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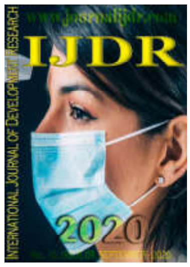

RESEARCH ARTICLE OPEN ACCESS

TO STUDY REJUNEVATION OF RIVERS AND STORM WATER MANAGEMENT

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ABSTRACT

Our vision is to scale up this inspiring body of work to develop a collective approach to river rejuvenation that focuses on addressing the needs of the entire eco-system. A multi-stakeholder approach provides a practical framework to integrate all these different pockets of development into a larger picture for maximizing their impact. In fulfillment of its agreement with the Government of India, a Consortium of 7 IITs ("Indian Institute of Technology"s) had prepared the Ganga River Basin Management Plan (GRBMP) and submitted it to the National Mission for Clean Ganga (NMCG), Ministry of Jal Shakti (then Ministry of Water Resources, River Development and Ganga Rejuvenation), Government of India in the year 2015. The GRBMP recommendations were to some extent broad-based strategic measures, but they included some detailed ready-to-implement actions. There was, therefore, a felt need to have substantial further inputs to the Plan that addressed several other specific issues for comprehensive, policy-driven and technology-based solutions for the restoration and conservation of River Ganga and other rivers of the country. The Centre for Ganga River Basin Management and Studies ("cGanga") was hence created through a Memorandum of Understanding between Ministry of Jal Shakti (then MoWR, RD & GR), Government of India and IIT, Kanpur in April 2016. The main objective of cGanga was identified as Continual Scientific Support in the Implementation and Dynamic Evolution of the Ganga River Basin Management Plan. In fulfilment of its objective, cGanga has been conducting many field and in-house studies as well as workshops and consultations with various stakeholders, executive bodies, monitoring agencies and experts on various components of GRBMP and its implementation. Based on these activities over the past few years, a clearer understanding emerged on some of the major implementation challenges of GRBMP. This led to a more refined and detailed strategic implementation procedure that combines robust scientific method with a socio-economic and administratively aligned policy framework as presented in this document. The present manual attempts to describe in a concise manner the background, objectives, vision, knowledge-framework, methodology, governance principles, restoration strategy, monitoring, feedback and correction mechanisms, and financial management of the river restoration and conservation plan. The document is intended to act as both a guide for the non-specialist reader or stakeholder as well as a broad instruction manual for specialized government / implementing agencies who may need to take account of significant variations in physical and social particulars of river basins in implementing the restoration plan successfully. The preparation of this report was enabled by the various studies, surveys, analyses, and discussions carried out by dedicated members of the cGanga team. In addition, key stakeholders, experts and community representatives of many river basins interacted with cGanga members and gave their valuable inputs unreservedly on many aspects of the present document.

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INTRODUCTION

The Rivers are the lifeline of civilization not least the Indian civilization. For not only do rivers provide freshwater, food, energy and other valuables to humans, they also receive, purify and carry away wastewaters and provide economic means of transport by navigation. And, while in normal times rivers are pleasant and fascinating to humans, they can also bring widespread death and destruction when they overflow with flood fury or suck away the hopes of life from parched lands when reduced to a trickle. Rivers are thus dynamic actors on landscape scales matching human actions in their scope of spatial influence and impact. The degradation of rivers in modern times has, therefore, had equally far-reaching – and at times cataclysmic – consequences on humans, with unexpected floods, droughts and water-borne diseases being the most common disasters caused by distressed rivers. The restoration and conservation of rivers is therefore of utmost importance for sustaining humanity and ecology through present and future generations in India. Large rivers are formed by the coming together of smaller lower order rivers – the tributaries – like the tertiary and secondary roots of trees joining in stages to form the primary roots that support entire trees. The lower order tributaries – like the tertiary and secondary roots of trees – are therefore of crucial importance in maintaining the health of rivers. They not only feed water, nutrients and sediments, but also significant biodiversity into higher order tributaries and the main stem of the river. It is not surprising, therefore, that river degradation often begins in the smaller tributaries, especially those flowing through or near urban settlements. The Committed and Focussed Approach River rejuvenation efforts in India have often focused on large rivers as a whole, but have failed to make much headway, partly because the task is too enormous to be grasped in its entirety and carried out cogently within a limited time span. Not only is the river too large to be observed and monitored comprehensively, the anthropogenic factors affecting the river are also often too diverse and unevenly distributed across the river basin. The task becomes much simpler when the effort to reverse the degradation process is focused on the smaller urban and semi-urban tributaries/drains, especially those that are perennial or can be easily made perennial. The latter includes the natural storm water drains that often function at present as wastewater "nala"s in the cities, but which can be easily converted to perennial water bodies by supplying them with treated wastewater round the year. The multiple benefits accruing from such rejuvenation – economic, environmental, aesthetic and cultural – are also immediate, and they impact large population groups which canvendor management system is for supporting the good quality of material, delivery on time, good service and cooperation, reasonable price, strong and close relationship to continuous improve, etc.

