Sustainable Design for Urban Water Management: A Case Study for Ground Water in U. P., India

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***Abstract*- The basic concept of existing infrastructure systems in urban scenario for water management (water supply and waste water treatment) is a century old. A thought should be given, whether the existing traditional concept, characterized by centralized structures, mixing of waste water streams of various qualities and open loop design is suitable to meet the new today's requirements with respect to sustainability. Since water infrastructure systems strongly affect the sustainability of water resources management, hence it becomes a prime objective to handle it with great care. Long term perspective should be developed to integrate technological, organizational and institutional innovations into coherent alternative urban water systems with imposed eco-efficiency.**

Underpinning the feasibility assessment, design and construction phases for a range of engineering infrastructure works requires a sound knowledge and understanding of how hydrogeology (groundwater) can be impacted and managed. With prolonged drought, emerging climate change impacts and population growth, increased demand for groundwater to augment water supply and greater recognition of the groundwater value presents new challenges and requirements for the engineering sector to meet out the sustainability issues.

Keywords: Urban water Infrastructure, Sustainability, Groundwater

1.0 INTRODUCTION

The basic concept of today's centralized water infrastructure systems for water management (water supply and waste water) in urban areas have been continuously spreading, accommodating the changing needs of the population served, with respect to public health and environmental concerns. In addition, these infrastructure systems are characterized by both very long useful life-spans and sunk costs. Thus, the water infra-structure can be characterized as a system with a very high technological path dependency.

Now a day, however, a debate on new technological trajectories for the urban water infrastructure is emerging due to the limitations for the existing paradigm which is characterized by centralized structures and open loop design with respect to water and nutrients, raising the question of its utility / suitability to fulfill the new requirements in terms of sustainability on one hand. While on the other hand, several technological breakthroughs promise to achieve the eco- logical aspects of sustainability. However, they cannot be integrated easily into the existing system and rather constitute a separate technological trajectory.

The governing paradigm for urban water infrastructure should consider the following:

* Of the overall expenditure for urban wastewater systems in a developed country on an average 80 % are brought up for the collection and only 20 % for the treatment of municipal wastewater.

* Finally, more and more substances like pharmaceuticals and their metabolites, antibiotic and endocrine substances are finding their way into the wastewater. Since the present treatment technology cannot handle these pollutants, new treatment technology are required to protect our waters, the aquatic habitats and ourselves from chronic damages.

* On the water supply side costs to provide high quality drinking water to urban areas are increasing, as substantial part of groundwater resources including those used for water supply are contaminated by nutrients (nitrogen) and pesticides from agriculture and therefore, require treatment.

The goal is to identify long-term strategic options and concepts for urban water infrastructure systems for water management which contribute to a sustainable development.

2.0 SUSTAINABILITY ASSESSMENT

The International Council for Local Environmental Initiatives (1994) gave the following practical and local interpretation of the concept of sustainability as it applies to urban areas: "Sustainable development is development that

DOI: 10.5176/2251-3701_2.2.73

delivers basic environmental, social and economic services to all residents of a community without threatening the viability of the natural, built and social systems upon which the delivery of these services depends." With respect to the sustainability of metropolitan and urban areas but also to the sustainability of water resources management the urban water infrastructures play a central role. Water infrastructure not only provides essential services to enable economic and social development in densely populated areas but also strongly affects the way society handles water as one of the most precious and limited resources. This is covered by ASCE's (1998) and UNESCO's (1999) definition of "sustainable water resource systems" being those water resource systems "designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity." Sustainable development is not about looking back at our accomplishments to defend or criticize but about using this platform of existing infrastructure as a springboard for the future. The task is to look ahead and ask ourselves how we can make it even better, taking into account that the world transforms with increasing population, changing values and technological progress.

To assess the relative advantages sustainability a hierarchical criteria system based on the three main dimensions of sustainability, representing social, economic and ecological aspects, should be developed.

