Final Report
On

Comprehensive Assessment of Thippagondanahalli Reservoir Catchment Area and its Preservation Zone

August, 2015

Volume-I

Prepared By

Center for Lake Conservation (CLC)
Environmental Management and Policy Research Institute (EMPRI)

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Final Report on

Comprehensive Assessment of Thippagondanahalli Reservoir (TGR) Catchment Area and Its Preservation Zone

Volume-I

Submitted to

HON'BLE HIGH COURT OF KARNATAKA, BENGALURU

August, 2015

(Hon'ble High Court of Karnataka Order dated 02/02/2015 in WP NO.38218/2013)

Prepared By:

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PREFACE

Water is life, every human being, now and in the future, should have access to safe drinking water. In the past, water bodies have been one of the outstanding features of Bengaluru. Over the years, there has been general degradation of the quality and quantity of water bodies mainly due to uncontrolled urbanization, encroachment of water bodies, pollution due to domestic sewage and industrial effluents etc.

An acute shortage of drinking water had occurred in the year 1922 with the drying up of Hesaraghatta tank. The situation demanded urgent remedial measures and as a result, construction of a TG Halli Reservoir on the river Arkavathi was commenced. TG Halli Reservoir was a source of excellent drinking water, to the city, till 1990's. However over the years the flow to the TG Halli reservoir got reduced and the water quality also deteriorated. To study the reasons for reduced inflow to the TG Halli reservoir, a study was entrusted to ISRO-INRIMT in the year 1999 by BMRDA. This study analysed the landuse/ landcover, drainage patterns, the geomorphology, slope, rainfall and other related factors. The study indicated rapid urbanization, encroachment of tanks, obstructions to drainages, over exploitation of ground water etc. as the major reasons for reduced inflow to the TG Halli reservoir.

The ISRO-INRIMT study considered the various aspects of TGR catchment area and suggested a host of remedial measures and regulations for controlling further developments that were damaging the quality and quantity of flow. Based on this report, Government of Karnataka brought out a notification dated 18.11.2003. As per this, TGR catchment area was divided into four zones restricting activities in each zone in an attempt to revive the river and the reservoir. However, despite the Government Order, developments have been taking place at a fast rate in the catchment area resulting in further deterioration of water quality and forcing BWSSB to stop the supply of drinking water from TG Halli reservoir since 2012. The concerned Authorities had issued demolition notices to some of the unauthorized constructions as per the TGR preservation Notification.

As a result, 61 Writ Petitions were filed by the owners of these buildings before the bench of Hon'ble High Court of Karnataka during 2013. This has led to a conflict situation between the local people and the Government Authorities. Further, the Government of Karnataka also withdrew the TGR preservation Notification dated 18.11.2003 on 24.07.2014 with the objective of taking stock of the current situation and issue fresh notification.

The Hon'ble High Court of Karnataka has taken up the matter (WP No. 38218/2013) and stayed the withdrawal of the TGR preservation Notification. Further vide Interim Order dated 02-02-2015, the Hon'ble High Court has entrusted EMPRI to take up a comprehensive study on the entire TG Halli reservoir catchment area. The present study has been conducted by EMPRI within the scope of the ToR given by Hon'ble High Court of Karnataka.

As a part of the study comprehensive field visits have been carried out by the Centre for Lake Conservation team at EMPRI to understand the present situation, developments that have taken place and for identifying the sources of pollution. Remote sensing and GIS analysis has also been carried out to find out the change in land use/ land cover. The properties concerning the Writ Petitions have also been visited and observations recorded along with photographs and GPS readings. Water quality has also been analysed by collecting samples. Both the Rivers Arkavathi and Kumudvathi are non-perennial and major water flow is seen only during monsoon. During summer the Arkavathi river is mostly dry except for the inflow of polluted water. The major reasons for the reduced inflow and deteriorated water quality are found to be massive changes in land use and land cover in the catchment, unplanned urbanization leading to change in drainage patterns, unauthorized obstructions to water flow, lack of maintenance of the cascading lake system, over exploitation of ground water leading to unsaturated condition of soil, discharge of untreated sewage and industrial waste to the river course.

The previous study reports on the TG Halli catchment area have also indicated similar problems resulting in reduced inflow to TG Halli reservoir as well as deteriorated water quality. The previous study reports mentioned that the TGR catchment area exhibited mostly agriculture and farming as main features but during the last decade, the situation has worsened and the Arkavathi bank has become a veritable goldmine for developers. The rapid development along the river stretch has resulted in encroachment on the riverbed, overexploitation of groundwater, pollution of water bodies by discharging untreated waste water and hence reducing and polluting the river. Seasonal encroachment for agriculture, soil excavation and quarrying are some of the major activities seen on the tank and river bed.

In recent decades, with more attention to sustainability and quality of life, there is a greater understanding of the vital role of urban rivers and riverfronts. With the help of available information, an attempt has been made to arrive at reasonable recommendations by reviewing national and international guidelines and also from the suggestions given by expert committee constituted for the purpose.

It is time to make serious efforts to take preventive measures in protecting our rivers by controlling and preventing further damage to our river systems. It should be kept in mind that, saving a river, cannot be achieved overnight; it is a long-term commitment. It needs determined effort from all directions to get desired results.

Bangalore,

(Ritu Kakkar)
Director General,
EMPRI

Abbreviations

%	Percentage
°	Degree
↓	Below
'	Minutes
' '	Seconds
°C	Degree Centigrade
AAS	Atomic Absorption Spectrometry
A-G	Acres and Guntas
ATREE	Ashoka Trust for Research on Environment and Ecology
BBMP	Bruhat Bangalore Mahanagara Palike
BCM	Billion Cubic Meter
BDA	Bangalore Development Authority
BDL	Below the Detectable Limit
b.g.l.	below grade level
BIAAPA	Bangalore International Airport Area Planning Authority
BIS	Bureau of Indian standards
BMRDA	Bangalore Metropolitan Region Development Authority
BMICAPA	Bangalore Mysore Infrastructure Corridor Area Planning Authority
BOD	Biochemical Oxygen Demand
BUZP	Bangalore Urban Zilla Panchayat
BWSSB	Bangalore Water Supply and Sewage Board
CETP	Common Effluent Treatment Plants
CFU	Colony Forming Unit
CGWB	Central Ground Water Board
CLC	Centre for Lake Conservation, EMPRI
cm	Centimetre
CNNL	Cauvery Neeravari Nigam Limited
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPDO	Central Poultry Development Organization
CWUI	Composite Water Use Index
DC	Deputy Commissioner for District
DMG	Department of Mines and Geology
DO	Dissolved Oxygen
DoEE	Department of Ecology and Environment, Government of Karnataka
DLF	Delhi Land and Finance (P) Ltd., Delhi
E	East
EC	Electric Conductivity
EO	Environmental Officer
EMP	Environmental Management Plan
EMPRI	Environmental Management and Policy Research Institute
ESZ	Ecological Sensitive Zone
et al.	Etalia

ETP	Effluent Treatment Plants
ft.	Feet
g	Gram
G+	Ground floor with (1^{st}/ 2^{nd}/ 3^{rd} floor)
GIS	Geographical Information System
G.O.	Government Order
GoI	Government of India
GoK	Government of Karnataka
GP	Grama Panchayat
GPS	Global Positioning System
ha./Ha.	Hectare
HFL	High Flood Level
Hon'ble	Honourable
HP	Horse Power
IAHV	International Association for Human Value
IB	Investigators Bungalow
IISc.	Indian Institute of Science
IN-RIMT	Indian Resources Information and Management Technologies Pvt. Ltd.
IRS	Indian Remote Sensing Satellites
ISRO	Indian Space Research Organization
IWRM	Integrated Water Resources Management
JSYS	Jala Samvardhane Yojana Sangha
KBJNL	Krishna Bhagya Jala Nigam Ltd.
KFD	Karnataka Forest Department
Kg	Kilogram
Km	Kilometre
Km^2	Square Kilometre
KNNL	Karnataka Neeravari Nigam Limited
KSNDMC	Karnataka State Natural Disaster Monitoring Centre
KSPCB	Karnataka State Pollution Control Board
KSRSAC	Karnataka State Remote Sensing and Application Centre
KSTDC	Karnataka State Tourism Development Corporation
KUWS&DB	Karnataka Urban Water Supply and Drainage Board
L	Litre
Lat.	Latitude
LDA	Lake Development Authority
LISS	Linear Imaging Self Scanning sensor
Long.	Longitude
LPA	Local Planning Area
LPCD	Litre Per Capita per Day
LPG	Liquid Petroleum Gas
Ltd.	Limited
LU/LC	LandUse and LandCover
m	Meter
m^3	Cubic Meter

MCM	Million cubic meters
MCFT	Million cubic Feet
MCL	Maximum Contaminant Level
MoEF	Ministry of Environment and Forest, Government of India
ml	Millilitre
MLD	Million Litre per Day
mm	Millimetre
mm^3	Cubic Millimetre
MPA	Magadi Planning Authority
MPN	Most Probable Number
ND	No Data
NGO	Non-Government Organisation
NH	National Highway
No.	Number
NPA	Nelamangala Planning Authority
NRCP	National River Conservation Plan
NTU	Nephelometric Turbidity Unit
ODP	Outline Development Plan
pH	Negative logarithm of hydrogen ion concentration
PIL	Public Interest Litigation
ppm	Parts Per Million
PSR	Pressure–State- Response
Pvt.	Private
RRZ	River Regulation Zone
RTAC	Research and Training Advisory Committee, EMPRI
RWH	Rain Water Harvesting
SH	State Highway
SOI	Survey of India
SOP	Standard Operating Procedure
sp.	Species
Sq. Km.	Square Kilometre
STP	Sewage Treatment Plant
Sy. No.	Survey Number
t	Tones
TDS	Total Dissolved Solid
TGR	Thippagondanahalli Reservoir
TMC	Thousand Million Cubic feet
tmc ft.	Thousand Million Cubic Feet
TOC	Total Organic Carbon
ToR	Terms of Reference
TSS	Total Suspended Solids
UDD	Urban Development Department
UGD	Under Ground Drainage
WENEXA	Water and Energy Nexus
WHO	World Health Organization

WP	Writ Petition
WRDO	Water Resources Development Organisation
yr.	Year
μg	microgram
μmhos	micromhos
μs	microsecond

Chapter No.	Content	Page No.

Volume-I

Volume-II (ToR-5)

(Writ Petitions connected to 38218/2013)

Volume-III
(Annexures)

Chapter-1: General Introduction

Chapter-2: TGR Catchment Area and Notification

Chapter-3: Literature Survey

Chapter-4: State of Affairs in TGR Catchment Area

Chapter-5: Change in Landuse/ Landcover for the period 2003-2014

Chapter-8: Analysis of Various Stakeholder Meetings

Chapter-10: Conclusions and Recommendations

Chapter-11: Commercial Superstructures

Chapter-12: Residential Superstructures

Executive Summary

Thippagondanahalli Reservoir [TGR] or T.G. Halli, also called as Chamarajasagar Reservoir is situated in the Bangalore Rural district. The TGR used to supply 145MLD of water to the Bangalore City for domestic purposes which gradually decreased. In the 1990s, the water inflow to TGR got reduced due to the rapid urbanization in the TGR catchment area. In order to ascertain the exact causes for the dwindling inflow to TGR, the BWSSB entrusted a study to ISRO. Based on the ISRO-INRIMT report, the Department of Forest, Ecology and Environment, Government of Karnataka had issued a vide Government Order no. FEE 215 ENV 2000, dated 18.11.2003 that segregated TGR catchment area into four conservation zones with certain regulations and concerned Government Authorities were given responsibility of implementation of the G.O. However the Government Order could not be implemented due to tremendous increase in population of Bangalore, high development pressure and lack of coordination between various agencies. So jurisdictional Authorities such as BDA, BIAAPA, etc. had issued the demolition Notices to unauthorized constructions, particularly in Zone-3 and 4 with reference to the 2003 TGR notification. The affected persons filed 60 Writ Petitions connected to WP 38218/ 2013 before the Hon'ble High Court of Karnataka.

Meanwhile the Karnataka Government withdrew the TGR preservation notification (G.O. No. APG 01 ENG 2011 dated: 24.07.2014) to take stock of the present situation and come up with suitable modifications to the Government Order. The Hon'ble High Court stayed the withdrawal Notification and appointed the *Amicus Curiae* to assist and provide detailed information regarding the current situation to the Hon'ble High Court of Karnataka. Hon'ble High Court of Karnataka directed EMPRI to carry out a comprehensive study and submit the report on TGR catchment area based on the Terms of Reference suggested by *Amicus Curiae*. In accordance with the Orders of the Hon'ble High Court of Karnataka, EMPRI had submitted the Interim Report on "Comprehensive Assessment of TGR Catchment area and its Preservation Zone" on 27.04.2015. However there was one case (WP. No. 48047/2013) that involved 870 households and it was not possible to carry out field surveys of so many properties within the short period given for submission of interim report. Incorporating the field observations of these household and some more analysis, the final report has been prepared. The Final Report is segregated into three volumes. The Volume-I has addressed all the Terms of Reference except the details of the field surveys connected to the writ petitions, Volume-II has the details of the 61 Writ Petitions before the Hon'ble High Court of Karnataka connected to the issue and the Volume-III has the annexures and supportive documents. There are 10 chapters in the Volume-I report, which are summarised below:

General Introduction of study has deliberated the importance of Hesaraghatta (Chamarajendra Reservoir) and Thippagondanahalli Reservoir (Chamarajasagar Reservoir), in the context of drinking water scenario of Bangalore city. The background of the study and the 10 Terms of References (ToR) directed by the Hon'ble High Court of Karnataka, have been explained in the Chapter I to provide the context and scope as well as limitations of the study.

The Chapter 2 (**TGR Catchment Area and Notification)** describes the study area of the project including TG Halli Reservoir, Hesaraghatta reservoir (sub-catchment area as Zone-1), Arkavathi river (sub-catchment area) and Kumudvathi river (sub-catchment area) in the TGR catchment area. Further, the location and villages falling under the four preservation zones, i.e., Zone-1, Zone-2, Zone-3 and Zone-4 as per the 2003 TGR preservation notification, are described in detail. Historical issues in the TGR catchment area as well as administrative issues concerning the implementation of TGR preservation Notification have been discussed.

The Chapter 3 contains the Literature Survey and describes the analysis of important previous study reports concerning TGR Catchment area. About 30 articles have been reviewed and the limitations of the study have also been discussed. Some important studies are given below:

i. Reduced inflow into TG Halli Reservoir- A remote sensing based evaluation in 2000 by ISRO (Indian Space Research Organisation) & IN-RIMT (Indian Resources and Information and Management Technologies Limited).
ii. The framework of policies and plans for sustaining T.G. Halli reservoir in 2002 by IN-RIMT.
iii. Reservoir catchment management using GIS and RS – A case study in Karnataka in 2008 by Saibaba *et al.*, in 12th World Lake Conference.
iv. Obstructions to flow of natural water in the course of Arkavathi river and its tributaries from its origin up to the TG Halli Reservoir in 2010 by CNNL (Cauvery Neeravari Nigam Limited).
v. Water management in Arkavathy basin - A situation analysis in 2013 by ATREE (Ashoka Trust for Research on Environment and Ecology).
vi. Kumudvathi river rejuvenation – Phase I project report in 2013 by IAHV (International Association for Human Values).
vii. Change analysis of drainage pattern for Tippagondanahalli catchment in 2014 by Chandana *et al.*, in 8th International Society for Photogrammetry and Remote Sensing technical symposium.

The fourth Chapter describes in details the State of Affairs in the TGR Catchment Area. The field observations made during extensive field visits by EMPRI team have been explained in detail to give an overview of the present situation of the TGR catchment area zone wise as per the first ToR. Existing situation of the TGR catchment area has been documented along with photographs and GPS readings. In the TG Halli reservoir itself, soil excavation, sand mining, dumping of wastes etc. have been observed due to absence of backshore fence and adequate protection. Further, seasonal encroachments of the TGR for agriculture and considerable spread of aquatic weed (*Eichhornia* sp.) in TGR due to eutrophication as a result of sewage inflow through the Arkavathi River have been recorded. The water stored in TGR is not used by BWSSB but the water flows down to Manchanabele dam, which is supplied to Mandya town for portable purposes. Hesaraghatta Reservoir extends over 11 villages and has become a popular tourist spot for photography and for picnic that has resulted in dumping of solid waste. Extensive soil excavation and dumping of wastes are happening due to lack of management and maintenance. Even though the Hesaraghatta Reservoir is free from the sewage influx, the water stored is not used for any purpose.

Zone-1 as per the 2003 preservation notification is spread over 550 villages under the Hesaraghatta, Arkavathi and Kumudvathi sub-catchment areas. Improper management of solid and liquid wastes generated by the expansion of old settlements in the Gramathana has resulted in the pollution of the waterbodies and river courses in the catchment area. Encroachment on waterbodies as well as on drains, quarrying, soil excavation, sand mining, solid waste dumping, and sewage influx etc. are the common problems in the Zone-1 catchment area. Further, most of the lakes in Zone-1 have dried due to seasonal encroachments by farmers and over-exploitation of groundwater. There are four industrial areas in Zone-1, which pave the way for the operating of small scale industries without consent from KSPCB that has resulted in the discharge of untreated effluents in to the streams of Arkavathi river.

Hesaraghatta sub-catchment area (606.57 km^2) spreads over 273 villages. Sewage discharge from households and industrial wastewater flowing to the storm water drains, dumping of solid waste in the lakes and its drains, possible encroachments by farmers on lake bed are the issues of concern in the Hesaraghatta sub-catchment area. Further, the series of cascading tanks from the Nandi hills in the Arkavathi river course are no longer overflowing. The wastewater and trade effluents are freely flowing in the streams and storm water drains, which pollute the major waterbodies and ultimately the Arkavathi river during monsoon season.

Arkavathi sub-catchment area (376.59 km^2) spreads over 123 villages. The absence of UGD in some of the habitations, has forced the community to use the storm water drain for discharge of sewage waste. In 2007, 110 villages were added to the BBMP area, but as these areas are not under the jurisdiction of BWSSB, the sewage generated by these villages are ultimately being released to the nearby waterbodies and to the rivers. Further, the effluents are directly let into the 2nd order drain of Arkavathi river near Madavara Kere. The Kumudvathi sub-catchment area (154 villages) has also been affected by groundwater over-exploitation, lack of proper management of solid and liquid wastes, quarrying, soil excavation, sand mining and encroachment on tanks. The combined Industrial Area (Sompura and Dabbaspet) have increased the mushrooming of unlicensed polluting industries adjacent to the Industrial area, which are polluting the drain. Necessary action needs to be taken up by concerned authorities to control and prevent encroachment of tanks and discharge of effluents by polluting industries.

Zone-2 as per the 2003 preservation notification is spread over the 33 villages. There are 34 brick kilns, 19 layouts, 19 poultry and goat livestock farms and two warehouses for LPG in the villages in zone-2. The issues in Zone-2 are soil excavation and sand mining in the villages of Gangenahalli and Goravanahalli respectively of Arkavathi river bank and illegal stone quarrying in Bidanpalya village. Sewage from the hamlet of Gangenahalli village is flowing to the Arkavathi river and further, the river bed in Nagasandra and Jogerahalli villages appears to have been encroached for growing horticultural crops which needs to be verified by concerned authorities.

