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Estimation of Open Channel Roughness by using Gradual Varied Flow Profiles

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Abstract

Open channel flow parameter estimation is an inverse problem, which involves the prediction of a function within a domain, given an error cri! Terion with respect to a set of observed data. Various numerical methods have been developed to estimate open channel flow parameters. For this study, Genetic Algorithm optimization technique is selected. Because of its inherent characteristics, genetic algorithm optimization technique avoids the subjectivity, long computation time and ill-posedness often associated with conventional optimization techniques. An accurate estimation of roughness coefficients is of vital importance in any open channel flow study. In flood routing in natural rivers, most channels have compound sections and the roughness values in main channel and flood plains are usually different.

In order to have more accurate results, the roughness of main channel and flood plains should be considered separately. It is possible to identify the values of roughness using optimization methods. However, studies on the inverse problem of estimating roughness values in compound channels are still limited. The present study involves estimation of open channel flow parameters having different bed materials invoking data of Gradual Varied Flow (GVF). Use of GVF data facilitates estimation of flow parameters. The necessary data base was generated by conducting laboratory experiments in Hydraulics Lab of civil Engineering at IIT Roorkee. In the present study, the efficacy of the Genetic Algorithm (GA) optimization technique is assessed in estimation of open channel flow parameters from the collected experimental data.

Computer codes are developed to obtain optimal flow parameters Optimization Technique. Applicability, Adequacy & robustness of the developed code are tested using sets of theoretical data generated by experimental work. Estimation of Manningâ€™s Roughness coefficient from the collected experimental work data by using Manningâ€™s equation & GVF equation were made. The model is designed to arrive at such values of the decision variables that permit minimized mismatch between the observed & the computed GVF profiles. A simulation model was developed to compute GVF depths at preselected discrete sections for given downstream head and discharge rate. This model is linked to an optimizer to estimate optimal value of decision variables.

The proposed model is employed to a set of laboratory data for three bed materials (i.e., d50=20mm, d50=6mm and lined concrete). Application of proposed model reveals that optimal value of fitting parameter ranges from 1.42 to 1.48 as the material gets finer. This value differs from the currently documented value i.e. 1.5. The optimal estimates of Manning€™s n of three different bed conditions of experimental channel appear to be higher than the corresponding reported /Stickler€™as€™ estimates.

Keywords: Estimation of open channel roughness; GVF profiles; Parameter estimation; Optimization methods; Manning€™s roughness coefficient

Introduction

Ethiopia is situated in the horn of Africa, and is bordered by Sudan, Kenya, Somalia, Djibouti and Eritrea. The surface area is more than one million square kilometers and the country stretches from latitude 3° North to latitude 15° North of the equator and from 33° East to 48° East longitudes MoWR [1]. It has a large population of approximately 77.1 million people with an annual growth rate of 2.4% FAO [2]. The country has nine regional governments, Tigray, Afar, Amhara, Oromia, Somalia, Benshangul-Gumuz, Southern Nations Nationalities and Peoples, Gambella, Harari and two city states Addis Ababa and Dire Dawa. Ethiopia belongs to one of the poorest African countries, with 52% of the population living below the national poverty line MoWR [1] and 31.3% of the population living below US$1 a day World Bank [3,4].

Eighty-five percent of the population of Ethiopia depends directly on agriculture for their livelihoods, while many others depend on agriculture-related cottage industries such as textiles, leather, and food oil processing. Agriculture contributes up to 50

percent of gross domestic product (GDP) and up to 90 percent of foreign exchange earnings through exports Davis et al. [5]. It is widely believed that Ethiopia has ample resources for agriculture. The country has 111.5 million hectares of land. While 74 million hectares are arable, only 13 million hectares are currently being used for agricultural activities Abate [6]. Water resources are also plentiful in many parts of the country. Referring to the 2007 Housing and Population Census of Ethiopia. Abate [6] pointed out that there were about 12 million farm households providing human resources for agriculture and related activities. Ethiopia's livestock resources are among the top in the world, at least in terms of quantity. The country also has a high level of biodiversity, with several different economically important crops indigenous to the country.