RESEARCH OBJECTIVES,SCOPE AND LIMITATIONS

In the light of the preceding discussions, the prioritized objectives of a River Basin Organization for the present approach may be summarized as follows:

Health of River to ensure that the river or natural water course is restored and maintained as a perennial river. This involves at least the following measures:

As custodians of rivers, RBOs must themselves develop their own understanding and information base about the rivers, and communicate and negotiate on the needed restoration measures with stakeholders.

- Assured clean water (or uncontaminated water) input to maintain the minimum desirable flows round the year.
- Maintaining adequate width and depth of flow suitable for aquatic life by way of structural interventions (like weirs and bunds) if needed.
- Preventing the influx of wastes and pollutants.
- Protecting physical integrity of the river and floodplains.

Conformity with local Ecology and Environment, such as:

- Connectivity with local water bodies.
- Unblocked natural drainage routes.
- Reducing catchment runoff rates to enhance groundwater recharge.

Maximizing Benefits from River, such as:

- Surplus water storage for human use.
- Fish and other aquatic cultivation.
- Tourism & Recreation.
- Navigation & Transport.
- Increased public revenues from river-centric activities.

Minimizing Damages or Losses due to River, such as:

- Minimizing Flooding and Water-logging.
- Land Reclamation.

Enhancing Benefits for Downstream Regions, such as:

- Improved Water Quality downstream.
- Improved Biodiversity downstream

Significance of The Study

The framework is significant in several ways.The restoration measures needed comprise comprehensive measures not only for the river but also for the floodplains and the entire catchment or watershed. Thus, attention should be paid on all aspects, namely:

Input Water Quality: A Four-Stage Water Quality Improvement Cycle is proposed as shown in the adjoining figure for municipal, industrial, commercial and agricultural-returned flows management so that the freshwater body receiving the water is not only ecologically and aesthetically satisfying, but is also a reliable source of water for human use. Thus, while Primary (and, where possible, Secondary) Treatment of municipal sewage ensures significant removal of organic and inorganic wastes, phyto-remediation of the ensuing wastewater in Wetlands removes and hydrologically connected to other water bodies in their neighbourhoods. Thus, ensuring the sustenance of and connectivity with other water bodies (including groundwater) in the region is of importance.

River-Related Infrastructure: Some structural interventions may be necessary to ensure the functioning of the river as a secure perennial river without obstructing terrestrial activities. Thus, for instance, weirs may be needed in river stretches with steep gradients to provide the necessary flow depths or flow velocities needed for river biota; or, embankments may be needed in regions that are susceptible to flooding during heavy storms; or bridges may be needed to secure river crossings for human and terrestrial animals.

Restoring/ Developing Aquatic and Terrestrial Biota: Both aquatic and terrestrial flora and fauna are essential for healthy rivers and their catchments. In catchments natural vegetation, in particular, helps in recharging water both in soils and in groundwater as well as in runoff purification; Hence efforts may be desirable to generate and maintain adequate levels of natural vegetal cover in the basin.

Likewise, adequate levels of aquatic flora and fauna should be maintained in the river and water bodies by controlling over-exploitation of biotic products and seeding with suitable species where needed.