Zone-3 and 4 of Arkavathi river course between Hesaraghatta Reservoir and TGR as per the 2003 preservation notification are spread over 53 villages of Bangalore Urban district. As the area is suburb of Bangalore city and National Highway-4 passes through the area, the area has seen rapid development without proper planning, which has resulted in the degradation of

Arkavathi river. Sprawling of buildings and new layouts in the Hesaraghatta, Ivarakandapura, Varthuru, Tarabanahalli, Thorenagsandra, Madhanayakanahalli, Siddhanahosalli and Adakimaranahalli villages have resulted in the dumping of solid and liquid wastes, and encroachment of 2nd, 3rd and 4th Order streams of Arkavathi river. Extensive quarrying in Kittanahalli village; granite slurry in streams of Arkavathi river in Giddenahalli, Kammasandra and Ravuthanahalli villages; industries in Kadabagere village; sand filtering unit in Alur and Bettahalli villages are the other issues documented in the Arkavathi river course. Further, the waterbodies in Heggadadevanapura, and Dhombarahalli, Makali and Harokyathanahalli villages have been converted in to layouts, godown and residential houses respectively which needs to be further verified by the concerned authorities.

Zone-3 and 4 of Kumudvathi river course as per the 2003 preservation notification is spread over 98 villages from Benegere village to Bidanpalya village. Lack of proper management of solid wastes and waste water in the villages has resulted in the deterioration of the water quality. Further, the sewage is let into the lakes of Benegere, Karimane, Heggunda, and Motaganahalli villages through the storm-water drains. The upstream of Kumudvathi river bed (above Thymagondlu village) appears to have been encroached for the agriculture activities and further, the encroachment of river bed by Yoga centre and layout in Aralasandra and Kempohalli villages have been documented. The extension of Sompura Industrial Area to Niduvanda village without the proper effluent treatment also adds its pollutant to the Kumudvathi river.

The Chapter 5 describes the overall Change in Landuse/ Landcover between the year 2003 and 2014, the remote sensing analysis has been carried out by the KSRSAC with the help of LISS-IV satellite imageries of 5.8m resolution. NH-4 (Bengaluru-Tumakuru), NH-48 (Bengaluru-Mangaluru) and NH-207 (Bengaluru-Dobbaspet) with State Highways (KA SH-3, 9, 39, 74, 86, 104) and Broad Gauge Railway Line (Bengaluru-Arsikere) are the major transport infrastructure in the TGR catchment area. The remote sensing analysis has revealed that the agriculture lands in the TGR catchment area has decreased while the built-up area has increased between the reference years 2003 and 2014. Village wise analysis of the developments has been carried out for the 200 villages located in the Zone-2, 3 and 4 and it was found that 15 villages (particularly Kadabagere, Heggadadevanapura and Huralichikkanhalli villages) have significant landuse/ landcover changes due to increased number of constructions and layouts.

Further it is found that some of the waterbodies have been encroached and converted into godowns (Taverekere, Makali and Heggadadevanapura villages), brick factories (Srinivaspura and Hajipalya villages), residential houses/ layouts (Harokyathanahalli, Dombarahalli and Heggadadevanapura villages) and Government institution in Dasenahalli village. With regards to permissions given for such developments, Panchayats, BDA, BMRDA, NPA, MPA, KSPCB, etc., were requested to provide information but complete information has not been received. With regards to the nature and purpose of superstructures, it was not practically possible to verify and record for each superstructure. But the ground truth verification of the properties connected with the Writ Petitions and general observations during field visits had inferred that there are three major types of superstructures. One major purpose for construction of superstructure has been Godowns under the Gramin Bhandaran Yojana Scheme. These warehouses were meant to be used for storage for agricultural purposes. However since there is no such requirement for storage of agricultural produce at present, these godowns are mostly being used as storage units mostly for finished goods and in some cases for Industries/ factories in operational or closed condition. Further, the mushrooming of godowns in these villages is due to the loan facility provided to the local people under the National Grameena Bhandara Yojana. Second major constructions of superstructure are the apartments, villas, layouts, and individual houses are used as residential spaces by either owners or rented. Third major constructions of the superstructures are industries. The constructions and layouts have in some places affected the drainage patterns.

The Chapter 6 has explained the Water Yield and Availability (ToR-6) in TG Halli reservoir as well as the Arkavathi and Kumudvathi rivers based on secondary data. Water inflow data of TGR collected from the BWSSB has been correlated with the rainfall data of TGR catchment area from 1937 to 2012. This analysis revealed that minimum of 600mm rainfall was recorded in the TGR catchment area and there has not been much variation in the overall rainfall in the catchment. But the inflow of water to TGR has dramatically reduced due to the changes in landuse, encroachment of 2nd and 3rd order drains due to urbanization, drain diversions by the unplanned developments, etc. There was no secondary data with the concerned authorities with regards to the availability of water in Arkavathi and Kumudvathi rivers since these rivers have not been gauged by the State Government or Central Government Authorities. In order to assess the water availability currently, the EMPRI team has plotted the water availability map by recording the geo-coordinates of the stretches where water was available during the field visits with the help of GPS. The 33 Km stretch of Arkavathi river is segregated into three categories such as dry river (from Nandi hills to downstream of Hesaraghatta reservoir), stagnant river (Tarabanahalli and Heggadevanapura villages) and river stretch having sewage flow (from Alur village to TGR). The Arkavathi river course in the Zone-1 (Hesaraghatta sub-catchment area) is linked with the major waterbodies through a cascading system. However these waterbodies are not overflowing in the last decade and therefore are not generating flow in the Arkavathi river. Ephemeral Kumudvathi river has water blotches in Basavenahalli, Doddakarenahalli, Kodihalli, Tippadabegur, Dodderi and Chikkamaranahalli villages i.e. for a total of 1.58Km stretch out of 48Km.There has been an acute shortage of ground water and the level of ground water is depleting year by year due to over-exploitation of groundwater near the rivers. Additionally, the groundwater fluctuations has also been analysed based on the secondary data (1980-2014) collected from the DMG for the Arkavathi and Kumudvathi sub-catchment area.

The Chapter 7 describes the Water Quality Deterioration and Reason for Pollution. Analysis has been done regarding past and present water quality of Arkavathi and Kumudvathi rivers and reasons for deterioration. As per the ToR-7, the water quality samples were collected from identified points and the analysis of important parameters was carried out. Arkavathi river water quality data for the previous years (2010-2014) were collected from the KSPCB, which are found to lack uniformity with data gaps. However it showed that the water quality has deteriorated to class-E due to the presence of coliform and high concentration of iron and lead. But the present water quality analysis based on 17 water samples showed that the Arkavathi river water quality is below class-E due to high concentration of nickel and manganese in Kadaranahalli village stretch and high concentration of iron and manganese in Alur, Heggadadevanapura, Makali and Madanayakanahalli villages. The data collected from KSPCB for Kumudvathi river water quality for the years 2013 and 2014 showed that the water quality has deteriorated to class-D due to the high concentration of iron. However the parameters analysed in the past lacked uniformity and there are data gaps. But the present water quality analysis based on water availability (three water samples) showed that the Kumudvathi river water quality is categorized as class-C due to the low dissolved oxygen, whereas the colour and manganese concentration exceeded the permissible limits in the Basavanahalli village. This may be due to the operation of stone crushers in the area.

TGR water quality data for the past years (2000-2014) were collected from the BWSSB, which are found to lack uniformity with data gaps. However the available secondary data showed that the EC, TDS, calcium hardness concentration and coliform count have increased over the years. This may be due to the brick kilns operating in the areas surrounding TGR. But the present water quality analysis results indicate class-E quality class for Arkavathi river inlet water and class-C quality class for Gangappanahalli village inlet water, whereas the outlet water from TGR can be categorized as class-D. Additionally, the groundwater quality data also has been analysed based on the secondary data (1995-2014) collected from the DMG for the Kumudvathi sub-catchment area and fresh ground water samples were collected and analysed as a part of the present study. When compared to the Kumudvathi river, the Arkavathi river is more polluted due to the ingress of untreated sewage from the settlements, industrial effluents and solid wastes. Further to the extent possible the reasons for pollution of Arkavathi and Kumudvathi rivers as per the ToR-8, were traced based on the ground verification, which showed that the point (storm water drains carrying sewage, wastewater generated from households and commercial establishments, illegal quarrying and effluent from unregulated small scale industries) and non-point sources (sewage from BBMP area and rapid sand mining) are polluting the Arkavathi river than the Kumudvathi river.

The Chapter 8 contains the analysis of Various Stakeholder Meetings and the concerns raised by the primary stakeholders and their suggestions. The efforts made by the Government Departments or Authorities to implement the Government Order of 2003 and for conservation of TGR catchment area have been explained. Four stakeholder meetings were conducted by EMPRI in Bachenahatti Gram Panchayat (Zone-2), Chaudanayakanahalli Gram Panchayat (Zone-2), Nelamangala Gram Panchayat (Zone-3 and 4 of Kumudvathi river course) and Bangalore North Taluk Panchayat (Zone-3 and 4 of Arkavathi river course). Lack of awareness about the 2003 TGR preservation Notification, difficulties in carrying out agriculture due to insufficient availability of surface and ground water, are the issues raised in the primary stakeholders in these meetings. The local residents also suggested to reduce the width of the buffer zone, demarcate the TGR boundary, relaxation of the buffer zone for old settlements taking into consideration their natural expansion and setting up a separate TGR catchment area conservation authority to coordinate with all the consent Departments.

The Chapter 9 contains the legal and policy matters related to conservation of rivers and waterbodies in India. Also methodologies and best practices adopted in other States in India and internationally in other countries for Rejuvenation, Conservation and Preservation of Rivers and River Courses in Urban Agglomerations have been elaborately reviewed. The National and International guidelines and Acts existing for preservation and conservation of rivers and its courses as per ToR-9 have been discussed. Also the regulation of human activities along rivers and lakes – Report 2002 prepared for the National River Conservation Directorate, MoEF by National Institute of Ecology, New Delhi; Maharashtra River Policy and Andhra Pradesh Government Notification on Osmansagar and Himayathsagar reservoirs conservation and other such examples have been discussed. Based on the review of National guidelines on conservation of Rivers, the chapter concluded that there is need for the State Level Water Regulatory Authorities for dealing with water issues in a holistic way; need to constitute basin level river Institutions; Developing strategies for each river especially in urban set ups; to establish national and regional institutes for research and training in river ecology and Involvement of public in the decision making and implementation of water management activities.

About 90 International guidelines have been collected and eight guidelines are elaborately reviewed including Pasig River in Philippines, Kallang River in Singapore, Bronx River in South East New York, Rivers of Japan, Urban Rivers of Malaysia, Jordon River in Israel, Nairobi River in Kenya with respect to urban agglomeration. Awareness creation for improvement of relationship between river and local population, effective implementation of existing policies, restoring the flow channel, participatory approach in decision making, planting trees along river sides, establishment of green areas on both sides of the River and its tributaries along the course within city centre, implementing suitable agricultural practices, promoting recycling and reusing of industrial effluents and installing the Gross Pollution Traps (GPT) along the river course are some of the best practices documented from the international guidelines.

The Chapter 10 contains the Conclusions and Recommendations (ToR-10) based on the earlier studies, the existing scenario of TGR catchment area and the suggestions from the concerned departments, Planning Authorities of the TGR catchment area, local population and detailed consultations with experts. The chapter has summarised all the findings in the TGR catchment area and concluded that there is reduction in Arkavathi and Kumudvathi rivers water flow and consequent reduction to TGR, which can be mainly attributed to the groundwater over-exploitation, unplanned rapid urbanization leading to change in drainage, lack of maintenance of the lakes and tanks in the cascading system, water intensive agricultural practices etc. Deterioration of water quality can be attributed to influx of untreated sewage from households, commercial establishments, industrial effluents, poor management of solid waste. Overall there is lack of coordination between the planning Authorities, implementing authorities and enforcement agencies. Further, the local people were not made adequately aware about the Government Notification of 2003. The concerned Planning Authorities, Gram Panchayats have not been able to ensure implementation of the Government Notification. An attempt has been made to give suitable recommendations to address the challenges of the TGR catchment area. These recommendations are prepared based on the three Advisory

Committee Meetings and 9th Research and Training Advisory Committee Meeting of EMPRI. Taking into consideration available guidelines and methodologies related to the rejuvenation, conservation and preservation of river courses in the other States of India and in the other Countries. Following are the recommendations in brief, formulated to rejuvenate, conserve and preserve the water courses in the TGR catchment area.

1. Formation of Multi-disciplinary Institution for the river basin to have effective coordination among the Government Agencies
2. Removal of unauthorized obstructions in river courses and its drain
3. Stopping the illegal quarrying, soil excavation and sand mining in the TGR catchment area
4. Preservation of lakes and river beds in the TGR catchment area and revival of tank system
5. Protection and Preservation of TG Halli Reservoir
6. Control of industrial effluent discharge into the river course
7. Alternative technologies for treatment of wastewater and use the treated water for Arkavathi river flow
8. Preservation and maintenance of storm water drains
9. Management of solid wastes
10. Regulation and management of groundwater
11. Adoption of Rainwater Harvesting System (RWH)
12. Decommissioning of abandoned bore-wells and tube-wells
13. Creation of Tree Plantation along the River Stretches
14. Encouraging climate resilient agriculture
15. Implementation of existing conservation zone till the formation of Authority and prevention of change in landuse pattern
16. Creation of adequate awareness among the local people

Volume-II of the Report deals with the existing status of the superstructures that are subject matter in the batch of Writ Petitions (WP) No. 38218/2013 and its connected 60WPs filed before the Hon'ble High Court of Karnataka as per the 5th ToR. Out of 61 WPs, 58 are connected to godowns, one is connected to layout development, one is connected to industry and one is connected to 870 individual residential houses. About 99% of the WPs are filed from the villages located in the Arkavathi river course, which also shows that there is remarkable growth in these villages. Ground verification was done by a team consisting of EMPRI representatives, Revenue Department, KSPCB representatives and the representatives of the petitioners. A Panchnama was drawn in each case which was signed by the members present. During the inspection, management of solid and liquid wastes, and the documents related to permissions and operation of superstructures were also verified. Ground verification of the superstructures has revealed that the godowns are not permitted by the Planning Authorities, and are rented to companies to store the finished products. Further, the solid and liquid wastes generated by most of these superstructures are directly polluting the Arkavathi river. A map is prepared showing the location, information and status for each of these superstructures connected to the Writ Petitions along with photographs and GPS location.

WP 48047/2013 was filed by the group of 870 householders distributed in the 20 villages (Zone-3 and 4 of Arkavathi river course), which are constructed between the years 1942 and 2000. Major superstructures are distributed in Adakamaranahalli, Siddanahosahalli and Dombarahalli villages and within the Gramathana limit. Within the 870 households, only 669 households could be identified and verified. The survey has revealed that some of the houses are built under the scheme of Ashraya Yojane and Janata Nivas Yojane. The households surveyed include multi-storied houses (G+1 to G+3) with commercial complexes or small provision for stores and mostly occupied by tenants. Houses renovated to G+2 and above are against the TGR preservation Notification located in Zone-4. Electricity and water have been supplied by BESCOM and Grama Panchayats respectively. Each house is facilitated with lavatory and soak pit for sewage, but generated wastewater is discharged into the storm water drains and in some villages, the solid wastes are disposed in open land or burnt because there is no proper system to manage solid waste.

Volume-III of the Report has the supportive documents of the Volume-I and II reports included as annexures such as the Government of Karnataka Notification, Hon'ble High Court of Karnataka Interim Orders, proceedings of meetings, Panchayat orders, Reports on TGR as biodiversity hotspot, Report on TGR drainage pattern, Landuse/ Landcover statistics and maps, Maps on encroachment of tanks, Secondary data received from various line Departments such as NPA, KSPCB, etc., The Karnataka Arkavathi and Kumudvathi River Basin Conservation and Development Bill, 2013 proposed by UDD, *Panchanama* for ground verification of 61 WP's superstructures, Questioner format used to survey the residential superstructures, Details of Decentralised Wastewater Treatment System (DEWAT) and concept note for the revival of Arkavathi river by use of the treated wastewater.

There is no single solution to conserve the TGR catchment area since the issues are highly complex and interlinked. So the integrated solution will be achieved only by the stringent implementation of recommendations for the sustainable management of TGR catchment area. The above recommendations may be considered for the implementation by the consent Government Departments/ Authorities who can develop their strategies and plans in detail. Further, the revival of the Arkavathi and Kumudvathi rivers are bound to be long term process that cannot be expected to happen in a short period of time. The desired results can be achieved only by sustained and coordinated efforts.

Chapter-1: General Introduction

> Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity.
>
> **-Kofi Annan, Former UN Secretary-General**

The importance of water is too obvious to require much elaboration. Water is life. It is one of the most critical natural resources for the continuance of life on earth. It is a scarce, precious and replenishable natural resource that cannot be created. Its true value can be known only when it is not available.

Bengaluru with an average rainfall of 900mm is the capital of Karnataka State and one of the important industrial centers of southern India that has witnessed rapid increase in population, particularly during the last decade. The population of Bengaluru has increased to 9.6 million (Census of India 2011, Karnataka) and geographical expansion of 2,196 km^2, on account of globalization causing invasion on peri-urban and rural areas.

Bengaluru's location in the semi-arid peninsular plateau region makes it naturally water scarce. The first official water supply for the city was from these water bodies- a 100 year old Hesaraghatta tank (Chamarajendra Reservoir) on the Arkavathi at a distance of 18-20km from city and the TG Halli reservoir (Chamarajasagar Reservoir) which was built in 1932, at the confluence of the river Arkavathi and Kumudvathi 35-40 km away (Mohan Kumar *et al.*, 2011). As the supply from local water bodies became inadequate with increase in population, the Cauvery water supply scheme was conceived. As the demand for the drinking water from the city is increasing, it has become important to revive/ conserve the existing water-bodies (Figure-1.1).

1.1. Background of the Present Study:

TG Halli reservoir was an important source of drinking water for Bangalore till 1990s. However over the years the flow to the TG Halli reservoir got reduced and the water quality also deteriorated. With the objective of understanding the reasons for diminished water flow to TG Halli reservoir and measures to be taken for its conservation, the Bangalore Metropolitan Region Development Authority (BMRDA) initiated a study through The Indian Space Research Organization-Indian Resources Information and Management Technologies Pvt. Ltd. (ISRO-IN_RIMT) in the year 2000. The study considered various aspects of the TGR Catchment and suggested a host of measures and regulations for further developments that was damaging the quality and quantity of flow. Accordingly the Government of Karnataka vide Government Order no. FEE 215 ENV 2000, dated 18.11.2003 declared four zones and regulated developments as given in Annexure-1.1.