It is known that the Southern Nations and Nationalities Regional State (SNNRS) have abundant land and water resources that can be used for irrigation development. Encouraging efforts have been done by Government and non-government organization to introduce irrigation development activities. Irrigation development plays an essential role in stabilizing crop production by either supplementing or replacing the need for natural precipitation. Irrigation makes agriculture more confidential. It stabilizes crop production by protecting against drought and by increasing crop yields, increases their income and crops that improve their diet Ebissa GK [7].

The proposed project of Gondoro diversion weir irrigation is predicted to bring both beneficial and adverse impacts on physical, biological and socio-cultural environment. Although the implementation of Gondoro diversion weir irrigation project has many benefits, obviously it will also bring a number of adverse impacts to the physical, biological and socio-cultural environment. Generally, the potential positive and negative impacts as well as the environmental mitigation measures of the irrigation project depend on:

a. Nature and types of the proposed irrigation project.

b. Environmental baseline condition of the project area i.e. the physical, biological and socio-cultural environment.

c. Environmental health condition of the project area.

d. The technological option adopted.

e. The legal, institutional and policy framework.

f. The environmental condition of the downstream.

Objectives

The aim of this study is to assess Environment Impacts and their mitigation measures. Major positive and negative impacts of this project during construction and operation phases as well as possible mitigation measures are briefly included in this study. Therefore, the main objective of this paper is to present a simple and unified framework along with examples and applications so that it can be accessible to a broader audience in the field.

Study Area

The Gondoro diversion project is located in the Omo-Gibe basin which is found in the southern part of Ethiopia. The area has high potential water and land suitable for irrigation development. The average altitude of the watershed of the diversion site is 2132 meters masl whereas the average elevation of the command area is 1900m. The entire watershed lies in Adiyo Woreda. The command area also lies within this woreda. The small scale irrigation project is anticipated by diverting water from Gondoro Stream which is a tributary of Gojeb River that eventually drains to the Omo-Gibe River. The catchment area of the Gondoro watershed at the diversion site is 10.5km^2. The maximum length of the river up to the diversion site is about 9.6km. The elevation of the river center at the diversion site is 2132 meter alms. Ebissa GK et al. [8].

Methodology of the Study

The methodology used in this assessment study was aimed at plainly defining and describing the environmental impact situation of the area and out lining the major environmental impacts and developing recommendations for implementation. Primary and secondary data were collected from the Kebele development agents, farmers and Wareda agricultural and development office using checklists through group discussion and key informant interview positive environmental impacts, negative environmental impacts and their mitigation measures.

Results and Discussions

Potential positive impacts of gondoro diversion weir irrigation project

Regardless of some adverse impacts, the project will have various positive impacts and benefits to the social, ecological and physical environment. The positive impacts that are assessed to be expected after the implementation of the Gondoro diversion weir irrigation project are the following

i. Increase in agricultural yields and production, generating additional revenues directly from the project output.

ii. Crop diversification. The introduction of irrigation enables farmers to diversify their crops based on local markets demand and export.

iii. Employment opportunities: during the construction phase there will be improved employment opportunities for local people and new comers.

iv. The project will provide water for cultivation of crop, irrigated fodder development, domestic purpose, livestock etc.

v. Food security further improved. In this case, the proposed small scale diversion weir irrigation will have a paramount importance in further improving the overall living conditions of the people residing in and around the

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project environment and will plays its own role in alleviating food shortage at the Kebele and woreda level.

vi. Improved forage varieties provided and increase animal productivity and production.

vii. Increase the opportunities to nursery site establishment, and forest seedling production and forest tree plantation.

viii. Mitigation of drought syndrome. Implementation of the project will be a means for drought syndrome.