Continuous Records: A complete inventory should be kept of all changes made and/or observed in the river and its basin (including key monitoring indicators) during the restoration-conservation period. These records will not only help assess the progress and success of the efforts, but can also help in overcoming unexpected obstacles in the progress as well as in implementing similar programmes in other river basins

River definition: River is a natural stream of fresh water that flows into an ocean or into a land locked water body and is usually fed by small streams (called tributaries). The tributaries join the main river, during its onward journey, forming a drainage basin. The drainage basin collects available runoff and ground water (GW) discharge. Continuous optimum flow is an inbuilt quality of a healthy river system. Perennial healthy river is a living eco-system. River can also be defined as is a hydrological, geomorphic, ecological, biodiversity rich, landscape developing natural system that plays key role for the freshwater cycle, balancing dynamic equilibrium between snowfall, snow-mass (including glaciers), rainfall, surface water, ground water and providing large number of social and economic services to the people and serves ecosystems in its watershed.

Natural responsibility of a river system: The natural responsibility of a river system is multifarious. The run-off uses the river course for its onward journey. The moving waters perform two functions. Under the first function, the moving water dissolves the soluble compounds and lifts loose material (rock fragments and soil etc). Under the second function, the running water transports the eroded sediments along with dissolved compounds. During transportation, it enriches the flood plane by depositing silt. In the final phase, the running river water deposits the transported detritus material to form the delta and the dissolved salts are added to the sea. The transportation of particles is selective and is controlled by their density, river bed slope and the flow velocity of running waters. It is different in different seasons and is influenced by rainfall and snow melt. River passes through different stages and tends to develop a smooth terrain. During its life, the river system continuously performs its natural function to different degree. Drop in the flow leads to degradation of river health, unsafe conditions for the survival of aquatic life, unfavorable environment for discharge of its natural responsibility and therefore when the continuous non-monsoon flow stops, the river dries temporarily, the hydrological cycle breaks and the river lose its functional natural identity.

Environmental flow: Environmental flow is that optimum quantity of continuously flowing water which is essential for the discharge of river's natural responsibility. The natural responsibility also includes eco-system safety, providing environment for survival of dependent creatures and vegetation.

Delineation of river system in India: All India Soil and Land Use Survey (AISLUS), Department of Agriculture and Cooperation, Government of India (GOI) has published a National Watershed Atlas in 1990. This atlas shows delineated and codified river catchments. This is five stage delineation subdividing major river-systems into smaller units and every unit and its sub-units have been given a permanent code number. According to AISLUS, there are 6 major water resource regions, 35 river basins, 112 catchments, 500 sub-catchments and 3237 watersheds. The sizes of these units are in decreasing order. Need based sub-division of watersheds in smaller units can be attempted.

Water availability in India: According to Ministry of Water Resources (GOI), India receives approximately 400.0 million hectare meters (mhm) precipitation (including snowfall) every year. Out of this quantity, approximately 203.7 mhm is evaporated, consumed by plants and is locked in the sub-surface (soil and aquifers) formations. The total yearly run-off in the country is around 196.3 mhm. The gross GW reserves in the country are 43.2 mhm. The yearly utilizable surface run-off and ground water is 69.0 mhm and 39.6 mhm respectively whereas nearly 127.3 mhm runoff is wasted every year.

Areas with declining non-monsoon flow: Stream gauging data and observations in different parts of the country shows that there is a general decline in the non-monsoon flow in practically all river systems. The noticeable decline of flow and drying of rivers in non-monsoon period is observed in peninsular rivers drained by smaller hydrologic units (sub-catchments and watersheds). The affected areas, in general, are as given below-

- Sub-catchments and watersheds of the major irrigation projects.
- Rain-fed areas.
- Down hill areas of degraded forest with depleting soil cover.
- Heavy ground water exploitation areas.
- Downstream of a river stretches from where large amount of flow is lifted.
- Areas in the neighborhood of deep open cast or underground mines.
- Sub-catchments and watersheds of the major irrigation projects.