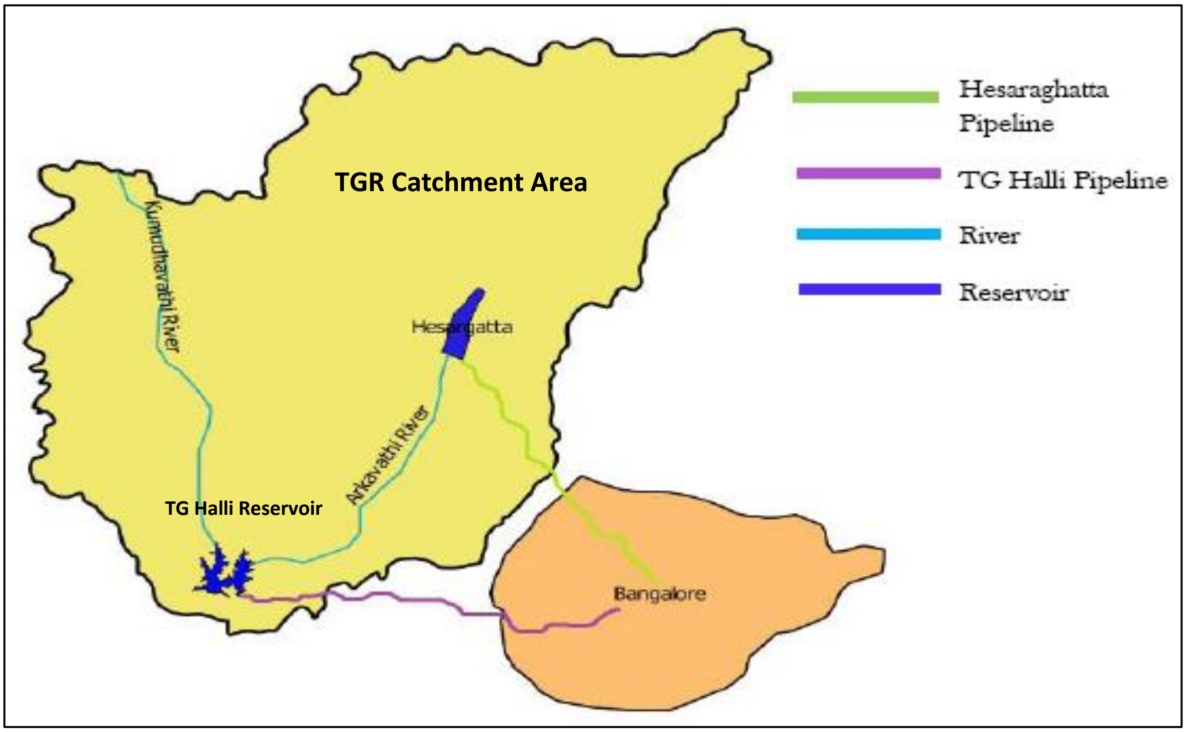


Figure 1.1: Drinking water supply to Bengaluru city, before December 2012

However despite the Government Order, developments have taken place at a fast rate in these zones. Also the quality of water has further deteriorated and BWSSB has stopped supplying drinking water from TG Halli reservoir since 2012. In the meantime the Government of Karnataka withdrew the G.O. dated 18.11.2003 vide G.O. No. APG 01 ENG 2011 dated 24.07.2014 (Annexure-1.2). The Hon'ble High Court took up the matter and vide Order, in case number: WP 38218/2013 dated 28.11.2014 has stayed the withdrawal of the G.O. dated 24.07.2014. The order of Hon'ble High Court of Karnataka has been annexed in Annexure-1.3. There are also a large number of Writ Petitions pending in High Court because of the interventions by BDA and other authorities to demolish or take action with regards to the unauthorized developments.

The Hon'ble High Court has appointed *Amicus Curiae* on 18.12.2014 in case number: WP 38218/2013, to get a holistic view of the entire issue. The order dated 18.12.2014 is annexed in Annexure-1.4. Further vide Order dated 02-02-2015 in case number: WP 38218/2013, the Hon'ble High Court has entrusted EMPRI to take up a comprehensive study on the entire TG Halli reservoir catchment areas (Annexure-1.5) which encompasses the detailed ToR for the study given in paragraph 1.4. The present study has been conducted by EMPRI within the scope of the ToR given by Hon'ble High Court. The study has been undertaken in a limited time frame of five months. Earnest effort has been made to obtain necessary information from various Government Departments/ Agencies, conduct field inspections and to study all published reports on TGR catchment, analyse the existing legal and policy framework and collect the best practices nationally and internationally. In the following section some basic information about the TGR catchment and important water resources has been given. However the details of the observations made during field verifications has been separately covered in chapter-4.

1.2. Thippagondanahalli Reservoir Catchment:

As per the report of ISRO, the TGR catchment i.e., the upper Arkavathi river catchment is 1453 km^2, covering parts of Doddabalapur, Nelamangala, Devanahalli, Magadi and Bengaluru Taluks. The National Highways Number 4, 48 and 207 pass through the catchment. There are three distinct sub-catchments in the TGR i.e., Hesaraghatta, Arkavathi and Kumudvathi covering an area 606Km^2, 376.6 km^2 and 462.6 km^2 respectively. TGR catchment consists of 735 villages and 85% of the catchment has a slope less than 3%, which can be classified as flat terrain. Catchment comprise mostly a rural landscape with agriculture and farming as main features but during the last two decades, a number of industries, housing complexes, unauthorized layouts etc., have come up in the catchment which are responsible for massive extraction of groundwater and also for polluting the watercourse due to discharge of untreated sewage. There are 541 tanks in the catchment which are mostly dry with high rate of soil excavation. (ISRO and IN-RIMT, 2002)

1.2.1. Hesaraghatta Reservoir:

In 1894 the Government proposed the first treated water supply to Bengaluru by enlarging the irrigation tank near Hesaraghatta constructed across the river Arkavathi about 15 kms from Bengaluru. The tank covers a surface area of 660.32 Ha and has a storage capacity of 19.68 Million cubic meters (MCM) of water (ISRO and IN-RIMT, 2002). An open channel conveyed the water from the tank up to Soladevanahalli over a distance of about 6 kms by gravity and from there the raw water was pumped to the treatment plant located at 18th Cross, Malleswaram, Bengaluru. There is a syphon at the Hesaraghatta tank used to discharge flood water when the reservoir is full and also there is rain gauge to measure the rainfall (Bangalore Water Supply and Sewerage Board [BWSSB], 2015).

Due to the proximity of the tank to Bengaluru a lot of unauthorized development has taken place in the catchment gradually reducing the inflow into Hesaraghatta tank. The tank became almost dry from 1980 onwards. However, there are a number of bore wells in the tank bed and water is drawn from these to meet the local needs (BWSSB, 2015). Reservoir is deteriorating and drying up (Figure-1.2), reducing its reliability as water supply source. As per the discussions with the local villagers by EMPRI research team, from the last 25 years water from Hesaraghatta tank is not supplied to the Bengaluru city. The reasons attributed for the deterioration of the tank are erosion, sand mining, encroachment, ground-water exploitation etc.

Figure-1.2. Hesaraghatta Reservoir

1.2.2. Arkavathi River:

The River Arkavathi is a tributary to river Cauvery, it takes birth in Nandi hills and runs for 190 km before joining river Cauvery at Sangam in Kanakapura Taluk with a total catchment of 4,150 km^2 from origin to confluence with river Cauvery (2^{nd} Advisory Committee Meeting under the study Thippagondanahalli Catchment area, Cauvery Neeravari Nigama Niyamitha, 2015). The river's catchment overlaps with the western portion of the rapidly growing metropolis of Bengaluru. The River covers parts of 5 taluks – Doddaballapur, Nelamangala, Magadi, Bangalore North, Bangalore South, within two districts – Bangalore Urban and Bangalore Rural. The river flows from north to south in the southwesterly direction downstream of Hesaraghatta tank for about 33km till TG Halli reservoir. The River feeds a series of cascading tanks and the two major water reservoirs (Hesaraghatta and Chamrajasagar) that were once major sources of water to Bengaluru city.

As the River Arkavathi is non-perennial, major water flow is seen only during monsoon and during summer the river is mostly dry except for the inflow of polluted water i.e. sewage from households and effluents from industries, thus rendering the river water unfit for use even during monsoon. And also due to over exploitation of ground water the retention of surface water has reduced leading to decline in the river flow.

1.2.3. Kumudvathi River:

The River Kumudvathi is a tributary of river Arkavathi which originates from Shivagange hills of Bangalore Rural district and eventually flows to Chamarajasagar Reservoir of Thippagondanahalli. The River is filled with water only in monsoon season and in the rest of the year it is in shriveled condition. The water trickles down to this river from North to South direction through fringes of drains connecting series of lakes and tanks across the villages of Nelamangala taluk of Bangalore Rural district and Magadi taluk of Ramanagar district (ISRO-IN_RIM). The encroachments due to extension of settlements and the emerging industries in the river catchment zone have induced anthropogenic activities which have resulted in decline in surface water as well as ground water in the region.

1.2.4. Chamarajasagar Reservoir (Thippagondanahalli reservoir):

With the drying up of Hesaraghatta tank in the year 1922, the situation demanded urgent remedial measures, for which Government constituted a committee under the chairmanship of Sir M. Visveswaraiah in the year 1926. After detailed investigation of all possible sources of supply including the rivers Cauvery and Hemavathy, the Visveswaraiah committee recommended

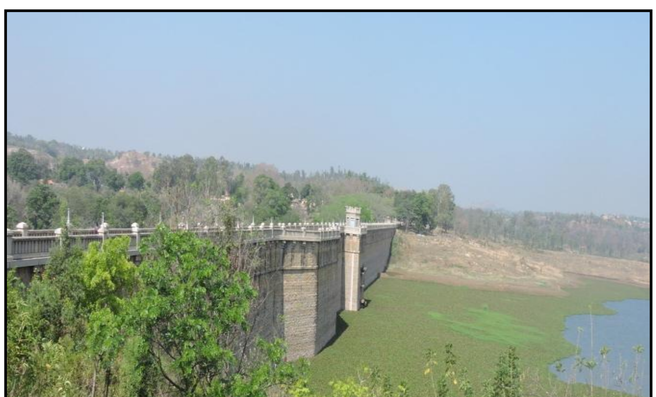


Figure-1.3. Chamarajasagar Reservoir

the construction of a reservoir on the river Arkavathi by building dam at T.G. Halli (Figure-1.3) 25 km from Bengaluru city downstream of Hesaraghatta tank. The dam was constructed with an impounding capacity of 1072 mcft. for a supply of 5 MLD of water to the city. During the year 1960-61, the height of the reservoir was raised to increase the capacity to 3340 mcft. Over a period of time suitable interlinking in the raising mains were made and the total supply was increased to 145 MLD from TG Halli (BWSSB, 2015).

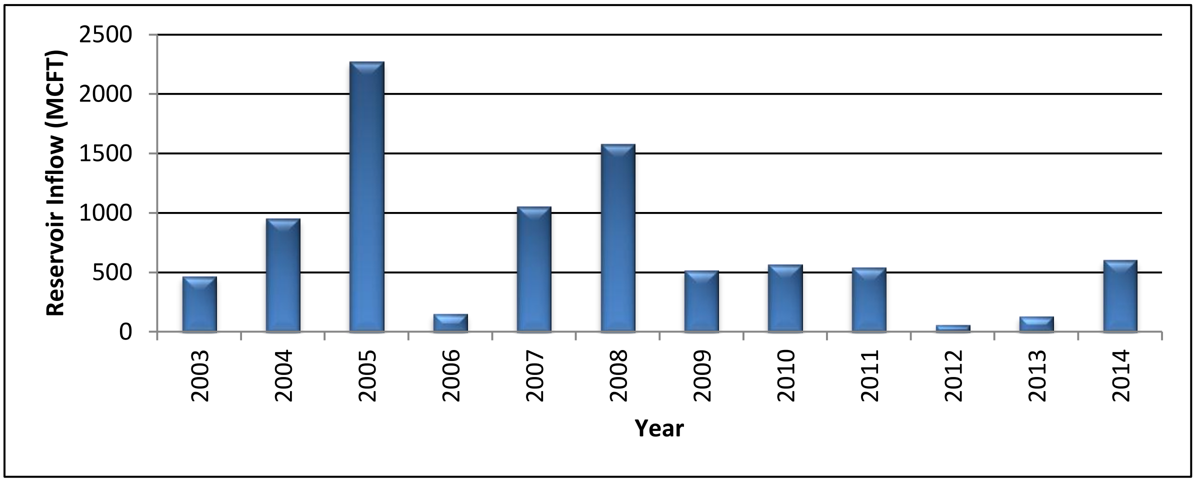


Figure-1.4. Inflow to TGR from catchment (BWSSB, inflow data of CRS reservoir)

The TG Halli treatment plant was constructed in 3 stages. The first stage treatment plant commissioned in 1933 consists of settling tank and rapid sand filter. The second stage treatment plant, commissioned in 1958, consists of clarifiers and filter bed of 6.7 MLD capacities and lastly the third stage commissioned in 1963 consists of clariflocculator and filter bed of 70 MLD capacity (Figure-1.5). The treated water is stored at Thorekkera intermediate pumping station before distribution to the city. At present the TG Halli treatment plant is not under working condition (Source-BWSSB).

Figure-1.5. Chamarajasagar Reservoir

As per Figure-1.4, TGR has received highest inflow in the year 2005. The TGR still receives some inflow mainly consisting waste water through the Arkavathi and Kumudvathi Rivers, leading to pollution in the water body. Till recently supply from TG Halli was scanty and was restricted to about 50 MLD on an average, that too for a few months in a year, and from December 2012 the supply of water was completely stopped (Diversion of 5 TMC of water from the Hemavathy Reservoir into the Arkavathi Catchment, BWSSB,).

1.3. Battle for Clean water:

For a long time i.e., from 1895-1972, the river Arkavathi was lifeline for Bengaluru city. The supply of water from two old reservoirs, commissioned during the British regime, viz, Thippagondanahalli and Hesaraghatta Reservoirs of Arkavathi river, a tributary of river Cauvery has become unreliable owing to the declining flow of water in the catchment. The river Arkavathi is presently under serious threat, since it is not getting the required rain water from its catchment, due to formation of substantial layouts within the catchment area changing the terrain and topography, unauthorised obstructions, over-exploitation of ground water, etc.

Over the past several years, parts of the catchment have been encroached, besides substantial silting has also been observed. The catchment of the river Arkavathi was predominantly agriculture in nature but due to its nearness to the city it underwent a change in land use by developments which are mostly unauthorized. These developments have in some places encroached on the river bed and also on the small streams that were conveying the rain water to the river, which has resulted in gradual reduction of flow. The entries of untreated sewage from these developments have polluted the river. Therefore there is no supply of drinking water from this source to the city since the last few years.

Hence meeting water needs of the growing population together with the expansion of water supply networks to Bengaluru city, remains a major challenge because of rapid change in water use pattern in the recent decades. As the population is increasing drastically, to meet the demand of the population, Cauvery water supply scheme stages I, II, III, IV, phase I and phase II was brought into the city, as it is not possible to supply water from Thippagondanahalli Reservoir (Figure-1.6) on the river Arkavathi due to lack of sufficient flow (Deepak Kumar and Vasudevan, 2009).

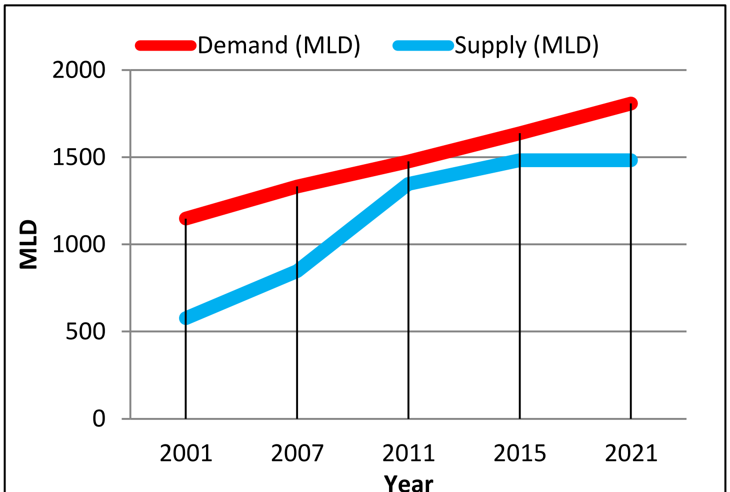


Figure-1.6. Demand and supply for Bengaluru City through Cauvery Source (Deepak Kumar and Vasudevan, 2009)

The expert committee chaired by B.N. Thyaga Raja, Engineer in Chief (retired), BWSSB, formed by the Government for identification of sources for sustainable water supply to Bengaluru for the next 50 years, in their report have stated that any augmentation of freshwater in future to the city will be only by diversion of water from the west flowing rivers and this water has to come to Arkavathi catchment only before supplying to Bengaluru city. Also protection of the Arkavathi and Kumudvathi catchment and rejuvenation of these rivers is essential to get back the earlier supply. The committee suggested that the entire catchment be declared as GREEN BELT and allow developments only under the green belt criteria (information taken from BWSSB contains a letter from B.N. Thyaga Raja, Engineer in Chief (retired), BWSSB, 2015 to Sri. Anjum Parvez, IAS, Chairman, BWSSB, Bangalore).

Since Cauvery and Arkavathi rivers are unable to meet the demand of the whole city a clean water scheme with recycling and reuse of treated wastewater should be implemented and also reviving of these rivers is a key factor to fill the huge gap between demand and supply of drinking water in Bengaluru city.

1.4. Terms of References:

The Department of Ecology and Environment (DoEE), Government of Karnataka (GoK) had entrusted the study on "Rapid assessment of TGR catchment area and its preservation zone" to EMPRI vide G.O. No. APG 96 ENG 2014 (Part-2) dated: 02.12.2014 (Annexure-1.6). Subsequently the Hon'ble High Court of Karnataka has given an interim order on 02.02.2015 and has entrusted EMPRI (Annexure-1.5) to carry out a Comprehensive assessment of TGR catchment area and its preservation zones, with following Terms of References (ToR):

1. To conduct a study and produce an accurate report on the exact state of affairs in the TGR Catchment area in general and Zones-2, 3 and 4 in particular by surveys with photographs, maps and sketches so as to eliminate any factual controversy in respect of the course and location of the Arkavathi and Kumudvathi rivers and constructions and developments that have taken place in Zone-2, 3 and 4.
2. To identify all superstructures and infrastructure that has come up in the TGR catchment area in general and Zones-2, 3 and 4 in particular, post the Notification No. FEE 215 ENV 2000 dt. 18/11/2003 issued by the Government of Karnataka and superimpose structures on map or satellite imagery. Particular attention will be put up in Zone-3 and 4.
3. To identify and denote the survey numbers of the superstructures and any infrastructure that have been put up, including details of the permissions, if any that have been granted by Authorities such as Planning Authorities, KSPCB, etc.
4. To identify the nature of superstructures and the purpose of presently being utilized.
5. To specifically identify the structures that are subject matter in the batch of 61 Writ Petitions filed before the Hon'ble High Court of Karnataka will be identified in the map or satellite imagery.
6. To estimate the TGR water yield for the past 30 years based on the secondary data available with the State Agencies and determine the availability of water in Arkavathi and Kumudvathi Rivers.
7. To determine the extent of water quality deterioration in the Arkavathi and Kumudvathi Rivers since the 2003 notification by water quality analysis from different points.
8. To identify and analyses the specific reasons for the pollution of Arkavathi and Kumudvathi rivers.
9. To identify the adopted methodologies in other States in India and in other Countries for rejuvenation, conservation and preservation of rivers in urban agglomerations.

10. To recommend methods for rejuvenating the Arkavathi and Kumudhavathi rivers and protecting the river ways from further deterioration and also to recommend the permissibility of further developments and establishment of superstructures in the TGR catchment area.

