controlled releases for maintenance of ecosystem in comparison to when the flow was natural.

2. Description of the study area and methodology

2.1. The study area

The Kirua swamps are located between Latitudes of 4°07′–4°34′S and Longitudes 37°26′–37°44′E within the Pangani basin just downstream of NYM dam. The dam is one of the most important man-made regulating reservoirs on the river, which started operation in 1968 incorporating a power plant with a capacity of producing 8 MW and ever since the flow downstream has been controlled. The swamps were estimated at 90,000 ha by Ivo-Norplan (1997) and it is said to have decreased to 36,500 ha (IUCN 2, 2006). Downstream of the dam there is a gauging station 1D8C serving the inflow into the swamp area. Fig. 1 shows the study area within the Pangani basin, the gauging stations and the layout sketch of site selected.

2.2. Methodology

In addressing issues of Eco-hydrology so far there is no recommended specific method but a number of them and each having one thing more or less than the other, with varying demand for

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doi:10.1016/j.pce.2008.06.054

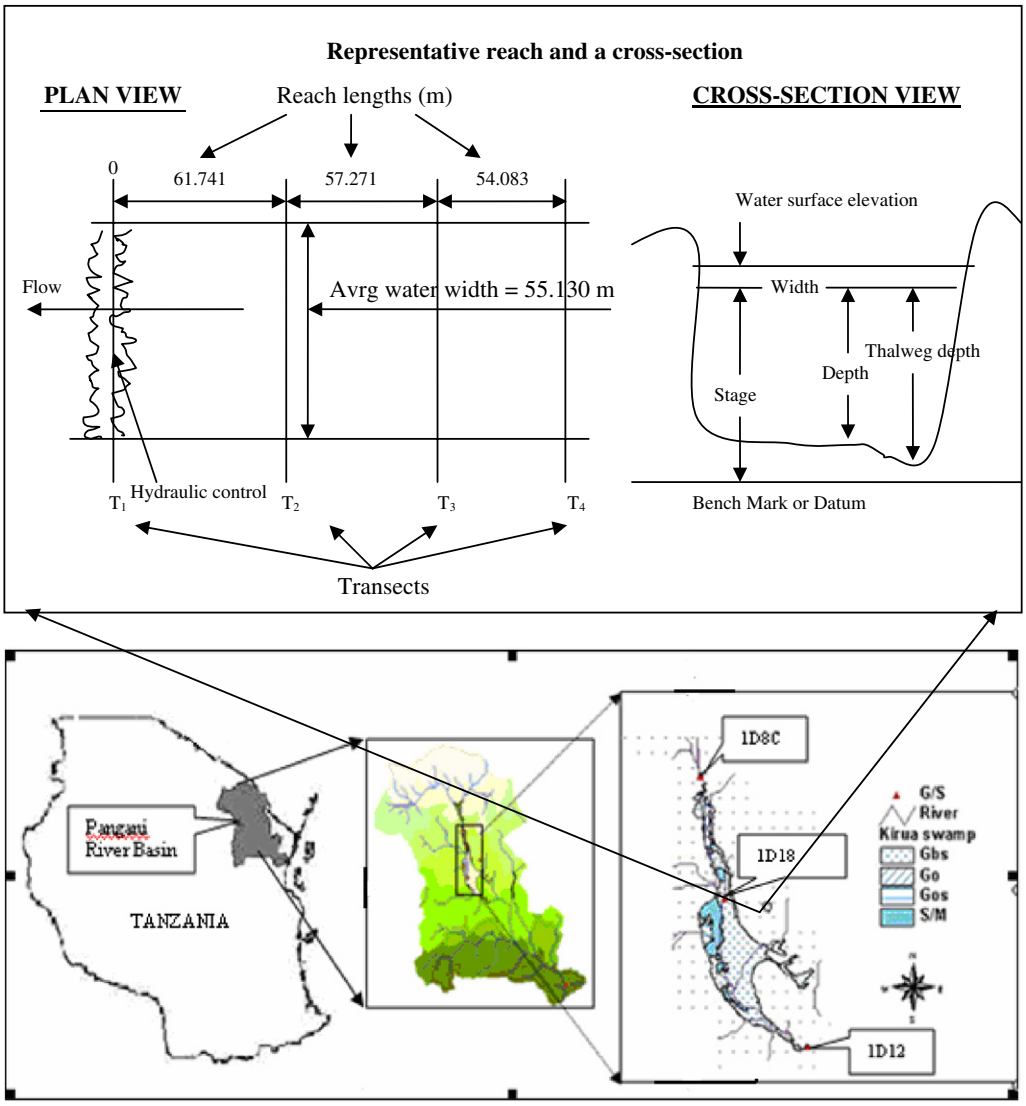

Fig. 1. Map of Kirua swamp system. G/S = Gauging Station; Gbs = Bushed grassland seasonally inundated; Go = Open Grassland; Gos = Open Grassland seasonally inundated; S/M = Permanent Swamp/Marsh. (Source: Modified from Moges, 2003).

data and time. These methods as stated by King et al. (2000) can be categorized into hydrological methodologies, hydraulic methodologies, habitat simulation methodologies and holistic methodologies.

The criteria for selection of methodologies were to capture the trend of flow variations with time; relate hydraulic parameters at present to ecology; limited field data; rapidness and effectiveness; and inexpensive. Thus in this study we settled for hydrological and hydraulic methodologies, with fish as species of ecological importance.

2.2.1. Hydrological methodologies

There are numerous methodologies that rely primarily or solely on hydrological data for deriving environmental flow recommendations, requiring only historical flow records. Also they are highly appropriate at the reconnaissance level of water resource development and for planning purposes, providing routine, yet low resolution estimates of quantities of water to be set aside for environmental maintenance. Such methods include Tennant method (or Montana method) according to Tennant in King et al. (2000) and flow duration curve analysis (FDCA).

Flow duration curves display the relationship between discharge and the percentage of time that it is exceeded. Where historical flow records are analysed over specific durations in FDCA, according to Gordon et al. in King et al. (2000), FDCs are used to derive specific flow percentiles (percentage exceedance values) associated with required suitable river conditions, often in combination with professional judgement, to produce environmental flow recommendations. Most recent methodologies based primarily on hydrological indices, also incorporate biological criteria in some instances (King et al., 2000).

Weaknesses of hydrological methodologies are: from ecological perspective is that it does not adequately address the dynamic and variable nature of the hydrological regime and also due to lack of ecological information as input, professional judgement is essential when these methodologies are employed.

The collected historical flow data were daily series from 1957 to 1994 for 1D8C. The data were then split into two groups representing natural and modified flow regime i.e. 1957–1967 and 1969–1993, respectively with highest flow of 255 m^3/s and lowest 2 m^3/s. Thus the FDC and hydrographs were developed for comparison between natural and modified regime (controlled releases).

2.2.2. Hydraulic methodologies

Hydraulic rating methodologies can be considered as an advance over purely hydrology based ones because they incorporate