Irrigation projects are built across rivers. Their reservoirs store run-off water brought from uplands. The uplands generally constitute small hydrologic units (watersheds, sub-catchments etc). The lands in these units are generally undulating therefore SW (surface water) gets drained immediately after flood / rains where as undulating lands with little soil cover facilitate quick draining of GW stored in degraded catchments and neighboring lands. The GW non-monsoon flows are therefore not sustained for long. The result is moisture / water stress in the terrain and flows deplete immediately after monsoon in small streams and the depletion gradually affect rivers flowing in watersheds and sub -catchments. The increasing GW exploitation worsens the situation and therefore non-monsoon flow ceases.

Rain-fed areas: The term rain-fed area is used by agriculture scientists for monsoon dependent areas. Most of the rain-fed areas are hard rock areas. They have generally shallow aquifers with poor storage capacity. The natural discharge generally dewaters the ground water aquifers immediately after monsoon. Due to increasing GW exploitation, the water table aquifers are emptied fast and therefore their contribution to the river system gets reduced.

This situation reduces ground water contribution to larger hydrologic units in non-monsoon season i.e. ultimately reducing the quantity and duration of flow in the entire river system. Down hill areas of degraded forest with depleting soil cover. Degraded forests with low crown density facilitate soil erosion. The depleting soil covers (thickness of soil cover) provide reduced storage space for GW recharge. Maximum run-off takes place during floods. The non-monsoon contribution from such areas is low. This situation ultimately reduces ground water contribution to larger hydrologic units i.e. reduction in quantity and duration of flow in the entire river system.

Heavy ground water exploitation areas: Ground water rich areas are generally over exploited. This trend is increasing in GW rich units in the country. Though the aquifers are replenished every monsoon but their contribution to river flow is continuously reducing due to increasing GW exploitation. This reduction in contribution ultimately leads to reduced ground water flow to larger hydrologic units i.e. reduction in quantity and duration of flow in the non-monsoon season in the entire river system. Downstream of a river stretches from where large amount of flow is lifted. Drinking Water supply schemes of metro-cities drawing large quantities of river water reduces the river flow in downstream. This lift ultimately reduces flow in the downstream of the river system. Similarly when the water is lifted from the river flowing in the neighboring hydrologic unit, similar effect is observed in the downstream stretch of the river flowing in the donor unit.

Areas in the neighborhood of deep open cast or underground mines Mineral extraction requires digging of earth and therefore during mineral extraction, lot of GW is released in the mine. This GW is pumped out and discharged in the nearest water course. Water pumping from the mine is similar to GW exploitation and therefore rivers situated in the immediate neighborhood of the mine generally face decline in the water table and in the non-monsoon flow of local rivers. The released water improves flow in the downstream rivers.

River rejuvenation vision: Observations indicate that the river flow is sustained till the underground water table is above river's bed level. As soon as the regional water table dips below the river's bed level, the river dries. The flow depletion or drying of rivers is generally observed initially near the origin and then progressively in the larger hydrologic units. In the background of intricate behavior of a river-system, proposed hydro-geological approach paper attempts to provide a conceptual platform for restoration of the flow in the river system. The sustainability of regenerated flow is dependent on river water utilization therefore the water use prioritization for different purposes are proposed

LITERATURE REVIEW

River rejuvenation is urgently required in flow stressed hydrological units in non-monsoon season therefore the hydro-geological approach for river rejuvenation stresses the need of hour. Flow data of a river at regular time interval during non-monsoon season at the outlet of each flow stressed relevant hydrologic unit. Corresponding average water table decline (GW balance / stage of exploitation) in a contributing hydrologic unit at corresponding time interval. Approximate quantity of SW required at regular time interval in non-monsoon season in the corresponding hydrological unit for river revival planning. The hydro-geological approach recognizes the fact that decline of water table is a cumulative effect of non-monsoon GW draft, natural discharge and sub-surface flow vis-a- vis the sub-surface contribution of GW, entirely depends upon the soil thickness and its GW parameters in the respective catchment. In the catchments, depleting soil thickness worsens the situation. Empirical methods are suggested to approximately assess the value of draft, discharge and sub-surface flow/ contribution potential along with thrust on soil erosion control/improvement measures