Impacts During Construction Phase and their Mitigation Measures

Biophysical environment

Impacts on soil erosion

The main activities that will disturb the topsoil and subsoil, and exposed to erosion will be construction of canals, drains, headwork structures (diversion weir) and quarrying to obtain construction materials. Main Canal and other canals construction aggravate soil erosion due to its effects in diverting and concentrating runoff water, and creating larger water harvesting areas. Soil erosion can be more serious along the main canal alignment where considerable cut and fill works are involved. Specifically, construction of canals for this irrigation scheme will enhance soil erosion mainly due to:

i. Cutting into the soils and rocks as well as clearing of the protective ground cover to construct the canal.

ii. Construction of cut off drains above the main canal to prevent from erasing the canal itself.

iii. Runoff flow collected from slopes and concentrating at the canals can cause remarkable soil erosion especially on hilly and undulated command areas especially if the rains commence before the accomplishment of the construction phase.

iv. Inappropriately disposed materials i.e. cutting of top soils is easily washed away by running water.

v. The design and construction of this irrigation project should integrate prevention and mitigation measures to reduce soil erosion and adverse impacts on soils. These are.

a) Minimize the area of ground clearance i.e. land clearing for headwork and canal construction should be restricted to what is absolutely necessary for the headwork and canal construction. Clearance and cutting into the soil outside the cleared width and the selected material sites should be avoided as far as possible.

b) Replanting right species of trees, shrubs and grasses in a right time on disturbed areas by headwork and canal construction, gullies, and erosion prone areas.

c) Excavated top soils or loss soils cut-off from the canal and selected material sites should be collected and preserved for reuse particularly clay soils for lining of canals and others for filling of gullies, borrow and quarry sites.

d) Control the volume, location and speed of water flows in the vicinity of exposed soils and slopes by providing with cut off drains to catch water before it reaches critical areas (gullies, and erosion), and diverting drains that can avoid excessive concentration flow and energy dissipation structures designed to slow fast running storm water in drains and by doing this reduce its downstream erosive potential.

e) Make allowance for seasonal climatic variations particularly rainfall and adjust the construction program accordingly. Cuts on erodible surface should be properly executed during dry season i.e. before the summer rains commence.

Impacts on water resources

The head work construction will modify the natural flow of the Gondoro River. Depending on local conditions especially in mountains and hilly areas, these changes can contribute to stream bank erosion, flooding, channel modification and siltation of streams and rivers. Apart from the modification of the natural flow, the existing and possible water pollution sources during the construction period are:

(a) The excavation of the earth,

(b) The handling of construction materials, especially the concrete.

(c) Organic or toxic pollution, as a result of oil and oil products leakage.

Abstraction of water from rivers for irrigation project construction may affect the daily demand for animal and ecological services.

In summary, the possible preventive and mitigation measures to minimize water pollution and conflicting demands include:

i. Carry out soil conservation measures.

ii. Run off from the vicinity of crushing plant, quarry and construction lay down area should be collected and treated as required.

iii. Avoid the risk of pollution to surface and groundwater.

Impacts on flora and fauna

The proposed main canal alignment passes all through cultivated land, grazing land, shrub land and barren lands. The main canal alignment does not intersect with natural or plantation forest. Therefore, no large natural trees that will be affected by the main canal or the head work structures. In general, the main canal alignment does not intersect a habitat that can provide protection for wild animals. During construction phase, apart from deforestation the operation of various construction equipments and vehicular movements are likely to generate noise.

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These activities will lead to some disturbance of wild life population. Since natural forest area of the watershed that rich in wild animals is located near to the headwork area and will be disturbed by noise and dusts generate from headwork construction activities. But in this case, so long as it is a small scale irrigation project, construction equipments that will generate maximum sound will not be utilized.

The design and construction of this irrigation project should integrate prevention and mitigation measures to reduce or avoid the impacts of flora and fauna. These are:

i. Locate the project (the head work and canal construction) from environmentally sensitive areas such as priority(protected) forest and grazing lands(wetlands).

ii. Avoid the extraction of stone, sand, gravel etc from forest areas and river bottom.

iii. Minimize the area of ground clearance i.e. land clearing for headwork and canal construction should be restricted to what is absolutely necessary for the headwork and canal construction.

iv. Avoid the use of dynamite/explosive particularly at the headwork area since the natural forest at the watershed, the home of wild life, located above the headwork may be disturbed by the noise.