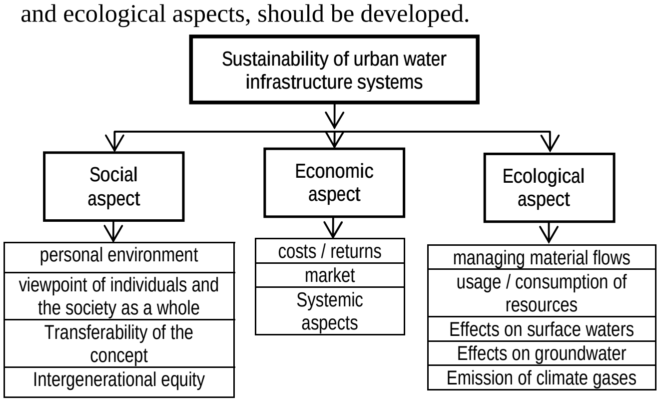


Figure-1: Basic structure of criteria system used to compare the sustainability of urban water infrastructure systems

3.0 GROUND WATER IMPLICATIONS FOR URBAN DEVELOPMENT INFRASTRUCTURE

Ground Water is a strategic resource due to its high quality and perennial availability. This however lacks sustainability because of declining and rising ground water levels deterioration of water quality. Ground water is recharged locally and its sustainable management is vital. It plays a key role in water management whether urban or rural.

From a groundwater water supply perspective, to design and construct the extractive and distribution engineering works, knowledge about the sustainable aquifer yield of the target groundwater resource to be exploited is necessary. In addition, groundwater chemistry should be ascertained for any necessary treatment as part of a sole or augmented supply source for a water treatment plant. Identifying and appraising the effectiveness of engineering options to manage groundwater disposal during construction activities or within the operation of commissioned works to meet statutory environment discharge requirements is dependent on knowledge of the chemical composition of groundwater.

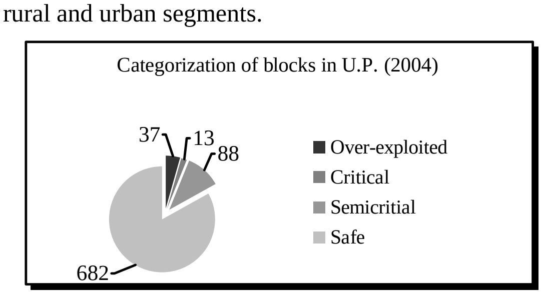
There are many relevant examples of areas where groundwater management requires particular attention in terms of implementing engineering works for urban development infrastructure, augmenting potable water supply (demand management and drought response purposes) and for the health and wellbeing of the industry. These examples demonstrate the increasing importance of how engineering works need to be designed and operated. Through adoptive design, engineering and operation, consultants have the opportunity to steer water authorities and stakeholders towards valuable awareness of the water dependency ground water has in the biophysical and hydrological cycles of our environment.

4.0 GROUND WATER SCENARIO IN THE STATE OF UTTAR PRADESH (INDIA): A BRIEF STUDY

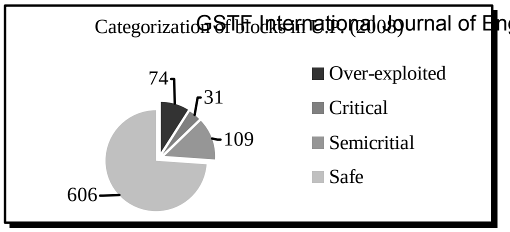
The state of Uttar Pradesh (UP), having a geographical area of 240 million hectare and a population of 166 million inhabitants accounting for 9% of India’s total land area, and 17% of its total population, is endowed with rich natural resource potential, lies in the fertile Indo-Gangetic plain with high natural soil fertility, abundant rainfall, and surface groundwater resources.

4.1 Present Scenario

The groundwater scenario in the state has significantly changed over the last three decades and various critical situations have also emerged related to groundwater quality and quantity. With the mindset that the state of U.P., extending largely over the Ganga basin, is endowed with richest repository of groundwater resource and also comprising the largest aquifer systems in the world, the resource has been indiscriminately exploited in both urban and rural segments without thinking that this may have adverse impact on the sustainability of the resource. The impact is that a glaring imbalance between ‘recharge’ and ‘discharge’ of groundwater has occurred within the shallow dynamic zone, causing widespread depletion of aquifers and also the quality deterioration in various parts of the state. In urban areas like Lucknow and Kanpur, the uncontrolled exploitation of groundwater over the last 20 years has heavily depleted the urban aquifers, almost reaching to an irreversible stage. The situation has already reached to a critical and alarming stage in various parts of the State both in rural and urban segments.



(Total stressed blocks: 138)



(Total stressed blocks: 214)

Figure-2: Categorization of blocks in UP in 2004 and 2008
Ref. No.: 5

4.2 An Overview

(a) Diverse setup:

The major portion of the state is covered by Ganga basin, comprising Yamuna, Ramganga, Gomti, Ghaghra, Gandak and Son sub basins, including rocky terrain of Bundelkhand. The mountain chain of the Himalayas in the north with high run-off plays an important role in passive recharging the vast Ganga basin.