1.4.1. Methodology Adopted:

For undertaking the study entrusted by Hon'ble High Court of Karnataka, EMPRI has taken multi-stakeholder approach by collecting updated information from concerned Departments, Government Agencies, analysis of previous reports on the catchment area, consultation with the experts, consultation with local people to elicit their views, etc. An Advisory Committee was formed (Annexure-1.7) consisting of representatives from all the line departments and three meetings of the Advisory Committee have been held. Further, a Technical Committee consisting of water resources experts were also formed (Annexure-1.8). Detailed presentation and deliberation has also been conducted with the Research and Training Advisory Committee of EMPRI. The following methodology has been adopted carrying out the study:

a. The 15 members core working team of Centre for Lake Conservation (CLC), EMPRI has carried out detailed field verifications in TGR catchment area in general and zones-2, 3 and 4 in particular to access the state of affairs as per ToR-1.
b. With regards to study of superstructures and infrastructure (ToR-2, 3 and 4) in the TGR catchment area as per the Order of Hon'ble High Court of Karnataka, the study was taken up by Karnataka State Remote Sensing and Application Centre (KSRSAC) by analysing the Land Use/ Land Cover change between the years 2003 and 2014 (LISS-IV).
c. For on ground verification of the properties involved in Writ Petitions, a Committee was formed consisting of representatives from the concerned departments including KSPCB (Karnataka State Pollution Control Board), BDA, Bangalore Urban Zilla Panchayat, BIAAPA (Bangalore International Airport Area Planning Authority), BMRDA (Bangalore Metropolitan Region Development Authority) and BMICAPA (Bangalore Mysore Infrastructure Corridor Area Planning Authority). This committee carried out extensive field verification of 61 Writ Petitions (WP). Whereas the 60 WP are connected to the individual superstructures and one WP is connected to the 870 households.
d. Secondary data available with the State Agencies such as BWSSB, Cauvery Neeravari Nigam Ltd., etc. were used to identify the yield and the availability of water in the Arkavathi and Kumudvathi rivers.
e. For assessing the deterioration of water quality in the two rivers of the TGR catchment area, 25 water samples were collected. Further, the water quality secondary data from KSPCB and BWSSB for the past years have been collected and analysed.
f. The National and International guidelines for the rejuvenation, conservation and preservation of river courses in urban agglomerations have been collected from the internet and analysed. The guidelines/ case studies/ rejuvenation efforts which were found to be more applicable to the context of the present study, have been analysed.

g. With regards to the recommendations for rejuvenating the two rivers and permissibility of further developments in the TGR catchment area, suggestions have been formulated in consultation with the experts, opinions expressed by three Advisory Committees (Annexure-1.9), Technical Committee (Annexure-1.10), four Stakeholder Meetings and the 9^{th} Research and Training Advisory Committee of EMPRI.

Within the time constraint, all efforts have been made to address all the issues as per the ToR and come up with suitable suggestions for rejuvenating the Arkavathi and Kumudhavathi rivers, and protecting the river ways from further deterioration.

Chapter-2: TGR Catchment Area and Notification

2.1. Introduction:

The issue in TGR catchment area became prominent in 1978-79, when 414 acres of land in the banks of Arkavathi River, within a distance of about 2 Kms from Chamaraja Sagar Water Reservoir at Thippagondanahalli, was converted to non-agriculture purposes for Arkavati Farmers Cooperative Society, to be developed as a township by DLF (Delhi Land and Finance Universal Ltd., Delhi). Necessary permissions were also accorded by concerned authorities. In 1984, BWSSB filed appeals before the Karnataka Appellate Tribunal against the orders of the Deputy Commissioner according permission for conversion of the lands for non-agricultural purpose leading to establishment of a township near TGR. The Tribunal dismissed the appeals of the BWSSB holding that it had no *locus standi* to present the appeals and its grievance was imaginary. Aggrieved by the order of the Appellate Tribunal, the BWSSB filed Writ Petitions before the Hon'ble High Court of Karnataka.

During the pendency of the Writ Petition (WP) itself, DLF (Delhi Land and Finance Universal Ltd., Delhi) realising the serious objections to the Township which it had proposed to establish had submitted a revised proposal as Green colony named as Arkavathi Green Valley Retreat Scheme with Central Sewerage System to the Government in 1985. In 1991, State Government considered the proposal and constituted an expert committee for reviewing the proposal. In the year 1992 the Hon'ble High Court had quashed the orders of land conversion, subsequent to which the DLF had filed WP in Hon'ble Supreme Court. In 1998, Hon'ble Supreme Court gave the judgment allowing the project subject to certain conditions, but various public organizations opposed this decision and finally the Government withdrew the permission given to DLF to construct the housing complex during the year 1999 (High Court of Karnataka vide order dated 24.04.1992 for the WP No. 19919-19954 and 21172-21177/1982).

Gradually the attention on the TGR and its catchment increased due to reduced and fluctuating inflow into the TGR which has been an important source of drinking water for Bangalore. A study was initiated by BMRDA and undertaken by ISRO to analyse the reasons for reduced inflow and suggest ways to increase the inflow and maintain the quality of water in the TGR. The study has been analysed in detail in Chapter-3. Based on the recommendations of the ISRO report, the Government of Karnataka issued a Notification for preservation of the entire catchment of TGR as well as stretches around Arkavathi, Kumudvathi and also the reservoir itself. The Notification, the preservation zones and the major components of these zones have been covered in this Chapter.

2.2. Thippagondanahalli Reservoir (TGR):

The first protected water supply from the Hesaraghatta tank across the Arkavathi river was initiated in the year 1895 to provide 55 LPCD (Litres Per Capita per Day) of water to 2,50,000 people in Bangalore City. But in 1922, the Bangalore community had experienced water shortage because of drying up of Hesaraghatta reservoir. In order to ensure water security for Bangalore community a Committee was constituted under the chairmanship of Late Sir M. Visvesvaraya, which suggested construction of a dam across Arkavathi river at Thippagondanahalli as TGR scheme.

Thippagondanahalli Reservoir is situated in west of Bangalore City, which was constructed at the confluence of Arkavathi river originating from Nandi hills and Kumudvati river originating from Shivaganga hills and beyond Tyamagondalu town. The construction of masonry dam was initiated in the year 1930 and completed in 1934 to store water upto 67.22MCM. Due to the rapid urban sprawl and increased demand for water, the TGR main dam and waste weir was raised by 10ft. to store 85.97MCM of water during the year 1954. During the year 1964, the water storage capacity was further increased to 94.72MCM as a third phase. TGR reservoir is spread over 15 villages with the height and length of the dam being 170 ft. and 1480 ft. respectively.

2.3. Thippagondanahalli Reservoir (TGR) Catchment Area:

TGR has a catchment area of 1453 km^2, which included the Hesaraghatta reservoir and 617 tanks. The cumulative storage of all these tanks and Hesaraghatta reservoir is 143 MCM (Million Cubic Metres); about one and a half times the storage of TGR (ISRO and IN-RIMT, 2000).TGR catchment area is located between the Latitudes 12° 56' and 13° 23' 15"N and Longitudes 77° 13' 30"and 17° 41'15" E. The catchment area extends upto Dobbaspet towards northwest of Bengaluru City on the Bengaluru to Tumkur National Highway (NH-4) and upto Nandi hills. The NH-4 connecting Bengaluru City with Pune, NH-48 connecting Bengaluru City with Mangalore and Bengaluru to Arsikere Broad-gauge railway line are the major transport infrastructure that passes through the catchment area. Nelamangala and Doddaballapur are the two major towns located within the catchment area.

Most of the TGR catchment is underlain by hard-rock, consisting of gneiss and granite, whereas the highly weathered soils extend from the land surface to about 20m below grade level (b.g.l.) and form a shallow aquifer. There are three sub-catchment areas in the TGR catchment area namely, Hesaraghatta (606.57km^2), Arkavathi (376.59km^2) and Kumudvati (462.60km^2) sub-catchment areas. The entire catchment area is spread over four districts namely Bengaluru Urban, Bengaluru Rural, Ramanagara and Chikkaballapura.

2.4. TGR catchment area preservation Notification:

In the 140thmeeting of KSPCB (24thJuly'2002) it was recommended that further developments in TGR catchment area should be regulated as per ISRO report to ensure the improvement of quantity and quality of inflow of water in to TGR, and also suggested to constitute a separate Authority for the conservation of TGR catchment area. Further, in a meeting conducted by Urban Development Department (UDD) chaired by Principal Secretary (8thJuly'2003) it was also resolved to protect TGR catchment area by regulating the activities to prevent the inflow of contaminants in TGR. Based on the recommendations of UDD, KSPCB and the ISRO/IN-RIMT (2000) report 'Reduced inflow into T.G. Halli Reservoir – A Remote Sensing Based Evaluation', the Department of Ecology & Environment had notified the entire TGR catchment area (1453 km^2) into four zones (Annexure-1.1) (G.O No.FEE 215 ENV 2000 dt.18/11/2003) to

(a) Protect the eco-sensitive catchment area by regulating anthropological activities and
(b) Provide water security for Bengaluru city in public interest since the water inflow to TGR was getting reduced.

TGR catchment area notification took into consideration the recommendations of ISRO report (2000) that suggested the following;

i. Declare entire TGR catchment area as conservation zone and adopt suitable land utilization strategy from the point of regulating the Urbanization/ Industrialization
ii. Declare about 10km radius around TGR as protection Zone
iii. Regulate buffer of around 2km on either side of the Arkavathi and Kumudvathi courses (within TGR catchment area) for protecting the TGR from further deterioration
iv. Implement necessary measures to prevent alteration of drainage course and impediments to the flow of water along the Arkavathi and Kumudvathi Rivers
v. Checking of uncontrolled disposal of effluent/sewage into the streams/ surface waterbodies within the catchment.
vi. Implementing suitable measures for controlling over-exploitation of groundwater in the catchment, implementing proper waste management system and implementing programmes for revival of the tanks in the catchment.

The notification declared that the directions would come into effect immediately (18thNovember'2003) and non-compliance of the same would attract penal action under sections 15 and 17 of the Environment (Protection) Act, 1986. The notification also directed the concerned Authorities (mentioned in the notification) to implement the directions with wide publicity of the provisions and submit the monthly compliance report on the action taken to the Secretary (Ecology and Environment), Department of Forest, Ecology and Environment. The notification also was copied to the Compiler of the Karnataka Gazetteer Department for publication in the Gazette.

The entire TGR catchment area is spread over 735 villages of the Middle Cauvery Basin, which were notified as four categorised zones (Figure-2.1) The entire catchment area falls under the jurisdiction of five Planning Authorities namely, BDA (Bangalore Development Authority), BMRDA, NPA (Nelamangala Planning Authority), MPA (Magadi Planning Authority) and BIAAPA. The numbers of villages in the different categorised zones falling under the NPA area are depicted in Venn diagram (Figure-2.2), the diagram also showed that the 550, 19, 21 and 4 entire villages fall in the zone-1, 2, 3 and 4 category respectively (Table-2.1). Village and Survey number wise categorised zone in TGR catchment area are illustrated in the NPA website (www.npa.in).

2.4.1. Zone-1:

The entire TGR catchment area was declared as Zone-1 apart from the other three zones. The area is spread in the districts of Bengaluru Urban (five hoblis in Bangalore North and Thavarekere hobli in Bangalore South taluk), Bengaluru Rural (four hoblis in Doddaballapur, Kundana hobli in Devanahalli and three hoblis in Nelamangala taluk), Ramanagara (Soluru hobli in Magadi taluk) and Chikkaballapura (Nandi hobli in Chikkaballapura taluk).

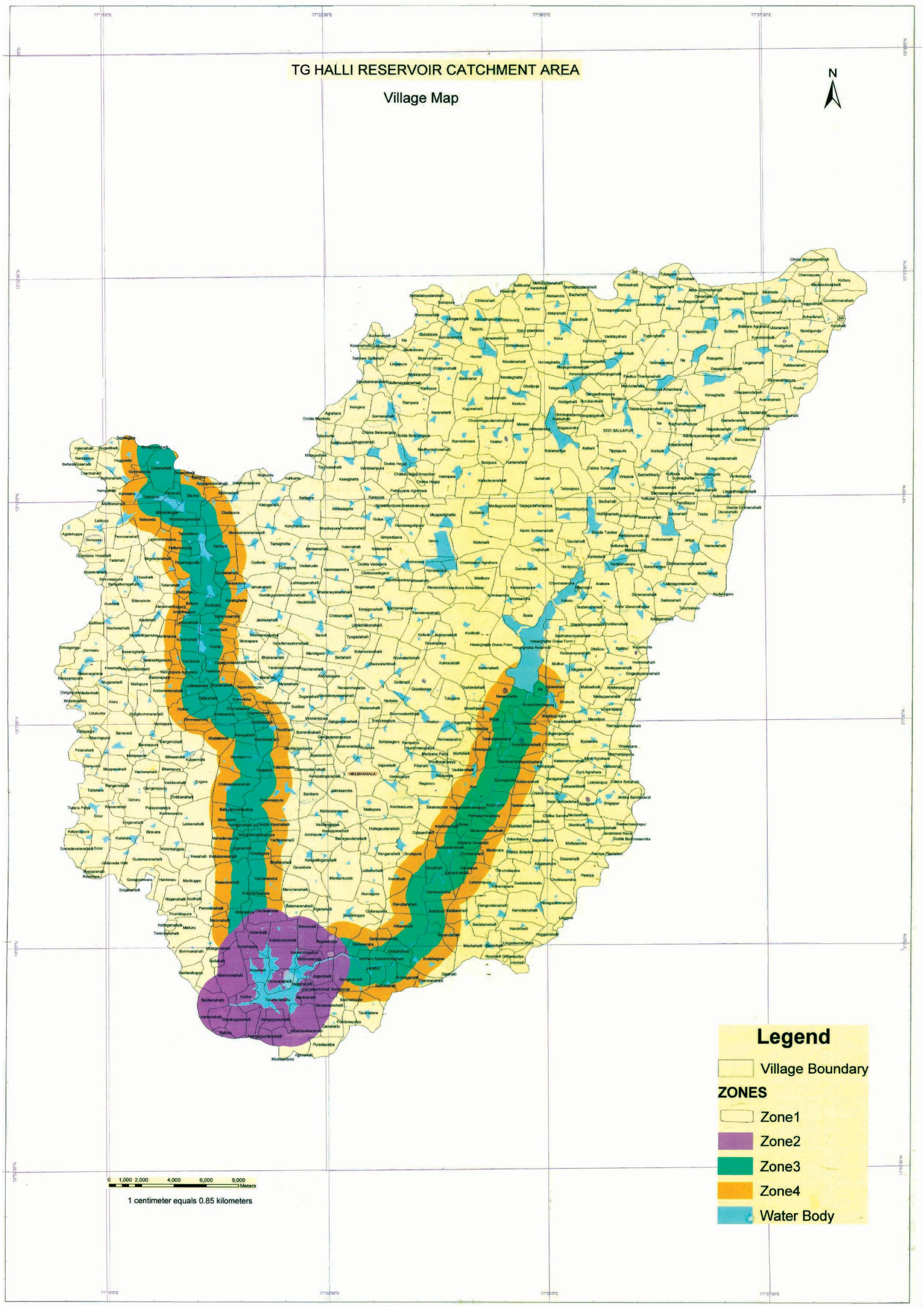


Figure-2.1: TGR catchment area map with categorised zone and village boundary (Source: www.npa.in)

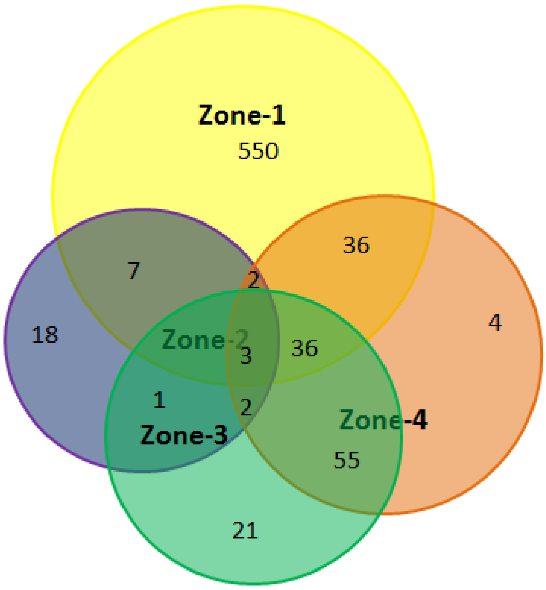


Figure-2.2: Venn diagram for number of villages in categorised preservation zones
(Source: www.npa.in)

Table-2.1: Zone-wise distribution of villages in the TGR catchment area

Zones	No. of Villages in Zone	Location of villages in River Course
1	550	Hesaraghatta, Arkavathi and Kumudvathi sub-catchment area
2	18	Around TGR
3	21	Six villages in Arkavathi and 15 villages in Kumudvathi river course
4	4	One villages in Arkavathi and three villages in Kumudvathi river course
1 & 2	7	-
1 & 4	36	17 villages in Arkavathi and 19 villages in Kumudvathi river course
2 & 3	1	Kumudvathi river course
3 & 4	55	19 villages in Arkavathi and 36 villages in Kumudvathi river course
1, 2 & 4	2	-
2, 3 & 4	2	Arkavathi river course
1, 3 & 4	36	11 villages in Arkavathi and 25 villages in Kumudvathi river course
1, 2, 3 & 4	3	Arkavathi river course
Total Villages	**735**	-

(Source: As per the map published in www.npa.in)

Zone-1 TGR catchment area is under the jurisdiction of Bengaluru Rural, Bangalore Urban, Chikkaballapura, Ramanagara Zilla Panchayat's and BBMP (Table-2.2) with the planning Authorities such as BMRDA, Bangalore International Airport Area Planning Authority (BIAAPA), Nelamangala Planning Authority (NPA) and Magadi Planning Authority (MPA).

Table-2.2: TGR catchment area location and its Jurisdiction Authorities

Zone No.	District	Taluk	Hobli	Planning Authority	Jurisdiction of
1	Bengaluru Rural	Doddaballapur	Tubgere	BMRDA	Bengaluru Rural Zilla Panchayat (ZP)
			Kasaba		
			Doddabelavangala		
			Madhure		
		Devanahalli	Kundana	BIAAPA	
		Nelamangala	Kasaba Nelamangala	NPA	
			Somapura		
			Thymgondala		
	Chikkaballapura	Chikkaballapura	Nandi	BMRDA	Chikkaballapura ZP
	Bengaluru Urban	Bengaluru North	Jala	BIAAPA	Bengaluru Urban Zilla Panchayat
			Hesaraghatta	BMRDA and BIAAPA	
			Yelahanka	BDA	BBMP
			Yeshwanthpur		
			Dasanapura	BMRDA and NPA	Bengaluru Urban Zilla Panchayat
		Bengaluru South	Tavarekere	BMRDA	
	Ramanagara	Magadi	Soluru	MPA	Ramanagara ZP
2	Bengaluru Rural	Nelamangala	Kasaba	NPA	Bengaluru Rural Zilla Panchayat
	Bengaluru Urban	Bengaluru South	Thavarekere	BMRDA	Bengaluru Urban ZP
	Ramanagara	Magadi	Kasaba	MPA	Ramanagara Zilla Panchayat
			Soluru		
3 & 4 Arkavathi River Course	Bengaluru Urban	Bengaluru North	Hesaraghatta	BMRDA and BIAAPA	Bengaluru Urban Zilla Panchayat
			Dasanapura	BDA and NPA	
		Bengaluru South	Tavarekere	BMRDA	
3 & 4 Kumudvathi River Course	Bengaluru Rural	Nelamangala	Kasaba Nelamangala	NPA	Bengaluru Rural Zilla Panchayat
			Somapura		
			Thymgondala		
	Ramanagara	Magadi	Soluru	MPA	Ramanagara Zilla Panchayat

While 550 villages are exclusively in Zone-1, there are many villages which are partly located in Zone-1 and partly in other Zones. For example, two villages are located partly in the Zone-1, 2 and 4; 36 villages are located partly in Zone-1, 3 and 4; and 39 villages located partly in Zone-1 and 4; whereas Sondakoppa village is located in all the Zones.