Impacts on aquatic environment

Impacts to the aquatic environment from the construction phase will result from headwork structures (diversion weir) installation and diversion structures in bypassing river flow. Locally, this will result in some loss of aquatic habitat and organisms at the headwork structures (diversion weir). As no migratory fish species are present in the rivers project area, due to their location, no significant impacts to fishery aquatic resources are anticipated. The dredging and deposition of dredged material is likely to affect the survival and propagation of micro benthic organisms. The macro-benthic life which remains attached to the stones, boulders etc. gets dislodged and is carried away downstream by turbulent flow. The areas where construction materials would be excavated, the benthic fauna will get destroyed. In due course, the area would however, get re-colonized, with benthic fauna. The density and diversity of benthic fauna, is however, much less than with the pre-dredging levels. Mitigation measure to reduce impacts on aquatic environment.

i. Minimize the dredging of materials (basaltic river blocks, boulders and cobbles) i.e. the amount of dredging materials should be restricted to what is absolutely necessary for head work structure.

Impacts on air quality and noise

The major effects on air quality and noise during the construction phase of this irrigation project will be impacts due to vehicular movement, an emission from various crushers, noise and vibration, and impacts due to operation of construction equipment. During construction phases of this irrigation project, there will be vehicular movement for transportation of various construction materials to the project site. Large quantities of dust and traffic problem are likely to happen due to movements of vehicles. Noise from construction equipment and vehicular movement will affect nearby residents and schools because the irrigation project site is nearby from settlement area. The operation of the crusher during the construction phase is likely to generate fugitive emission. In addition to these, during construction operations both mobile and stationary equipment such as grader, concrete mixers and air compressors can generate noise in excess of the above noted guideline. Mitigation measure to minimize impacts on air quality and noise.

i. Reduce noise at the source to minimize its effects on wildlife and people living along or around the project.

ii. Materials will be stored in appropriate places and covered or sprayed to minimize dust.

iii. Since it is a small scale irrigation project using hand hammer.

iv. Construction activities will be scheduled carefully to minimize noise impact from construction machinery. Night time & use of noisy machines will be prohibited.

Impacts on quarry and borrow pits

Extraction of materials from quarries/borrow pits involve site clearance and movement of large construction materials from local sources to the construction sites, and will result in significant quantities of wastes or eroded materials, and possible changes in topography or ground surface relief features. In this project, the source of dimension stone and coarse aggregate is from the river bank. Additionally site soil compaction is selected. The site is a private farm land of four household.

Thus, the impact would be to forgone the crop product obtained from the land, potential soil erosion and where the excavated pits are deep they present a risk to animals. Impacts of Quarry:

i. The extent of each pit quarry should be clearly marked on the ground.

ii. Filling excavated top soils or loss soils cut-off from the canal and leveling of the exploited blocks before abounding the used quarry.

iii. In order to minimize the effect of flood and erosion the surface rainwater has to be diverted through appropriate ditches or channels above the quarry. It is recommended that, above the quarry, the ditches of about 0.7m wide and 0.6m deep has to be constructed and lined with clay in the points where erosion pressure is strong.

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iv. To minimize the erosion effect, plantation of trees and grasses that provide anchoring effects against water runoff.

Impacts on socio-economic environment

Loss of usable lands: The main canal alignment from the headwork up to the end is cultivated lands used to grow different annual crops. Some cultivated, and shrub land will be taken up by the proposed irrigation project main canal alignment. Those shrub lands are usually communal properties as well as the owners are direct beneficiaries of the project and so long as the project is primarily for serving the local community, there will be no direct compensation for loss of cultivated land and shrub land. The farmers were also interested to forgone their pieces of land touched by the canals without any compensation.

Impacts on sites of cultural and religious values: The construction of the proposed irrigation project will not cause adverse impact on cultural, religious and other environmentally sensitive areas.

Impacts on public health and sanitation: Even if the size of the project is small; experiences from other construction sites indicate that a large work force dominated by single men will attract women to the area for several purposes. This can lead to the aggravation of the prevalence of sexually transmitted diseases (STDs). In this case, if the contractor employee's migrant daily laborers, the spread of sexually transmitted diseases will be high in the project area.