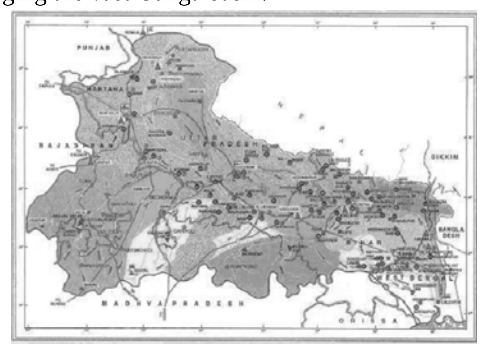


Figure-3: Ganga basin
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Due to diverse hydrogeolocial and geomorphological setups, spatial and temporal distributions of groundwater availability are non-uniform and range from plenty in alluvial plain to scarce in Bundelkhand. The state can be broadly divided in four major hydro geological units, characterized by different groundwater conditions, namely Terai zone, Central Ganga Alluvial Plain, Marginal Alluvial plain and Southern Peninsular zone. The small parts of Bijnor and Saharanpur districts fall in Bhabhar zone, which extends south of mountainous range of Himalayas. The alluvial formations comprise Multi aquifer system, explored down to 600m., promises excessive and productive groundwater resources. The peninsular shield comprises discontinuous aquifers of limited potential in weathered and fissured sediments.

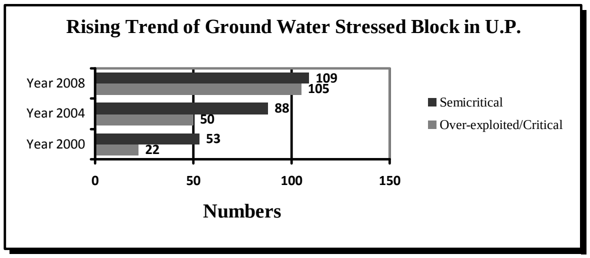

Figure-4: Rising Trend of Ground Water Stressed Block in U.P.
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(b) Depth to groundwater levels:

The depth to groundwater levels also varies widely in different regions of the state, depending upon the variations in aquifer setups and hydrogeological conditions. The general trend of groundwater level is observed from 02 meters below ground level (mbgl) to as deep as 30 mbgl. The wide variation in groundwater level prevails all across the state. In the canal commands, shallow water levels of less than 02 mbgl are reported, where as the deeper water levels of more than 20 to 30 mbgl are observed in ravenous tract along Yamuna river and also in the over-exploited Lucknow, Kanpur cities.

City /Urban area	Average water level decline (cm/year)
Lucknow	73
Kanpur	45
Agra	40
Varanasi	23
Aligarh	40
Ghaziabad	22
Mathura	36

Table-1: Water level decline in Major Cities of U.P.
Ref. No.: 5

(c) Resource availability

Rainfall and recharge from other sources replenishes groundwater every year, wherein rainfall is the main source of recharge to groundwater storage. Most of groundwater development is taken up from the dynamic zone of water level fluctuation in the unconfined aquifers, where normally active recharge takes place. In this active recharge zone, the blockwise annually replenishable groundwater resource for U.P., as estimated by State Groundwater Department, based on 31 March, 2004 data applying the norms of Groundwater Estimation Committee-1997(GEL- 97), reveal the average stage of groundwater development as 69.5% with net groundwater recharge of 7.01 million hectare metre (mham) and gross annual groundwater draft/withdrawal of 4.88 mham.

4.3 Ground Water Related Problems

The major challenge is the proper understanding of the dynamics of groundwater flow under different hydro geological conditions both in space and time, with a view to manage the resource more sustainably for maintaining the future water supplies and also the demands of agriculture, domestic and industry sectors.

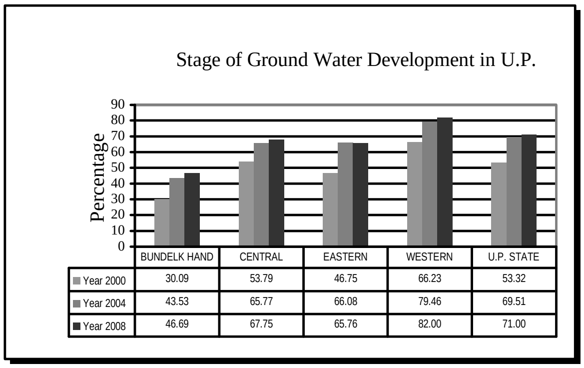
Following four major groundwater related problems have been identified in the State:

1. Over-exploitation/indiscriminate extraction of groundwater in both the rural and urban areas, resulting into significant decline of groundwater levels, mostly affecting the western U.P.
2. Water logging /shallow and rising water levels and soil sodicity affecting the agricultural productivity in Eastern and Central parts of the State.
3. Contamination/pollution hazards related to groundwater resource are now widely reported from different districts. It is emerging as a major problem.
4. Poor availability as well as relatively poor development of groundwater in Bundelkhand-Vindhyan area.