The Authorities responsible for the regulation of various activities are:

i. Overexploitation of groundwater are to be regulated and checked by the Department of Mines and Geology, and further they should not grant any fresh leases or licence for mining, quarrying and stone crushers in the TGR catchment area of Zone-1.

ii. UDD, BWSSB and NPA are to monitor the disposal of solid and liquid wastes in Zone-1 if done without scientific processing.

iii. Department of Agriculture/ Horticulture are to ensure adoption of rain water harvesting systems in all the existing buildings, within 18th May'2004. Further the Department should also promote organic farming including bio-fertilizers and bio-pesticides in Zone-1.

Further, the Zone-1 TGR catchment area is classified into Hesaraghatta sub-catchment area (C05CAM31), Arkavathi sub-catchment area (C05CAM32) and Kumudvathi sub-catchment area (C05CAM30) based on the watershed maps (WRIS, ISRO) are given in the Figure-2.3a, 2.3b and 2.3c respectively.

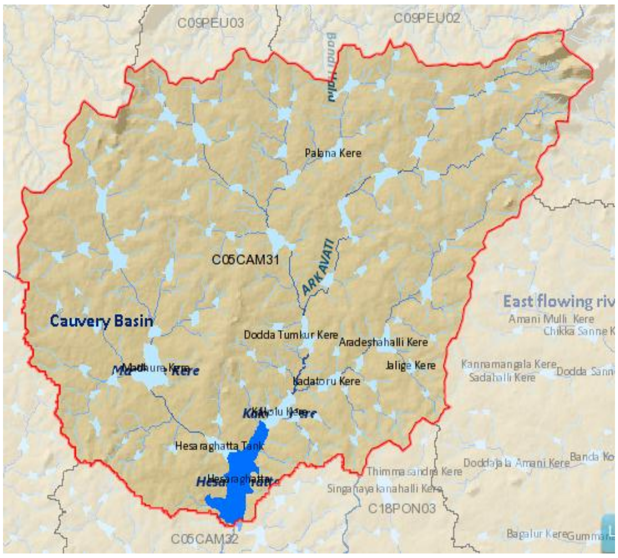


Figure-2.3a: Hesaraghatta Sub-catchment area

Figure-2.3b: Arkavathi Sub-catchment area

2.4.1a. Hesaraghatta Reservoir:

Hesaraghatta reservoir is an important waterbody located in the zone-1, which was used as the source of water for Bangalore city earlier by BWSSB. The earthen dam across the Arkavathi river in Hesaraghatta reservoir was constructed in the year 1881 with the height and length of 37.6 ft. and 5200 ft. respectively. The storage capacity of the reservoir is 1.1TMC (Thousand Million Cubic feet) with the water spread area of 6.8 sq.km over 11 villages. Most of the zone-1 TGR catchment areas fall in the Hesaraghatta sub-catchment area, which spread across the 606.6km^2.

Figure-2.3c: Kumudvathi Sub-catchment area

2.4.2. Zone-2:

The area covered within 2 kms from the TGR boundary was notified as Zone-2, where agriculture and related activities were only permitted. As per the Notification, the zone-2 area should be monitored by the UDD (Urban Development Department), BMRDA (Bangalore Metropolitan Region Development Authority), NPA (Nelamangala Planning Authority), BDA (Bangalore Development Authority), BWSSB (Bangalore Water Supply and Sewerage Board) and Directorate of Municipal Administrations. The area is spread across Bengaluru Urban (Thavarekere hobli in Bangalore South taluk), Bengaluru Rural (Nelamangala Kasaba hobli in Nelamangala taluk) and Ramanagara (Magadi Kasaba and Soluru hoblis in Magadi taluk) districts (Table-2.2).

2.4.3. Zone-3:

The Area covered within 1 km distance from the river banks of Arkavathi (only from Hesaraghatta tank upto TGR) and Kumudhavathi was defined as Zone-3. As per the Government Order only agricultural activities and agriculture related (allied) activities like horticulture, sericulture, plantation, farm forestry, poultry, cattle, goat, piggery, fisheries, etc., were permitted in this zone. Apart from the 21 villages that are completely in Zone-3; 55 villages are located partly in the Zone-3 and partly in zone-4; one village is located partly in the Zone-3 and partly in Zone-2; and one village is falling partly in Zones-2, 3 and 4 (Table-2.1).

2.4.3a. Arkavathi River Course:

The main stream of the Arkavathi river has its origin in the Nandidurga, Nandi hills in Chikkaballapura district, North of Bengaluru, joined by its first major tributary, the Kumudvathi river at TGR. The river runs 190 km and joins the Cauvery river at Sangam in Kanakapura taluk with the total catchment area of 4,150 km^2, which is part of the inter-state Cauvery River basin. The ephemeral Arkavathi river originates from Nandi hills taking a southwest path through Hesaraghatta tank and further South joins TGR. The sub-basin covers parts of eight taluks – Doddaballapur, Nelamangala, Magadi, Bangalore North, Bangalore South, Ramanagara, Anekal and Kanakapura within three districts– Bangalore Urban, Bangalore Rural and Ramanagara. Kumudvathi, Vrishabhavathy and Suvarnamukhi are the three tributaries of Arkavathi river. Arkavathi River sub-basin catchment overlaps with the western portion of the rapidly growing Bengaluru City under the jurisdiction of BBMP (Figure-2.4). Arkavathi river sub-catchment area is spread over 376.6 km^2 and flows from Nandi hills for 36 km length to reach Hesaraghatta reservoir.

TGR catchment area includes part of the Arkavathi catchment area as sub-catchment. The physiography of catchment area showed that the terrain has a gentle slope towards the South and the landscape is uneven with plains, hills and valleys. Major drainages of the TGR catchment area are the Arkavathi and Kumudvathi rivers, which are part of the Cauvery river basin. The network of streams/ nalas joining with either Arkavathi or Kumudvathi rivers forms the drainage pattern as dendritic and few places it is parallel to sub-parallel, which are controlled by joints and fractures.

Zone-3 and 4 of Arkavathi river course in TGR catchment area is spread only in the Bengaluru Urban district (Hesaraghatta and Dasanapura hoblis in Bangalore North and Thavarekere hobli in Bangalore South taluk). Zone-3 and 4 areas are under the planning Authority jurisdiction of BMRDA, NPA and BIAAPA. Two planning authorities sharing the jurisdiction boundary in Bangalore North taluk of Bangalore Urban district are Hesaraghatta hobli under the BMRDA and BIAAPA, and Dasanapura hobli under the BMRDA and NPA. As per the preservation notification, NPA prepared map, which show that the Arkavathi river course is spread over six entire villages in Zone-3; one entire village located in Zone-4; one village is located partly in Zone-2, 3 and 4; 14 villages are located partly in Zone-3, 1 and 4; 21 villages are located partly in Zone-3 and 4; and 22 villages are located partly in Zone-1 and 4 (Table-2.1).

2.4.3b. Kumudvathi River Course:

Kumudvathi river is a tributary of Arkavathi river encompassing major part of Nelamangala taluk, Bangalore Rural district and a part of Magadi taluk of Ramanagara district. It originates from a spring “Kumbha Thirtha”, which is located on the Eastern side of Shivagange hills. Hundreds of streams are flowing from different directions joining to form the trunk stream of the river, which measures 45 kms before it confluences with river Arkavathi at TGR. Non-perennial Kumudvathi river flows from North to South with a number of storage tanks along the streams. Kumudvathi watershed (460 Km^2) spread on 278 villages is located in the left bank of Cauvery watersheds and coded as 4B3B8 in the watershed atlas of Karnataka published by KSRSAC. Administratively, the watershed covers 195 villages of Nelamangla taluk (327 Km^2) and the rest of the area is covered in 83 villages of Magadi taluk (133 Km^2). The basin has 18 mini watersheds ranging in size from 12 to 40 Km^2 (Figure-2.5). There are 233 tanks in the basin, which are fed by one or a set of streams during the rainy season. 90% of the Kumudvathi watershed rainfall is monitored by the three rain gauges located in the Thyamagondalu, Nelamangala and Solur villages. The project report prepared by IAHV (International Association for Human Values, 2013) has assessed the water yield potential of Kumudvathi river as 2875.20MCFT. For reference, the same is produced in Table-2.3.

Zone-3 and 4 of Kumudvathi river course in TGR catchment area is spread in the districts of Bengaluru Rural (Nelamangala Kasaba, Somapura and Thymgondala hoblis in Nelamangala taluk) and Ramanagara (Soluru hobli in Magadi taluk). Zone-3 and 4 areas are under the planning Authority jurisdiction of NPA and MPA in Bangalore Rural and Ramanagara districts respectively. As per the map prepared by NPA marking the various Zones as per the Notification along the Kumudvathi river course, 15 villages are located in Zone-3; three villages are located in Zone-4; one village is located partly in the Zone-2 and 3; 34 villages are located partly in the Zone-3 and 4; 22 villages are located partly in the Zone-1, 3 and 4; and 17 villages are located partly in the Zone-1 and 4 (Table-2.1).

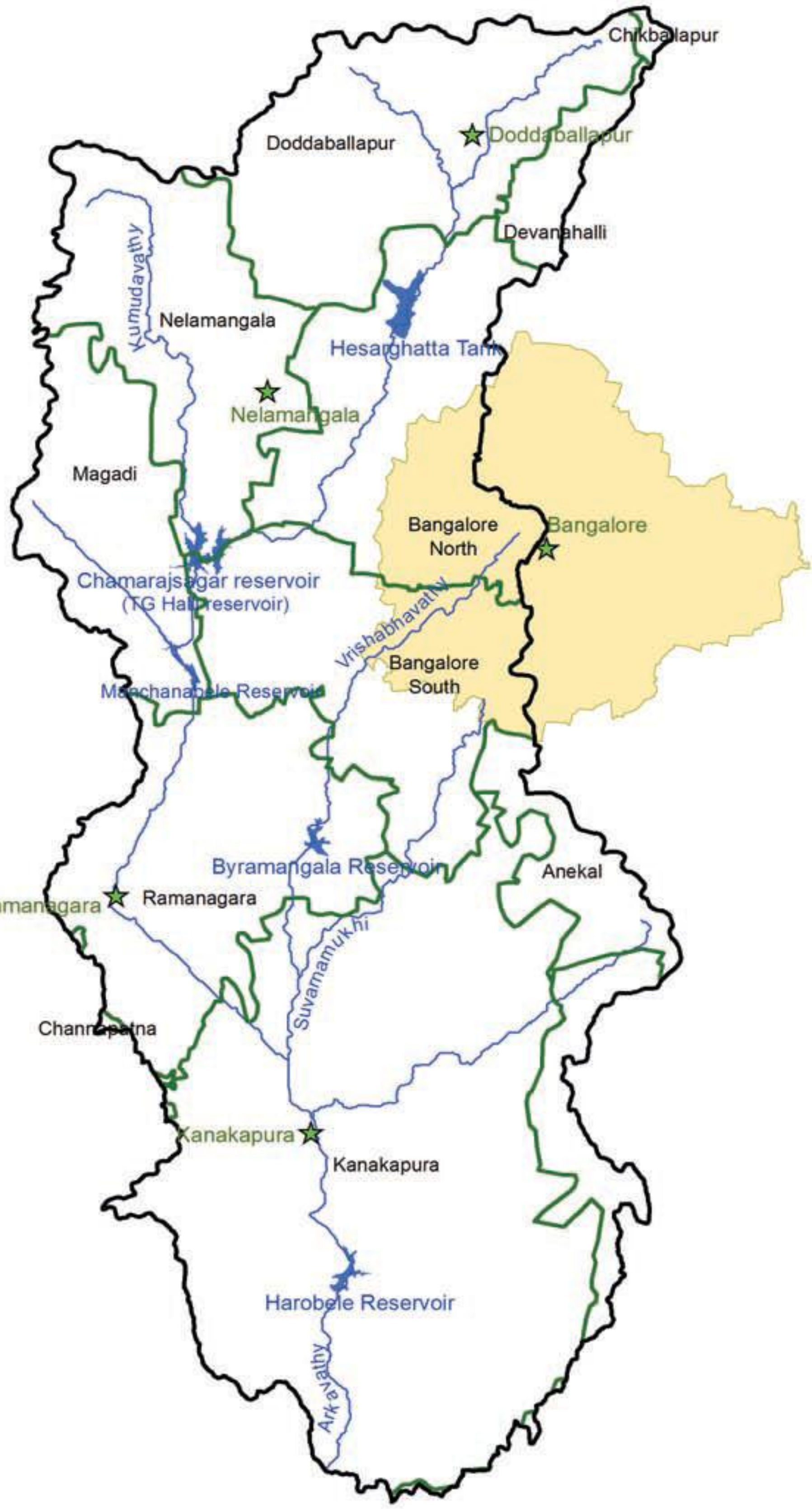


Figure-2.4. Arkavathi river Sub-catchment area (Source-ATREE, 2013)

2.4.4. Zone-4:

A ribbon of 1km distance from the Zone-3 river banks of Arkavathi and Kumudvathi on both sides were declared as Zone-4. In this area only green category industries were permitted with compulsory rainwater harvesting system and waste water treatment facilities. New buildings with only ground and first floor were permitted with adoption of rainwater harvesting systems. Other regulatory/civic agencies were supposed to issue permit only after Consent for Establishment (CFE) is obtained from KSPCB with regard to new industries. Apart from Zone-1, all the other Zones (2, 3 & 4) were to be regulated and monitored by UDD, BMRDA, NPA, BDA, BWSSB and Directorate of Municipal Administrations. The present status of each zone in the TGR catchment area and pollution factors in the catchment area are elaborately deliberated in subsequent chapters.

Table-2.3. Water potential of Kumudvathi river (Source-IAHV, 2014)

S.No.	Mini Watershed	Watershed Code	Area in Sq.km	Yield in Mcft.
1	Makankuppe	4B3B8P1	35.71	223.18
2	Tavarekere	4B3B8P2	23.62	147.58
3	Kerekottiganuru	4B3B8Q1	19.96	124.73
4	Gundenahalli	4B3B8Q2	18.56	115.97
5	Tyamagondlu	4B3B8Q3	40.36	252.20
6	Hemapura	4B3B8R1	32.77	204.78
7	Pallarahalli	4B3B8R2	37.12	231.99
8	Gangabhairappanapalya	4B3B8R3	23.80	148.72
9	Mondigere	4B3B8S1	25.00	156.23
10	Teppadabeguru	4B3B8S2	27.89	174.32
11	Kempahalli	4B3B8S3	21.90	136.86
12	Srinivasapura (Vannasandra)	4B3B8T1	25.98	162.34
13	Mahadevapura (Vannasandra)	4B3B8T2	19.91	124.43
14	Torehosapalya	4B3B8T3	20.71	129.41
15	Kannasandra	4B3B8U1	26.52	165.70
16	Dasegowdanapalya	4B3B8U2	19.51	121.91
17	Motaganahalli	4B3B8U3	12.14	75.89
18	Kavalapalya	4B3B8V1	28.64	178.96
	Total		**460.09**	**2875.20**

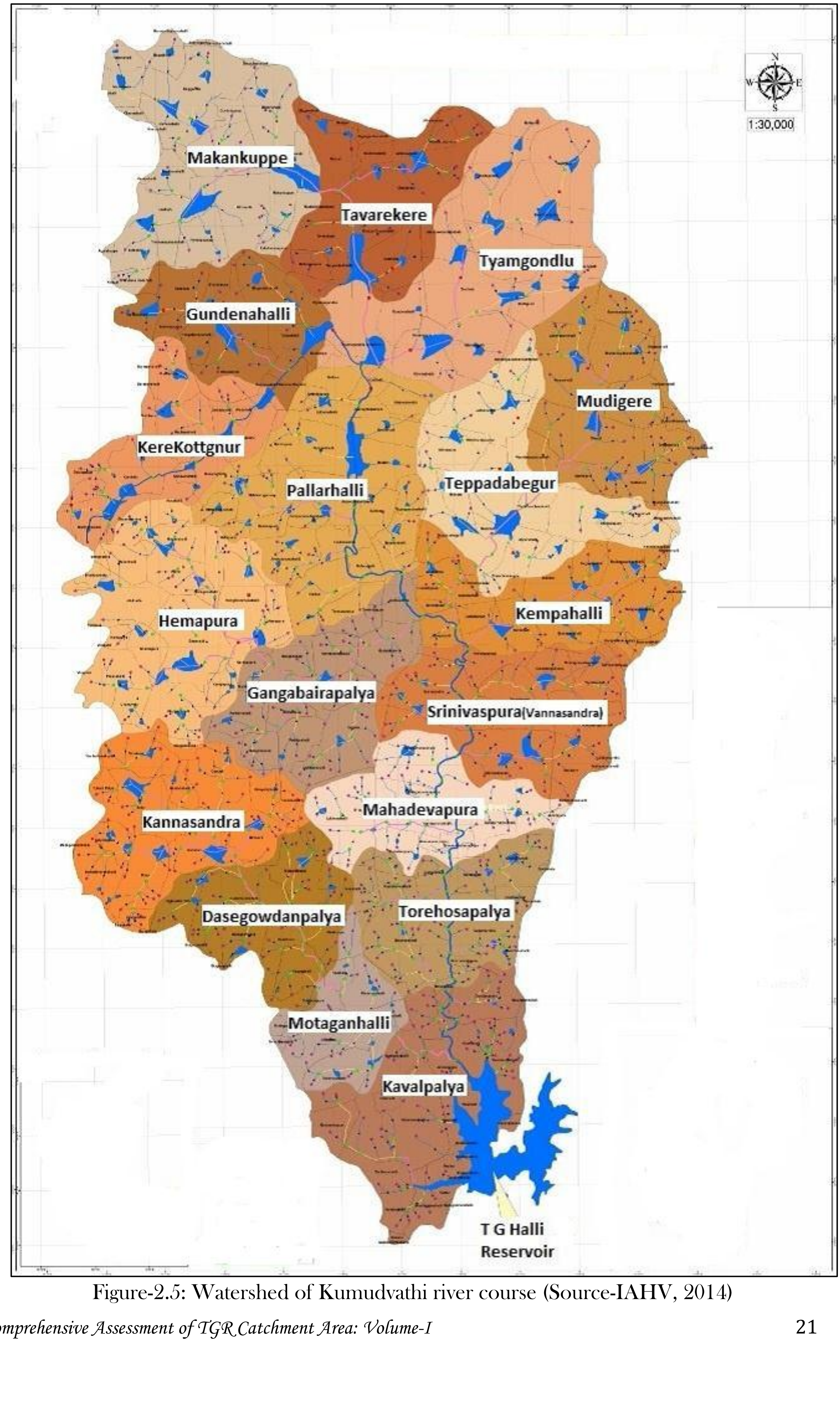


Figure-2.5: Watershed of Kumudvathi river course (Source-IAHV, 2014)

2.5. Reasons for Ineffective Implementation of the Government Order:

Though the notification was issued with the best intentions of protecting the TGR catchment and thereby ensuring sustained flow to the TGR, there were certain shortcomings in the process of notification as well as implementation that resulted the Government Order ineffective:

(i) The Notification was not published in the Karnataka Gazette, though a copy was marked to the Gazette for publication.