River rejuvenation approach

In monsoon season, adequate water flows in practically every river -system so there is no need to further augment their flows. The real challenge is in non-monsoon season therefore the river rejuvenation approach suggests-

- Identification of flow stressed hydrological units.
- Identification of factors responsible for depleting non-monsoon flow in the corresponding unit .
- Data on A, B and C (refer above).
- Situation analysis in each stressed hydrological unit
- Suggestions with source for flow revival in the individual hydrological unit.
- Need of scientific input and continuous efforts to refine approach.
- Management of Climate Change

Identification of stressed hydrological units: Watersheds and sub-catchments are the fifth and fourth hydrologic units (AISLUS). These units are located in higher reaches or upstream and are part of the larger hydrological unit. They are the home for small order streams. During monsoon, the streams flowing in these units carry flood waters but during non-monsoon, flow stress (flow depletion and stream drying) in the initial reaches is generally observed. Flow monitoring, at suitable time intervals may be done at the outlet of all watersheds and sub-catchments by using velocity-area or any other suitable method. This exercise will identify stressed hydrological units and stress duration. Suggested monitoring shall broadly identify the flow stressed watersheds and sub-catchments and similar exercise could be carried forward to larger hydrologic units. This exercise will classify hydrologic unit wise stressed and dry rivers along with stress duration.

Identification of factors responsible for depleting non-monsoon flow: During flow monitoring, reconnaissance survey should be undertaken to identify the factors responsible for depletion of non-monsoon flow. The information thus collected shall identify the reasons (factors) responsible for depleting non-monsoon flow in the investigated hydrological unit.

Data on A, B and C (refer above): The data spelt is broadly needed for the river revival. It is therefore stressed that the flow data at regular time interval during non- monsoon season at the outlet of each flow stressed relevant hydrologic unit, corresponding average water table decline (GW balance / stage of exploitation) in a contributing unit at corresponding time interval and the approximate quantity of SW required at regular time interval in the corresponding hydrologic unit may be collected / determined. Rainfall data of minimum past ten years will also be collected.

Situation analysis in each unit: The situation analysis aims to assess the flow depletion trend in non-monsoon season and assess corresponding GW draft (quantity) and approximate month-wise quantity of SW needed for recharge along with identification of other traditional initiatives.

Suggestions for flow revival in the individual hydrological unit: The out come of the situation analysis and interpretation of data should conceptualize hydrologic unit wise structural (desired SW and GW structures) and traditional initiatives. Need of scientific input and continuous efforts to refine approach. Since the earth crust is heterogeneous in nature, therefore there is an unquestionable need for scientific input and continuous effort to refine the approach in different litho-units and their variations/situations for successful restoration of flow in different hydrological units. The approach also needs assessment of relationship between agro-climates and incoming climate change effects.

Management of Climate Change: It is believed that the climate change is expected to influence the rainfall pattern and its quantum. It may increase the flood intensity in certain pockets therefore flood management through water conservation activities would be required. Similarly, in decreasing rainfall areas, an appropriate strategy will be required to assess the probable impact of climate change on river water management activities and planning of structures.

Prioritizing river water use for sustainability of flow

For sustained non-monsoon flow, the approach paper advocates prioritization of river's water in the non-monsoon months. The suggested prioritization in decreasing order is as given below-

Environmental flow. Drinking Water and basic needs. Water use for livelihood and agricultural (exclude water intensive crops). Water use for Celebrations, Public Gatherings on festivals or religious occasions, Fairs and Cultural Tourism. Hydro-power. Water intensive crops and water consuming activities. Industries. Others if any. The river water allocations should be made after meeting the requirement of the environmental flow. The drinking and basic needs should be assessed and quantifiable allocations be made. Further allocations could be made after meeting the above requirement. The allocations for basic and other needs should be reviewed and revised every ten years following the up-to-dated census data. Depending upon the water availability, the approach considers it appropriate (if viable) to support economic activities but it discourages non-essential water intensive / consuming activities in the water stressed or water deficit stretches. The use of river water for meeting drinking water needs of nearby locality or city or adjoining agriculture fields or other hydrologic unit should be permitted after meeting environmental flow, drinking and basic needs.

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