Some of the mitigation measures for impacts associated with health and sanitation following the construction of the project include:

i. Employ the local people for labor work purpose.

ii. Provision of health education including sex education.

Environmental Impacts Forecast for Operation Phase and their Mitigation Measures

Impacts on biophysical environment

Impacts on soil resources

This project may cause soil degradation particularly if the irrigation operations are non-conservation base. Acidification, organic depletion, compaction, nutrient depletion, chemical contamination, and erosion are all forms of soil degradation that can be brought about by inappropriate land use practices. As soil degradation develops, land productivity starts decline and in extreme cases it can stop nearly all plant growth. As it was mentioned in the baseline condition of the project area (land degradation part), soil losses and land degradation were not a problem in the catchment since the population pressure is less as a result the catchment is still densely covered by forest. During the operation of this project, soil loss and land degradation problems will be aggravated at the command area. As it was indicated in the baseline condition, top (plough layer) of the soil has showed the indication of acidic soils. This problem would likely to be aggravated during irrigation operation.

Mitigation measures effective in reducing adverse impacts on soil resources are:

i. Replanting right species of trees, shrubs and grasses in a right time on disturbed areas such as canals and cut off drains. It is proposed to develop plantation on both sides of the main canal. Thus, nursery should be developed one year ahead of the actual schedule of the plantation. Grass species and trees/shrubs up to a height 3m should be planted where canal passes through cultivated land.

ii. Biological and physical conservation measures. For the time being, naturally well treated. However, this should be kept sustainably. This will be achieved through local community participation and kebele environmental protection committee.

iii. To reduce soil acidity, reduce the addition of artificial chemicals and adding alkaline substances like lime.

iv. Planting leguminous plants to improve soil structures and nutrient.

v. To reduce stream bank erosion, leaving at least 20m buffer zones of undisturbed vegetation between the site of the project (command area) and water body (River bank of Gondoro).

Impacts on water resources

During the operation of the project, the command area may have non-point sources of pollutants including nutrients (particularly nitrogen and phosphorous), sediment and pesticides on water sources. These crop farm pollutants may inter to the surface water through direct surface run off or through seepage to ground water. Moreover, sediments produced by farming induced erosion can often transport excess agricultural chemicals resulting in contaminated run off, which in turn affects aquatic habitat. The main source of excess nutrients in surface water from non-point sources of this project expected to be chemical fertilizers. Pesticides used for pest control in agricultural operations can also contaminate surface as well as ground water resources.

Conclusion

This study was carried out to assess Environmental Impact Assessment and their mitigation measures. The proposed project of Gondoro diversion weir irrigation is predicted to bring both beneficial and adverse impacts on physical, biological and socio-cultural environment. Although the implementation of Gondoro diversion weir irrigation project has many benefits, obviously it will also bring a number of adverse impacts to the physical, biological and socio-cultural environment.

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EIA certainly has a crucial role to play in addressing environmental issues surrounding project development and especially irrigation projects. The integration of environment into development planning is the most important tool in achieving sustainable development. Environmental protection and economic development must thus be dealt with in an integrated manner. EIA process is necessary in providing an anticipatory and preventive mechanism for environmental management and protection in any development. Several developing countries are still at the infancy stage of operationalization of their EIA processes. The need for capacity building for quality EIA is also eminent in these countries. Despite these small setbacks, environmental impact assessment has become an integral part of project planning one, which is continually being improved for posterity

Generally, the potential positive and negative impacts as well as the environmental mitigation measures of the irrigation project depend on.

a. Nature and types of the proposed irrigation project.

b. Environmental baseline condition of the project area i.e. the physical, biological and socio-cultural environment.

c. Environmental health condition of the project area.

d. The technological option adopted.

e. The legal, institutional and policy framework.

f. The environmental condition of the downstream.

After assessing the environmental impact, the project is found to be environmentally non degradable, technically appropriate, economically viable and socially acceptable [9-51].

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