(ii) The process of providing an opportunity for raising objections after the issue of draft notification was not followed.

(iii) Adequate awareness about the notification was not created between the communities after the notification.

(iv) Though it was envisaged that concerned authorities would submit reports on a monthly basis to Secretary, Environment, the same was not followed.

(v) While the notification has aimed to regulate uncontrolled developments, there has not been much focus on prevention of alteration of drainage courses, monitoring the uncontrolled disposal of effluent/sewage into the streams/ surface waterbodies and particularly over-exploitation of groundwater.

(vi) KSPCB's suggestion to constitute a separate Authority for the conservation of TGR catchment area mentioned in the notification was not initiated. As there was no separate Authority to monitor and regulate the activities in the TGR catchment area even after a decade, the directions given by the notification could not be properly implemented.

(vii) No systematic effort for promotion of organic farming was taken up by the Department of Agriculture/ Horticulture as per Zone-1 regulation.

(viii) Proper demarcation of boundaries has not been done leading to ineffective implementation.

(ix) While the notification aimed to regulate ground water exploitation to do irrigation activities, there has been no micro-irrigation/ drip irrigation plans implemented in the TGR catchment. Since the water tables have gone down over the years, the farmers have expressed difficulties in carrying out agriculture.

(x) Any such Notification affecting communities necessitates continuous communication and dialogue with the local communities which have been found to be lacking. Planning and implementation of schemes should be done in association with the local people to ensure success.

(xi) Multiple Government Authorities have also issued orders/ directions which are in contradiction to the Government notification of 2003. Some of them which have been obtained are given below:

   a. The Bangalore Urban Zilla Panchayat has issued orders that 500m buffer should be strictly maintained as a no development zone, instead of 1 Km as per the 2003 Notification (Annexure-2.1).
   b. The Tahsildar, Bangalore (North) has acquired 6 acres of land in Survey No. 25 of Alur village under the Rajiv Gandhi Housing scheme for weaker sections. This falls in Zone-3 of the Notification.

c. Bangalore Development Authority (BDA) has constructed flats for implementing Alur BDA Housing Project with Ground +3 storeys in Alur village, falling in Zone-4 as per the notification.
d. Zoning Regulation (Volume-3) in the Revised Master Plan - 2015 of BDA (2007) considered the 250m radius expansion for the old settlements (Grama Thana) of the villages as natural growth (Section-4.13.2.iii) in their jurisdiction.

Chapter-3: Literature Survey: Analysis of Study Reports Published for TGR Catchment Area

3.1. Introduction:

On the TGR catchment area, there have been many studies carried out in past by Government Organisations, NGOs, individual researchers etc. Since the time allotted for the current study was limited, extensive literature survey of various previous studies has been carried out to get as much information on the area as possible. In the following paragraphs, the major findings of the earlier reports on the basis of scientific/ socio-economic studies have been enumerated in brief. Since the ISRO-INRIMT report submitted in the year 2000 has been the most extensive study so far and also since it formed the basis of the 2003 Government Notification regulating developments in the catchment, the report has been analysed in detail. As far as the other reports are concerned, only the basic finding has been mentioned.

3.2. Review of the ISRO Report:

3.2.1. Overview:

Tippagondanahalli Reservoir (TGR) had supplied 120MLD (Millions of Liters per Day) of potable water to the Bengaluru City since 1964. But after the year 1995, TGR was unable to provide consistent supply, so BMRDA entrusted a study to Indian Space Research Organisation (ISRO) in association with Indian Resources Information & Management Technologies Pvt. Ltd. to evaluate the TGR catchment and to ascertain the reasons for the reduced inflow into TGR. Indian Space Research Organisation (ISRO) in association with Indian Resources Information & Management Technologies Pvt. Ltd (IN-RIMT) submitted a study report titled “Reduced Inflow into TG Halli Reservoir- A remote sensing based evaluation” in the year 2000. This study has addressed the following major components:-

1. Physical system of the TGR, inventory of natural resources in the TGR catchment and their changes over the decade
2. Hydro-meteorological phenomenon.
3. Reasons for reduced flows and
4. Environmental issues and Environmental Management Plan (EMP) for the TGR catchment.

The study identified the aerial extent of the TGR catchment, i.e., the Upper Arkavathi river catchment to be 1953 sq.km covering parts of Doddallapur, Nelamangala, Devanahalli, Magadi and Bangalore taluks. There are three distinct sub-catchments of the TGR, with aerial extents of 606.6 sq.km (Hesaraghatta), 376.6 sq.km (Arkavathi) and 462.6 sq.km (Kumudvathi).

3.2.2. Objectives and Scope of the study:

To understand the reasons for reduced run-off/inflow into TGR, the study was carried out with the following objectives:

1. Assess and evaluate the changes in the land use/land cover pattern in the TGR Catchment in the past 15 years
2. Assess the groundwater and surface water resources and to arrive at water balance
3. Evaluate the drainage/stream conditions in the catchment
4. Evaluate the geological and structural features and their control on water resources in the TGR Catchment
5. Assess the spatial distribution and intensity of rainfall, rainfall trend and other hydro-meteorological conditions.

3.2.3. Approach adopted in the study:

An integrated approach involving remote sensing techniques for the derivation of spatial information along with collateral data and detailed field inventory was adopted in order to understand the reasons for reduced inflow into TGR.

3.2.4. Methodology:

Visual interpretation of kharif and summer season satellite imagery acquired during 1983, 1988-89, 1993-94 and 1998 was carried out along with necessary collateral and ground truth information to generate land use/ land cover maps of the TGR catchment on 1:50,000 scale. Spatio-temporal changes that have taken place between 1983 and 1998 in terms of urban growth and other land use pattern within the catchment was analysed.

Field survey covering all the villages of the catchment was carried out to gather information regarding water supply and sanitation conditions, waste disposal methods, socio-economic conditions, drainage conditions, cropping pattern etc., were undertaken. Satellite data used was IRS-1C (Indian Remote Sensing Satellites) LISS III (Linear Imaging Self Scanning sensor) imageries of March and November 1998, IRS-1B LISS II imageries pertaining to November 1993 and March/April 1994, IRS-1A LISS II imageries of December 1988 and March 1989 and Landsat MSS data of October 1983 and February 1985. The other collateral data included rainfall data, census information, climatological information, reservoir level data (TGR and Hesaraghatta) from BWSSB, observation well data from Dept. of Mines and Geology, well inventory data etc.

3.2.5. Natural Resources Assessment:

3.2.5a. Slope: Major portion of the TGR catchment is characterized by the presence of nearby terrain level to gently sloping area (0-3% slope). Out of the total TGR catchment, 47.3% of the area is plain with 0 -1% slope, 38.24% of the area is very gently sloping (1-3%). These two categories of the slope together representing 85.57% of the TGR catchment, contribute less to the surface run-off during rainfall and generally water spreads over large areas and finds more scope for infiltration. Gently and moderately sloping areas (3–10% slope) are generally seen between the plains and strongly sloping hills and represent 11.79% of the catchment. Strongly sloping and steep sloping areas (10-35%) together cover only 1.76% and are seen on the sides of Shivagange, Nandi hills and surrounding the TG Halli reservoir.

3.2.5b. Hydro-geomorphology: The TGR catchment forms part of the Precambrian shield of Peninsular India. Further, the study report has analysed the geology in terms of prospect for groundwater recharge and potential for runoff. The following analyses have been made:

- Denudational Hills: moderate to high hills of large aerial extent with great potential for run-off. (Constitutes only 1.3% of the total TGR catchment)
- Residual hills: isolated or group of small hills interspersed with narrow hills that act as zones of high surface run-off (0.24 % of TGR catchment)
- Inselbergs: isolated moderate to highly elevated residual hills acting as high surface run-off zones (0.02% of TGR catchment)
- Pediment Inselberg Complex: Gently undulating plains dotted with number of small hills with moderately high run-off and poor to moderate ground water potential (1.54% of the TGR catchment)
- Pediment: Gently sloping erosional bedrock surface with detritus with overall poor ground water prospect with moderate to good prospects along fractures/lineaments (3.52% of TGR catchment)
- Pedi plain: Flat or gently sloping surface, constitutes major portion of TGR catchment (80.47% of the total area) with moderate potential for ground water.
- Buried Pedi plain: Landscape of low relief with comparatively thick overburden of weathered material, ground water prospect being generally good, covering 12.28% of TGR Catchment.
- Dykes: Intrusive rocks cutting across the other litho-units randomly and play a very important role in the movement of ground water normally groundwater prospect is good in the upstream side of dyke perpendicular to the stream.

3.2.5c.Land use/ Land cover: Land use/ land cover mapping for the TGR catchment was carried out by visual interpretation of multi season satellite data of kharif and summer seasons for the years 1983, 1988-89, 1993-94 and 1998 (Figure-3.1). The mapping was done on 1:50,000 scale. Description of different land use/ land cover classes found in the study area are given below:

- **Built-up land:** The total built up land was found to have increased from 1674.12 ha in 1988 to 5020.12 ha in the year 1998 (200% increase). The breakup of built up land area as given below:
    i. **Village / Settlements**: Changed from 296.34 ha. (1988) to 368.3 ha. has (1998) [24% increased]
    ii. **Towns:**Changed from 217.89 ha (1988) to 809.44 ha (1998) showing an increase of 270%

iii. **Urban/New Layouts**: Changed from 1056.36 ha (1988) to 5242 ha (1998), indicating fivefold increase, mainly around Bangalore City, Nelamanagala town and Dodddaballapur town.

iv. **Industrial land / layouts**: Changed from 105.22 ha (1988) to 533.89 ha (1998) around Nelamangala, Doddaballapur towns and near Dobbaspet.

- **Agricultural land and cropping pattern:** The study revealed that in TGR catchment there was an increasing trend of agricultural land being used for growing commercial trees (*Eucalyptus/ Casurina/ Acacia*). The crops grown were paddy in low-lying areas and ragi, maize, potato, vegetables, pulses, oil seeds etc. in the uplands. The study found that coconut constituted an important plantation crop whereas other important plantation crops included areca nut, mango, sapota, vegetables, grapes, mulberry, flowers etc. The GIS analysis showed a decline in agricultural plantation/garden crops/vegetables from 18307.20 ha (1988 – 89) to 15741.61 ha (1993-94). There was also an increase in agricultural fallow [493.68 has in 1993-94 to 627.97 in 1998].

- **Forests:** A gradual decrease was found in the areas covered by forest plantation (like Eucalyptus) and increase in scrub forest between 1988-89 to 1998.

- **Wasteland:** A decrease in total wasteland was found in TGR catchment area (land with/without scrubs, stony waste, gullied land and marshy areas) from 19018 ha (1988) to 14017 ha (1993). Stony wasteland was found to be covered by quarries.

- **Commercial Plantations:** The study found that there was a tremendous increase in commercial plantations (*Eucalyptus, Casurina, Acacia*) since these plantations were found to be more economically viable due to increase in agricultural wages. The area covered by commercial plantation during 1988-89, 1993-94 and 1988 was found to be 7064.51 ha, 15833.14 ha and 26982 ha respectively.

- **Quarrying:** The area under quarries was found to have increased from 208.29 ha (1988-89) to 376.5 ha (1998).

- **Waterbodies:** Comprising of areas under tanks, reservoir and rivers. In the TGR catchment surface water spread during the year 1988, 1994, and 1998 were 5901 ha, 6724 ha and 6378 ha respectively.

Hence the study by ISRO-IN_RIMT had already indicated a trend of new residential, industrial layouts within the catchment. The increase was more prominent during 1994-1998 with new layouts mostly developed on wastelands and even agricultural land. There was a major decrease in crop land and increase in commercial plantations. Also there was increase in quarries.

3.2.5d. Hydro-Meteorological Studies: The rainfall data of Nelamangala, Bangalore North, Magadi, Doddaballapura and Devanahalli for the period 1980-1998 was analysed. On an average the TGR catchment was receiving 16-60% during monsoon (June-September) and 22-25% during post-monsoon (October-December). Post-monsoon rainfall and their intensities were found to be more significant from the point of generation of surface rainfall.

For analysing the trend in rainfall, data was taken from Central Ground Water Board for the period 1901-1980 and analysed. Over the year 1901-1980, general rise in rainfall was indicated in Bangalore North, Magadi, Nelamangala and Doddaballapura except Devanahalli where rainfall remained more or less constant. There was a deficit in rainfall in all the five stations in the year 1982, 1985, 1989 and 1990, whereas during the year 1988, 1991 and 1993, all five stations had recorded excess rainfall.

Further for the surplus rainfall years 1988, 1991, 1993 and 1998 an attempt was made to assess the quantum of runoff. The maximum cumulative runoff was assessed as 362 mcm after subtraction of 11% (44mcm) as ground water recharge. A comparison of the estimated inflow based on surplus rainfall and inflow inferred by BWSSB data (from withdrawal and storage records) showed that the estimated inflow had not actually reached the TGR reservoir.

3.2.5e. Water Resources: The study pointed out that around 541 irrigation tanks (541), constructed around the second and third order streams, constituted the main surface water source. Due to interception of appreciable volume of water by tanks of varying sizes at different reaches, substantial reduction of runoff was found before reaching TGR. Out of the rainfall runoff, at least 30% of the runoff contributed in filling of 541 tanks and groundwater recharge. Further, the 40% of runoff accounted for seepage losses in tanks due to gaps in rainfall spells, accelerated groundwater recharge (11%) due to over-exploitation, immobility of surplus water due to flat terrain, filling up quarries, evaporation and transitional losses. The water spread areas of the tanks have been compared with the SOI (Survey of India) toposheet (1973-74) and found to be less on an average indicating shrinking of the tanks. To some extent these tanks were supplying water for irrigation.

3.2.5f. Groundwater Resources:

It was found that groundwater resources were being tapped to a great extent in the TGR catchment for domestic or irrigation purposes. A survey of open/dry wells was conducted by visiting each village within the catchment, inventorying the wells and interviewing the people. Most of the open wells in the upper portions were found to have become dry during summer. It was seen that the villages in the area have gone in for a large number of bore wells, some of them through Government schemes. An inventory of 9373 bore wells within the catchment area indicated the indiscriminate drilling of borewells. In some cases, borewells were found to be drilled down to a maximum depth of 450 ft. Most of the borewells drilled upto 200 ft., 15 years before the study, were found to have dried because of depletion of water table. In some cases it was seen that pumps were being operated continuously where there is power supply.

Water table fluctuations indicate that in parts of TGR catchment ground water tapping was much higher than the recharge. Water Balance Study was carried out to assess the annual dynamic resource and ground water graft. Groundwater draft and dynamic resources calculation revealed that in the TGR catchment area groundwater was over-exploited so the water table was continuously depleting. Composite Water Use Index (CWUI) was used to estimate the annual requirement of groundwater based on human, livestock population and crop water duty, i.e. volume of water required for crops and agricultural plantations. CWUI showed that 272 villages had medium to high water consumption, particularly in the vicinity of rivers and tanks.

Environmental aspects: The study has also reflected on the tremendous pressure on the ecological and environmental aspects due to unsystematic growth, lack of appropriate sanitation measures, water supply and solid waste disposal in the settlements. The study mentioned presence of effluents/ sewage from Peenya to Dasanpura from industrial and urban settlements, which contaminated ground water. The study also found that the ribbon development along two National Highways from Peenya to Nelamangala was polluting the Arkavathi river by their untreated effluents/ sewerage (Figure-3.2), which also lead to contamination of groundwater source through the open fracture systems in the country rock. Further, the micro-level pollution source analysis found that the large number of brick manufacturing units (soil excavation in waterbodies) and poultry farms lead to land pollution in TGR catchment area. Peenya and Makali village industrial effluents were directly discharged into streams of Nagasandra and Madavara tanks near Makali village, which was found to flow through Arkavathi course and reach TGR, whereas, Kumudvathi series was not affected seriously.

Water quality was analysed for 52 samples including ground water and surface water samples. Almost all the samples of surface water showed high concentration of all the parameters compared to prescribed standards. Ground water in both the micro watersheds also showed signs of contamination due to urban sewage and industrial effluents.

3.2.5g. Conclusions regarding cause of decreased water inflow to TGR:

The study concluded the following reasons for decreased water inflow to TGR:

- Since the slope of the catchment is less than 3%, the total incidental runoff tends to spread over the land and influence recharge than forming run-off.
- The coarse-textured soils having infiltration rate ranging from 10-16% hinders the generation of run-off.
- The geology/ geo-morphology as a whole is not ideally suited for generation of run-off
- Truncated nala and minor impediments in the form of gully plugs, barriers, check dams, built-up areas hinders the flow of water.
- Since there are large number of tanks and depressions, the tanks tend to lose some storage, when there is intermittent rainfall.
- Due to dynamic and continuous urbanization in the TGR catchment, in certain places first and second order streams have been blocked due to construction of railway line, roads and new layouts, thereby affecting free movement of surface run-off.
- The study also revealed that there is appreciable rise in reservoir if there is a good daily rainfall of more than 40mm continuously for few days. Also there should be few showers of short duration (more than 60 mm/day) during monsoon and post-monsoon period in Nelamangala, Bangalore North and Magadi regions.

3.3. Indian Resources and Information and Management Technologies Limited (IN-RIMT) report on the framework of policies and plans for sustaining T.G. Halli reservoir, 2002:

Based on ISRO Report, the Principal Secretary, urban Development Department (29th Aug'2000) directed BMRDA to prepare an implementation plan with legal framework for implementation. BMRDA entrusted the study on 'Framework of policies and plans for sustaining TGR' in 2002 to IN-RIMT to evolve proper action plans which can be implemented under the framework of policies. Further, the report prepared by IN-RIMT was finalised after discussion with Secretary, Department of Ecology and Environment and BWSSB. But the study area had not considered the Hesaraghatta sub-catchment because the Hesaraghatta tank downstream had low runoff potential to TGR and the 10 km radius around TGR upstream and linear stretch of 2 km wide along Arkavathi and Kumudhavathi Rivers were taken as Ecological Sensitive Zone (ESZ) for detailed study (Figure-3.3).

In the report by Indian Resources and Information and Management Technologies Limited (IN-RIMT) the framework of policies and plans for sustaining T.G. Halli reservoir have been analysed following an approach of Pressure–State- Response (PSR) developed by UNEP. The approach defines a region in terms of Pressure (P) on the environment; Status (S) of environment; and Response (R) of the society as well as the system with respect to the load imposed. The analysis has indicated that TGR catchment has the potential to provide necessary services to the human enterprise, if proper strategies are adopted for sustainable use of the system. In order to assess the problem, the response of the society and enterprise has been analysed.

3.3.1. Societal Response:

A. Encroachment of agricultural land, tank beds and stream courses: It was observed that farmers have kept considerable extent of arable land as fallow in anticipation of getting them converted to commercial usage. Drainage courses have been levelled and diverted at many places for other purposes. The interview of farmers revealed that in the TGR catchment area, the agriculture had lost its scope due to the inconsistent rainfall, non-availability of timely labourers, increase in agricultural labour cost, financial constraints due to smaller land holdings, irregular supply of power to IP sets, price fluctuation, non-regulated market, migration of farmers to urban, increased land prices due to proximity to Bangalore City, reduced water storage in tanks, low yields in bore-wells, etc. Farmers reported that many cattle had died due to drinking of polluted water, which was let out by industries during the monsoon season.