4.4 Management Goals for Groundwater resources

- To fix allowable withdrawals based on sustainable use of aquifers for irrigation, domestic and industrial water supplies as well as for the ecological needs.

- To integrate groundwater quantity and quality in decision making.
- Focused attention to overexploited/critical areas (Urban stressed and Rural stressed Areas).
- To practice rainwater harvesting and aquifer recharging.
- To adopt conjunctive use management of surface and groundwater.
- Deepening and rejuvenation of wells and protecting water bodies.



	BUNDELK HAND	CENTRAL	EASTERN	WESTERN	U.P. STATE
Year 2000	30.09	53.79	46.75	66.23	53.32
Year 2004	43.53	65.77	66.08	79.46	69.51
Year 2008	46.69	67.75	65.76	82.00	71.00

Table-2: Stage of groundwater development in UP
Ref. No.: 5

"Sustainable management of groundwater resource in the state of U.P. should be envisaged through conservation and protection of aquifers ensuring regulated extraction and judicious development of groundwater and minimizing its wastage and controlled utilization in problem areas of the state by initiating conjunctive use applications and adopting concept of Integrated Water Resources Management (IWRM), wherein, IWRM, an interdisciplinary and multi sectoral concept, is based on perception of water as an integral part of ecosystem, a natural resource and economic good". Sustainability of groundwater resources for utilization by future generations must therefore be a high priority, not only for the purpose of fulfilling needs for water usage but also for bringing people into harmony with their natural environment.

5.0 PLANNING GUIDELINES FOR URBAN WATER MANAGMENT:

5.1 The Regulatory Framework

5.1.1 Purpose

The purpose is to provide an overview of the regulatory framework as it applies to the planning of water supply and sewerage services.

5.1.2 Key Principles

Planners must be aware of the regulatory framework and its potential impacts on options and implementation programs relating to the provision of water supply and sewerage services.

5.1.3 Importance

It is important that planners are aware of the legislative and regulatory framework relating to water supply and sewerage services because:

* Non compliance may result in prosecution or loss of reputation.
* Community health and wellbeing may be threatened.
* Significant project delays may result in order to rectify failures of compliance with approvals processes.
* Projects and approval processes may have regulator imposed deadlines.

5.2 Planning Process

5.2.1 Purpose

The purpose of the planning process is to:

* Identify service needs in the short, medium and long term in order to deliver defined service standards, social, environmental and financial outcomes.
* Determine the optimal strategy that delivers the defined outcomes at the lowest financial, social and environmental (triple bottom line) cost.

5.2.2 Key Principles

Planning should include a comprehensive and rigorous identification of all options to meet the defined service levels, including options based on non-asset solutions.

Non-asset solutions, full lifecycle costs, risk and maximizing existing infrastructure capability should be considered either toconstruct new assets or replace assets.

Effective planning outcomes can only result from rigorous analysis, the application of strategic thinking skills and the adoption of an integrated approach to urban water planning which considers, where appropriate, water supply, sewerage and management of storm water as a single system.

5.2.3 Key Elements

The planning process is illustrated in figure 5. For clarity, the process has been shown to be linear. In practice, it is more likely to be iterative.