B. Shift towards bulk supplies and overexploitation: To meet the demand-supply gap, it was observed that bore wells had become the order of the day. Many industrial units were found to be buying water from individual farmers who were supplying water commercially.

C. Blind spots in planning and implementation: The study found lack of co-ordination between the works of different Government agencies. The Gram Panchayats were permitting developments of residential layouts without referring the matter to BMRDA or Town Planning Authorities. The Industries department had permitted establishment of industries even on the bank of Kumudvathi.

D. Need of the hour and available options: The study emphasized on the importance of integrating environmental considerations in the planning process, economic and sectoral development, developing anticipatory and preventive strategies for developmental projects and demonstrating sound ecological policies that benefit development. The study has emphasized on **strengthening Nelamangala Planning Authority (NPA)** to increase its effectiveness.

E. Policy for TGR catchment: The study adopted the policy of Governance as "Ensuring sustainable development of the TGR catchment, conserving the natural resources of the catchment and protecting the TGR from any kind of contamination and maintaining the optimal inflow of water in the TGR".

3.3.2. Suggested strategies:

a. **Declaration of a part of the TGR catchment as Ecologically Sensitive Zone (ESZ) with help of already existing laws**

   An area of 455.30 Sq. km (10 km radius around the TGR and linear stretch of approximately 2 km along the main course of Arkavathi river upto Hesaraghatta and Kumudvathi) as ESZ of TGR catchment area (Figure-3.4).

   Sub-zone-1: Only agriculture was suggested.

   Sub-zone-2: Only agriculture and allied activities like animal husbandry, dairy farming and poultry farm was proposed.

   Sub-zone-3: Permitted activities suggested were residential layouts, a few selected industries, subject to compulsory adoption of waste recycling, ground water recharge measures and rain water harvesting as well as compulsory clearance from KSPCB and BWSSB.

b. **Strengthening the existing NPA in term of manpower, infrastructure and preparation** of outline development plan for the Local Planning Area of NPA were proposed. Taking into consideration, the action plans required to be implemented for sustainable development of TGR catchment.

c. Some of the **action plans/ programmes** suggested were:

   - **Action Plans for sustaining quantity of inflow**

     - Improvement of drainage courses with details of priority stretches for removing clogging (Arkavathi from Makali village upto TGR and Kumudvathi from Tonachinakuppe upto Avalakuppe as priority-I and Kuluvanahalli, T. Begur and other tank cascades as priority-II)

     - Prevention of further development and exploitation of ground water by conservative use of available resources for public purposes was proposed. Prevention of further development of ground water for non-agricultural purposes, rainwater harnessing and recycling of used water by industrial units, strict regulation by KSPCB against ground water based enterprises etc, were some of the other important suggestions.

- Revival and rejuvenation of 344 tanks by doing repairs, desilting, connecting underutilized tanks directly, developing pisciculture, bigger tanks to be developed as recreation centres, etc. were proposed.

- **Action Plans for sustenance of quality of water flowing into TGR**
    - Prevention of non-agricultural activities in BDA's green belt area and other areas falling outside the LPA (Local Planning Area) of NPA in the TGR catchment- 15% of the villages of ESZ come under the jurisdiction of BMRDA, 19% under BDA and rest under NPA. These three agencies should coordinate to prepare an ODP (Outline Development Plan).
    - Restriction on the development of new layouts/ resorts- no new layouts should be permitted in ESZ and existing ones, if needed, should be shifted out.
    - Curtailment of industrial activity in the TGR catchment- Development of any industries other than poultry, dairy farms and animal husbandry should be totally avoided.
    - Industrial establishments located around Makali village and Peenya industrial areas as well as the rural habitats were found to contribute to pollution. A special notification by the State Government was suggested for the protection of TGR catchment under Section 19(3) of Karnataka Water Act, 1974.
    - Enforcing consortia approach for waste management for setting up Common Effluent Treatment Plants (CETP) at suitable locations was suggested.
    - Establishment of rain gauges and run off gauges at suggested places, water quality monitoring spots and analysis of results was also suggested.

3.3.2. Limitations of the study:

- The limitations of the report were that there was no clear relationship established between the objective of conservation of the river with the width of the buffer zones of ribbons of 1 km and 1-2 km on both sides of river Arkavathi and Kumudvathi. Also the existing habitations were not taken into consideration and there was no suggestion regarding the natural expansion of the existing Gram Thana's or the inhabited areas. There was limited consultation with the public.

- The Land Use/ Land Cover Analysis were done with available imageries with poor spatial resolution (1983), and hence it is important to take stock of the present situation by updating the data.
- The recommendations regarding regulations on development have not been prioritized, other than guidelines to protect water quality (Srinivasan *et al.*, 2015). Considering the severity of developmental pressure in a city like Bangalore, without adequate institutional mechanism such restrictions are very difficult to be implemented. Though the report has talked about strengthening the NPA which is only one of the multiple Governmental stakeholders, it has not laid out a plan or strategy for inter Departmental coordination required for achieving the desired objectives in the study area.
- The diagnostic appraisal and analysis of the system carried out earlier by ISRO/IN-RIMT was able to bring out the problems and was able to suggest programs of action, but has not accurately assessed the strength of the consent Authorities to implement these regulations/ programs.

3.4. Study commissioned by CNNL (Cauvery Neeravari Nigam Limited) on 'Obstructions to flow of natural water in the course of Arkavathi river and its tributaries from its origin up to the TG Halli Reservoir', 2010:

The study was commissioned by CNNL, to identify all encroachments and obstructions in the river course as well as other aspects including land use pattern changes, ground water situation, study of rainfall etc. Field inventory of obstructions/ encroachments etc. was carried out. A total of 83 obstructions in Hesaraghatta sub-catchment, 115 obstructions in Kumudvathi sub-catchment and 277 in Arkavathi sub-catchment were identified. The study also concluded that there was a major problem of ground water over exploitation upto 142.1% in the entire TGR catchment area, which was found to be more pronounced in the Arkavathi sub-catchment. The study recommended the following actions for the rejuvenation of the rivers: (1) Regulation of groundwater development (2) Restriction of further spread of exotic plantations (3) Restoration of river course and tanks by removing the encroachments and obstructions (4) Setting up an Authority for development of regulations in the TGR catchment.

3.5. Study by ATREE (Ashoka Trust for Research on Environment and Ecology), 2013:

The study estimated the level of water availability for the Arkavathi sub-basin community and revealed that most of the groundwater samples were polluted with nitrates. Further the study also revealed that there was increasing electricity consumption due to pumping from borewells, as the density of wells increases and the groundwater level dropped. In the study, six distinct hypotheses have been tested for finding the reasons for drying up of TGR and Hesaraghatta reservoir, which are (i) substantial increase in commercial plantations have resulted in reduction in recharge and consequent reduction in surface flow (ii) Upstream extraction of groundwater by farmers, industries and households has increased greatly in the last two decades, so the groundwater levels have declined hundreds of feet, and this may be decreasing runoff, causing first order streams to dry up (iii) Channels and tank beds have been encroached upon or fallen into disrepair. As the integrity of the watershed is destroyed, water no longer flows into tanks. Tanks no longer overflow into the Arkavathi River (iv) Illegal sand mining of stream beds has decreased recharge into aquifers and consequently affecting base flow (v) Temperature increases due to climate change or urban heat island effects may be increasing evaporation and evapotranspiration (vi) Rainfall magnitudes and/or intensities are changing, thereby reducing inflows. They have concluded that the first three hypotheses are substantiated and effects on surface flow due to climate change and decrease in rainfall are not substantiated.

3.6. Brief Description of other reports produced for TGR Catchment area:

- In 2004, IISc. (Indian Institute of Science, Bangalore) scientists have studied and listed biodiversity hotspot area of the TG Halli Reservoir and reported 55 species of flowering plants, two species of lichens, one earthworm specie, 26 species of butterflies, crab, four species of amphibians, five species of lizards, 10 species of snakes, one tortoise specie, 111 species of birds and eight species of visiting mammals (Annexure-3.1).
- In 2009, PIL (Public Interest Litigation) was filed in the Hon'ble High Court against the State and the KSPCB for allowing hazardous waste treatment plant to be set up near the TGR. The court ordered the KSPCB to set up the plant in some other area. BMR (Bangalore Metropolitan Region) Audit report (2010) revealed that the inventory of polluting sources maintained by KSPCB was based on the industries applying for Consent for Establishment/Consent for Operation and others that came to light during the limited inspections conducted by its Regional Offices. They found that the 46 industrial units (highly polluting-12, moderately polluting-6 and least polluting-28) were operating in Zone-3 of the TGR catchment area, besides 46 godowns, 12 layouts and three colleges were also there.
- The entire TGR catchment area was categorised as over-exploited in 2004 by the Central Groundwater Board (CGWB) and there was no improvement till 2011 (CGWB, 2006 & 2014).
- Saibaba *et al.* (2008) found that there were 382 medium and large industrial units, and six unauthorised waste dumps (Figure-3.5) in the TGR catchment area during the year 2007.
- Rajashekara and Venkatesha (2011) had documented the occurrence of aquatic birds to enlisting 30, 31, 24 and 30 species in Hesaraghatta, Nelamangala, Somanahalli and Thippagondanahalli lakes respectively. They also stated that the aquatic weeds are absent in Hesaraghatta and Thippagondanahalli lakes as they are well maintained natural reservoirs for supplying of drinking water to Bangalore city.
- Chandrashekar *et al.* (2012) stated that the Manchanabele dam constructed across the River Arkavathi has the catchment area of 1590km^2, Out of which, 152km^2 is an independent catchment area. They conducted the water quality study in the dam and catchment area and found that the reservoir water was polluted by the wastewater but the water was suitable for irrigation purposes.

- KSTDC (Karnataka State Tourism Development Corporation, 2014) had earmarked Thippagondanahalli as a most backward category tourism spot with expectation of medium tourist arrivals in its proposed policy for the year 2014-2019.
- Rajashekara and Venkatesha (2014) stated that the birds are good bio-indicators in the agro-ecosystems and should be protected to conserve the agro-biodiversity and environment. They conducted the study between 2008 and 2010 on insectivorous bird in the villages of Hesaraghatta, Nelamangala, Somanahalli and Thippagandonahalli and found that the number of bird species was highest in Hesaraghatta and Thippagondanahalli. The percentage of population density of insectivorous birds was highest in Hesaraghatta (14.23) with least (3.12) diversity and the highest diversity (3.44) of birds were observed at Thippagondanahalli.
- Chandana *et al.* (2014) studied the drainage change analysis between the year of 1900 (Cadastral map) and 2009 (merged CARTOSAT-I and LISS-IV imagery) and found that 180 drainages had vanished and 1598 drainages were encroached out of 2436 total drainages (Figure-3.6). Major encroachments were found in the Nelamangala taluk (5776.55m), whereas most of the drainages were encroached by fallow land, crop land, plantation and built-up area (Annexure-3.2).

3.4.1. Study reports on Arkavathi River:

- Srinivasa (2009) had stated that all the waterbodies connected to the Arkavathi river are polluted resulting in contamination of groundwater in all aquifers and suggested to evaluate and apply the best management practises. He also suggested that the Total Maximum Daily Load was very important for judicious use of water resources.
- Nandini *et al.* (2009) had found environmental degradation of the Arkavathi basin including sewage pollution, illegal encroachment on wetlands, illegal quarrying and sand mining (mud-lifting) on the basin floor, deforestation of catchment zones, the use of heavy detergents in laundry works in the water bodies, brick making factories, etc.
- Venugopal and Ramasesha (2009) found that the Arkavathi river had lost its assimilating capacity due to the reduction in the run off generated because of land use change and urbanization.
- Shivashankar (2009) stressed that the integrated approach such as advanced agriculture practices should be considered to rejuvenate Arkavathi.
- Shashirekha (2009) study had revealed that 92.7% of groundwater samples were polluted in Arkavathi watershed. Her study also revealed that the Gogo exporters Pvt. Ltd. and Himshu Ltd. industry in Doddaballapur taluk and also industries in Peenya were contaminating the groundwater.
- Vishwanath (2009) had suggested that the river basins institutions should be established for planning and managing the Arkavathi river basin.
- Subhajyothi Das (2011) had discussed that the recharge of groundwater table is the only way for the revival of Arkavathi river.
- Farooqi (2011) found that the groundwater is being pumped more than that of rechargeable quantity which was the major problem in Bangalore.

- Srikantia (2011) stated that the rejuvenation of Arkavathi river is possible, if only local leadership, the stakeholders and NGOs participate in the process.
- Hegde and Subhash Chandra (2012) found that the rivulets and streams of the Arkavathi river flowing amidst mounds, hills and rock-cut valleys are mainly trained by Northern East and Western South lineaments and they also suggested that the groundwater table should be allowed to revive up to the unconfined aquifer horizon.
- Srinivasan *et al.* (2015) had conducted more than 60 Water Literacy Meetings with the TGR catchment area farmers and found that the primary causes of Arkavathi River flows drying in the TGR catchment was groundwater extraction and increased obstructions along the stream course, which were anthropogenic in origin. They also added that the climate change could play a critical role in further exacerbating water stress in future.

3.4.2. Kumudvathi River:

As the Kumudvathi river was comparatively less polluted than the Arkavathi river, only few studies have been published. Lingaraju *et al.* (2013) and Subhajyoti Das (2014) have proposed artificial recharge and rainwater harvesting to augment and restore the depleted groundwater aquifers in the Kumudvathi sub-catchment area and they also found that the 2nd and 3rd order streams of Kumudvathi river are favourable for construction of recharge wells as the weathered zone is nearly 15–20 m thick with dense fractures.

3.5. Conclusion from the Previous Studies:

The previous studies conducted in the TGR catchment area from the year 1981 to 2015 had revealed that many issues exist in the TGR catchment area from the last two decades. The following are concluded from the review of literature and reports published so far:

1. Water flow in the Arkavathi and Kumudvathi rivers has drastically reduced, which resulted in the reduction of inflow water rate to TGR. Following are the reasons identified in the previous studies:
    a. Slope of the TGR catchment area is less than 3%, so the total incidental rainfall runoff tends to spread over the land/ waterbodies. Therefore the geo-morphology of the TGR catchment area is not ideally suited for generation of run-off.
    b. Due to urbanization, 1st and 2nd order streams of Arkavathi river have been blocked due to construction of railway line, roads and new layouts, which has resulted in reduced inflow.
    c. Truncated nala and minor impediments in the form of gully plugs, barriers, check dams, built-up areas hinders the flow of water to reach the rivers.
    d. 180 drainages had vanished and 1598 drainages were encroached out of 2436 total drainages in the TGR catchment area. Major encroachments were in the Nelamangala taluk by fallow land, crop land, plantation and built-up area.
    e. Over-exploitation of groundwater in the TGR catchment area, whereas the groundwater was categorised as dark zone in 2004 and there was no improvement till 2011.

2. Deterioration of water in the Arkavathi river and TGR due to following reasons
    a. Environmental degradation of the Arkavathi basin by sewage pollution, encroachment on wetlands, quarrying and sand mining on the basin floor, deforestation, brick making factories, etc.
    b. Unauthorised waste dumps in TGR catchment area.
    c. 92.7% of groundwater samples were polluted in Arkavathi watershed.

3. Some of the suggestions to conserve the TGR catchment area by the previous studies are as follows:
    a. Declare part of TGR catchment area as Ecologically Sensitive Zone (ESZ).
    b. Revival and rejuvenation of tanks.
    c. Establishment of water quality monitoring spots, rain gauges and run-off gauges in Arkavathi and Kumudvathi rivers.
    d. Restriction of further spread of exotic plantations.
    e. Artificial recharge and rainwater harvesting to augment and restore the depletion of groundwater aquifers.
    f. Enforcing consortia approach for waste management for setting up Common Effluent Treatment Plants (CETP).
    g. Restrict over-exploitation of groundwater.
    h. Setting up an Authority/ River basins institutions for development of regulations in the TGR catchment.

4. Sand mining, temperature increases due to climate change and rainfall magnitudes are hypothesis, which are not substantiated with the drying of Arkavathi river.
5. KSPCB is monitoring only the industries who applied for Consent for Operation.
6. TGR is a most backward category tourism spot, even though it is a biodiversity rich area.

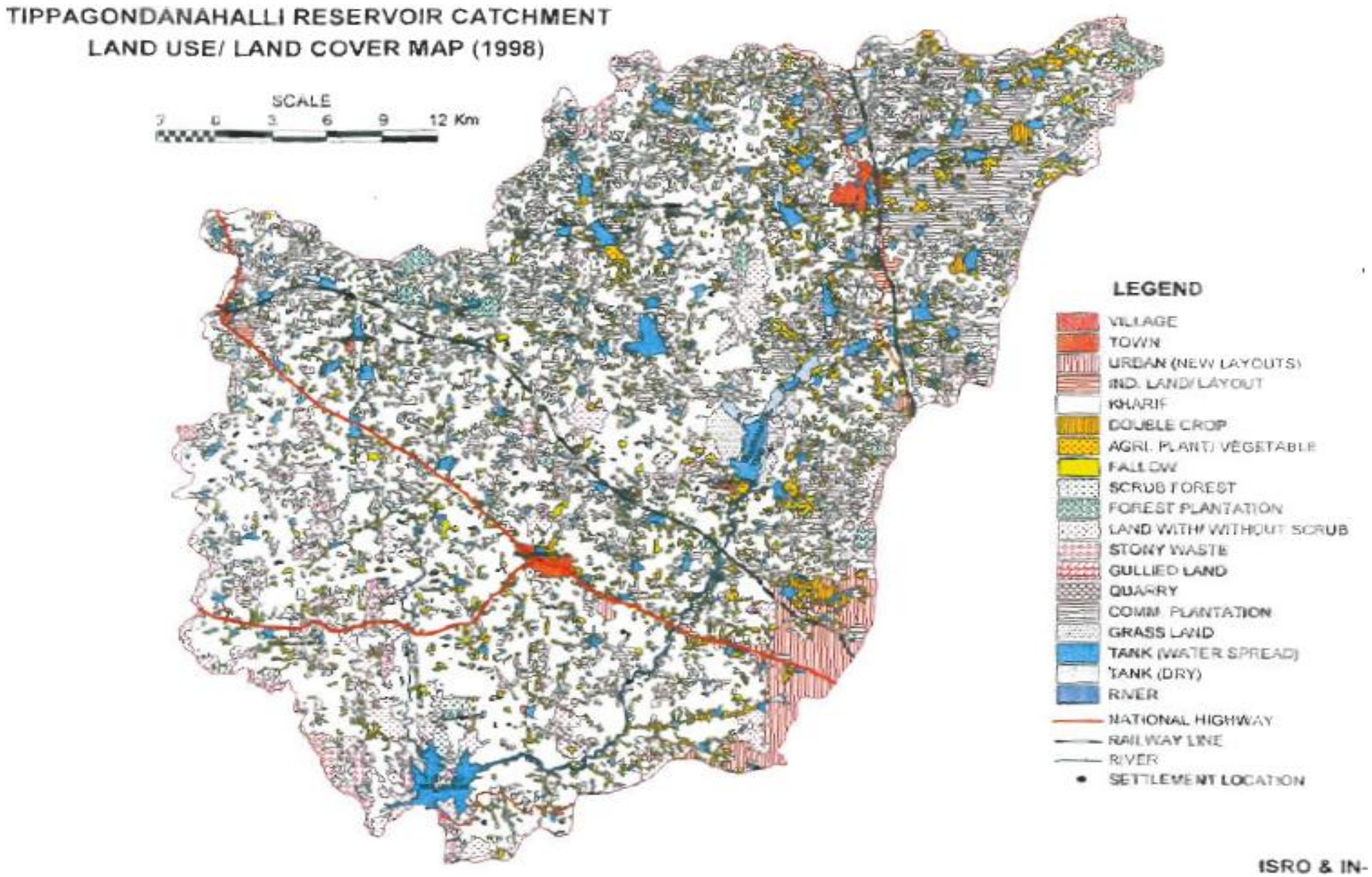


Figure-3.1: TGR catchment area Land Use/ Land Cover Map (1998)