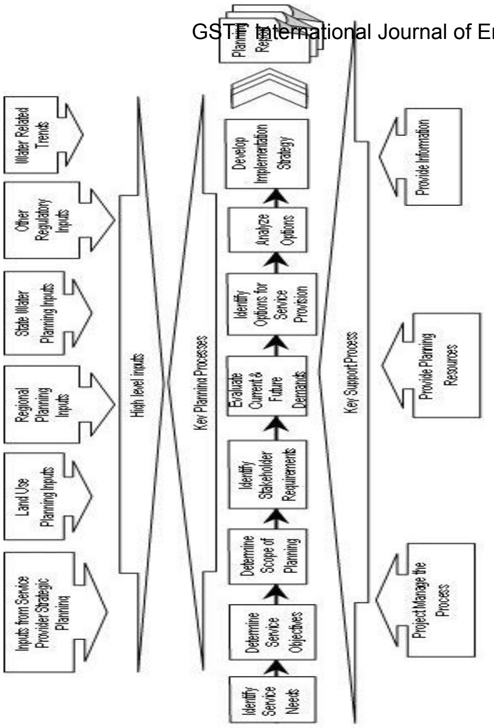


Figure-5: The Planning Process

Ref. No.: 4

5.3 Demand/Flow and Projections

5.3.1 Purpose

The accurate assessment of water demand and sewage flow forms the basis of all planning studies. It should be examined on the underlying basis of future demand and flow based on historical records, future growth and water usage projections (internal and external separately) particularly with a required water quality, so that the potential magnitude of water recycling from various sources (e.g. Storm water, wastewater), or supply from alternate sources (e.g. rainwater tanks, bores) can be assessed.

5.3.2 Key Planning Parameters

All unit water consumption or wastewater flow should be specified as per EP (equivalent person). Equivalent person is defined as "water supply demand or the quantity and/or quality of sewage discharge for a person resident in a detached house". The term equivalent person is also applied to:

* The number of persons who would have water demand equivalent to the establishment being considered.
* The number of persons who would contribute the same quantity and/or quality of domestic sewage as the establishment being considered.

5.3.3 Water Supply

Key planning parameters to be determined are listed in Table 3.

Parameter	Comments
Average Day Demand (AD)	Separate out into internal and external demand.
Mean Day Maximum Month (MDMM)	This is the highest 30 day moving average daily water demand during a year. Parameter used in Queensland only to reflect demand persistence in response to climatic conditions.
Peak Day Demand (PD)	Previous guideline used the term Maximum Day Demand (MD).
Peak Hour Demand (PH)	Previous guideline used the term Maximum Hour Demand (MH).
Non-revenue water (NRW)	Refer to IWA "best practice" standard approach to water balance calculations. Components include real losses, apparent losses and unbilled authorized consumption.

Table-3: Water Supply Planning Parameters

Ref. No.: 4

5.3.4 Sewerage

Key flow parameters to be considered are listed in the Table 4.

Parameter	Comments
Average dry weather flow (ADWF)	This is the combined average daily sanitary flow into a sewer from domestic, commercial and industrial sources (WSAA). Note: this excludes any IIF.
Peak dry weather flow (PDWF)	The most likely peak sanitary flow in a sewer during a normal day. It exhibits a regular diurnal pattern with morning and evening peaks (WSAA).
Peak wet weather flow (PWWF)	Includes: PDWF + GWI + IIF
Groundwater infiltration (GWI)	Groundwater (non-rainfall dependent) infiltration. Generally exists for sewers laid below groundwater table. Groundwater infiltration enters the system via defective pipes or joints and leaking manhole walls. GWI can generally be estimated as the flow between midnight and 4.00 am during dry periods.
Rainfall dependent inflow & infiltration (IIF)	Peak (rainfall dependent) inflow and infiltration. This includes flow discharged into sewer from: • unauthorized roof, ground or storm water drainage • leaking manhole covers • disconnected sewers • low disconnected traps

	• Indirect infiltration of rainwater entering defective pipes and joints from the surrounding soil. Refer to the WSAA Sewerage Code for further details.

Table-4: Key Sewage Flow Parameters
Ref. No.: 4

5.3.5 The Planning Horizon

The planning horizon would depend on a number of factors including:

* Lead time including approvals to construct infrastructure
* Growth rates
* Possible infrastructure staging options.

For water services the overall planning horizon for major resource and system components should be 50 years.

An ultimate development scenario based on a stated population density, should be considered particularly in relation to identifying:

* The location of essential infrastructure for early procurement of land/easements
* Long term constraints (e.g. pipeline corridors that may only accommodate one main)
* Optimal staging strategies.

6.0 CONCLUSION

The proper management of water and allied engineering works (water supply and natural resource management) is a need to ponder over the existing conditions, due to prolonged drought and emerging climate change. The trend of growth in population all over the world, resulting in global industrialization is ongoing and increasingly pressing to redefine and reform the thought process to achieve the sustainability models for a better tomorrow. Prudent use of natural resources in a well defined technical frame will help to achieve the same. Consultants have the opportunity and responsibility to steer water authorities and stake holders towards valuable awareness of the interdependency of water management with other urban infrastructure elements through adaptive design, engineering and operation for Sustainability.

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