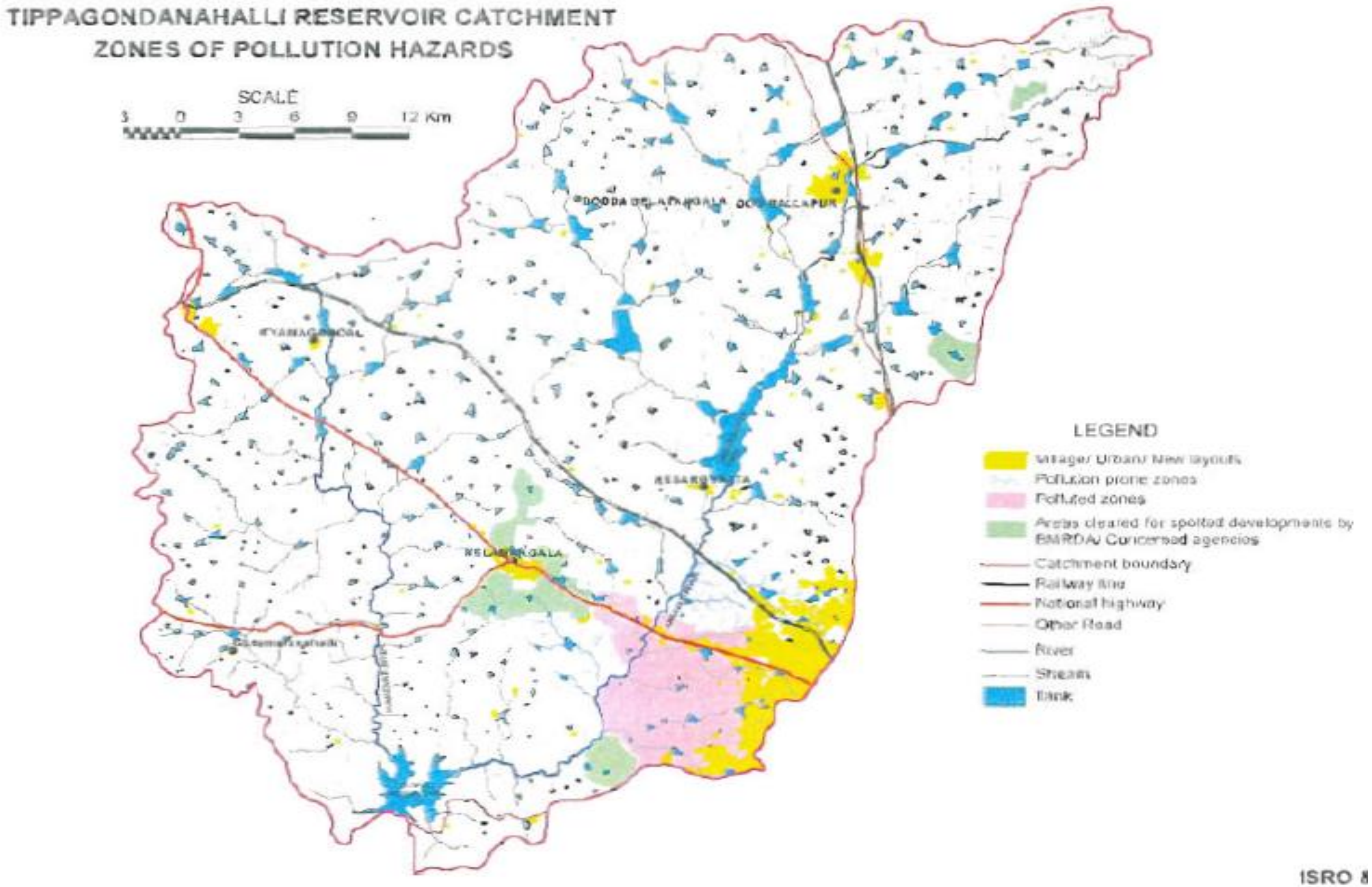


Figure-3.2. Pollution hazards zones of TGR catchment area (1998)

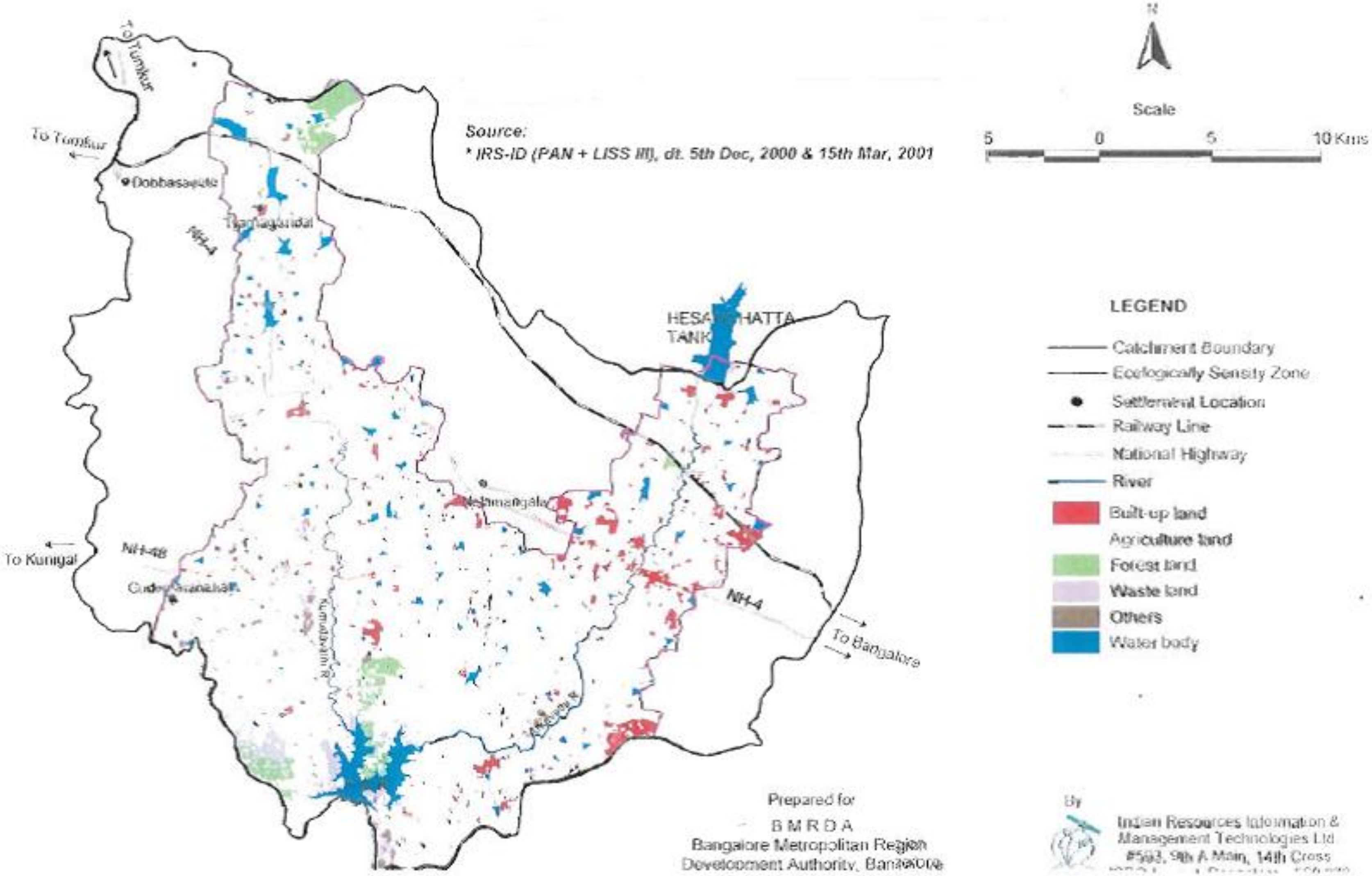


Figure-3.3. Ecologically Sensitive Zone demarked by IN-RIMT, 2002

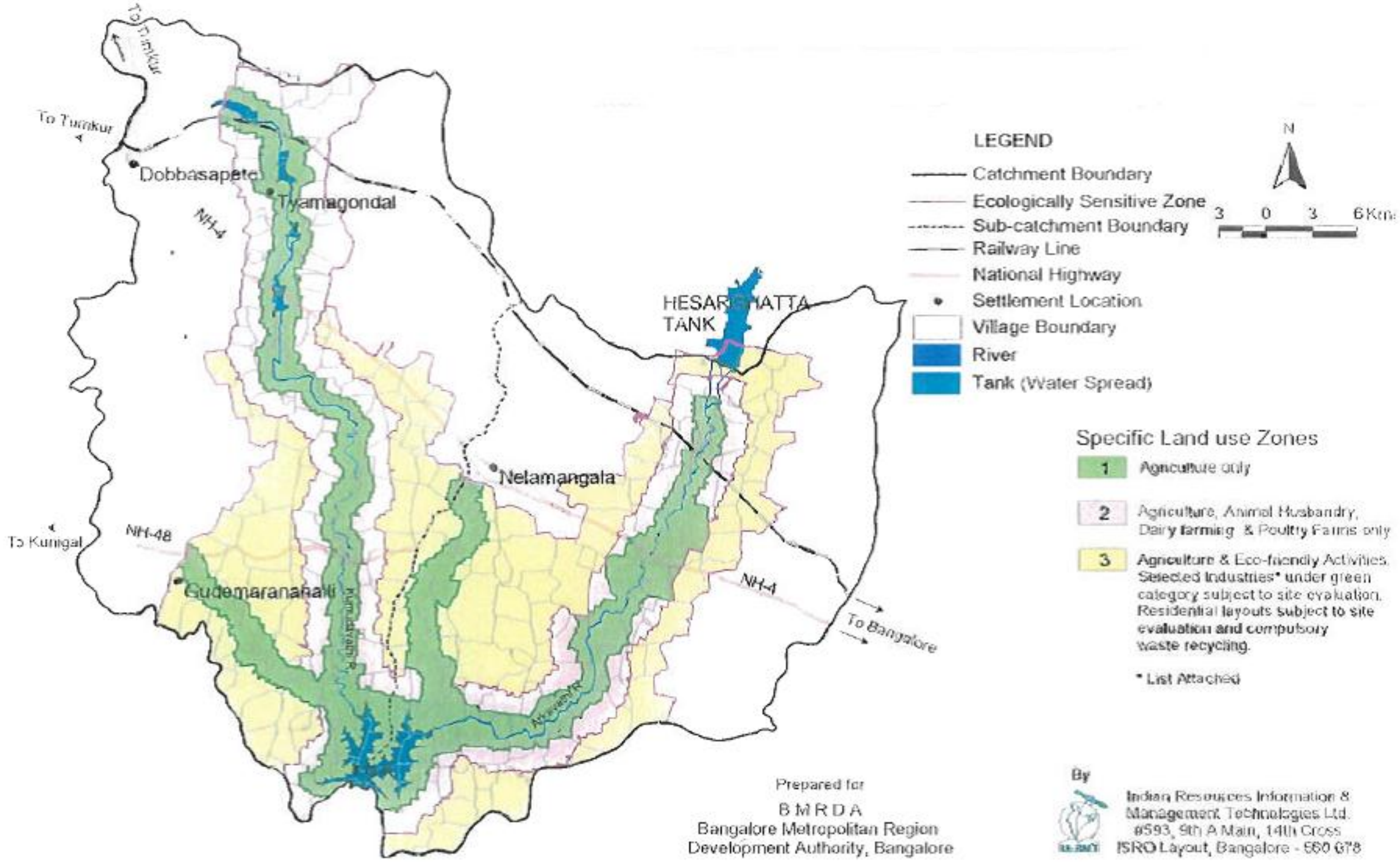


Figure-3.4. IN-RIMT proposed sub-zone classification

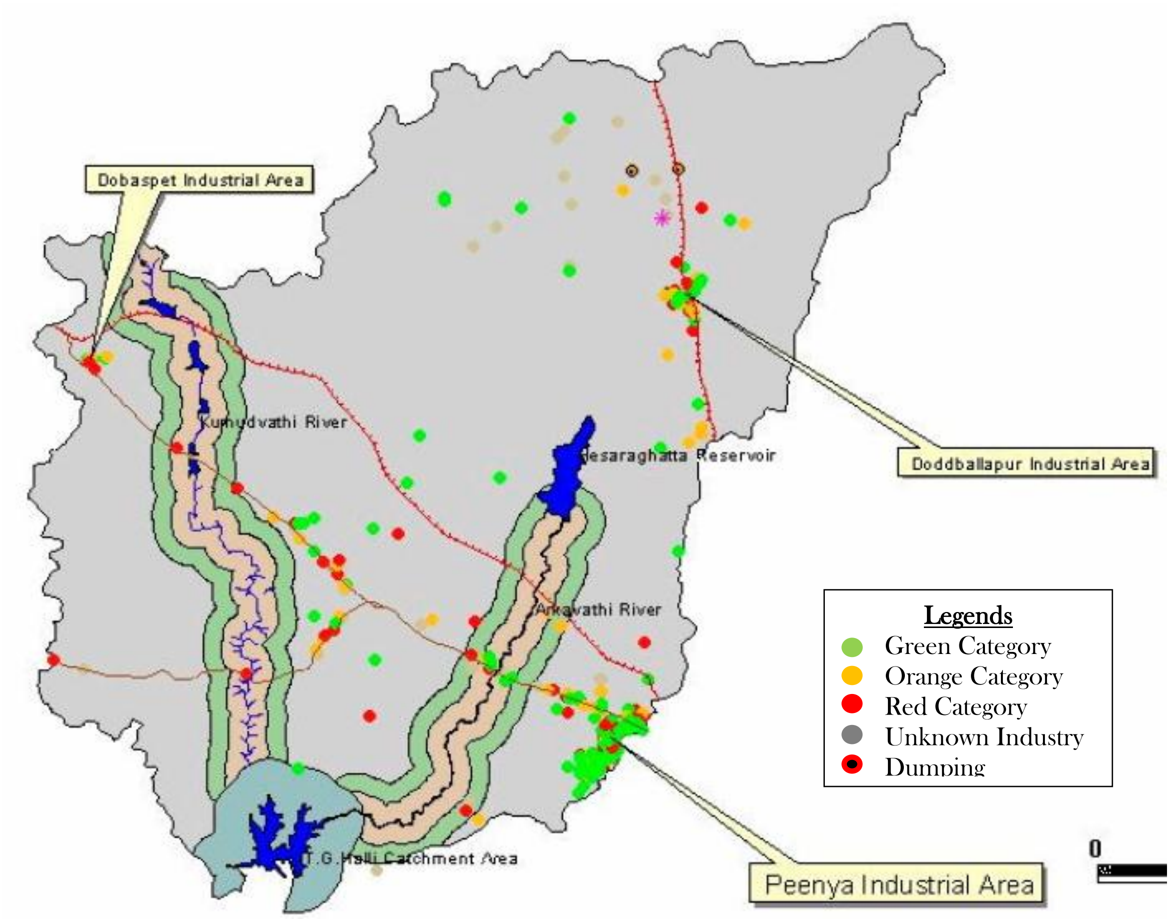


Figure-3.5. Location of Industries in TGR catchment area, 2007

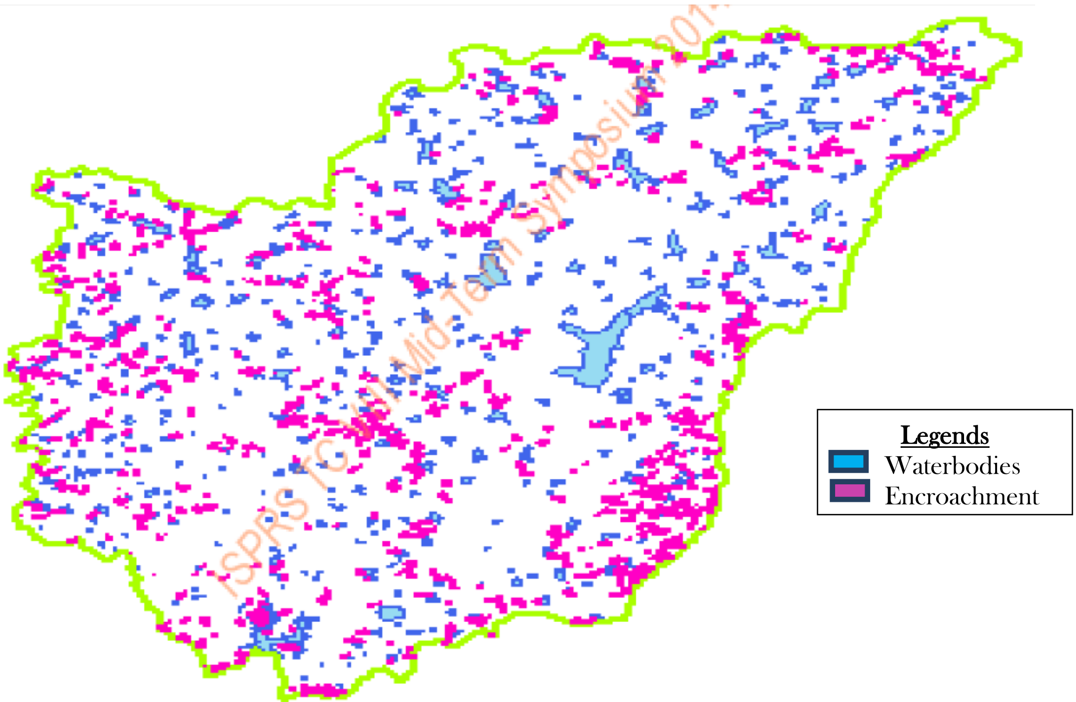


Figure-3.6. Encroachment of drainage in TGR Catchment area (1900-2009)

Chapter-4: Current situation in TGR Catchment Area

4.1. Introduction:

Catchments and watersheds are land areas that drain to a Hydro Network. The determination of their boundaries is necessary for a hydrological system. Drainage boundaries are used in water availability studies, water quality projects, flood forecasting programs, as well as many other engineering and public policy applications. A catchment is defined as the land area that contributes runoff to a given Hydro Edge. Any raindrop falling on an Edge catchment has a unique path to a Hydro Edge and is routed down through the Hydro Network. Reservoirs occupy a prominent place in the history of irrigation in South India and is useful life saving mechanism in the water scarcity areas which are categorized as Arid and Semi-arid zones. The rivers, reservoirs and lakes all over the country without exception, are in varying degrees of environmental degradation. The degradation is due to encroachments, eutrophication (due to the inflow of domestic and industrial effluents) and siltation. There has been a quantum jump in population during the last century without corresponding expansion of civic facilities resulting in deterioration of rivers, reservoirs, and lakes, especially in urban and semi urban areas becoming sinks for the contaminants. The degradation of reservoir and lake catchments due to deforestation, stone quarrying, sand mining, extensive agricultural use, consequent erosion and increased silt flows, have vitiated the quality of water stored in reservoirs and lakes. Infrastructure development, housing projects and inflow of untreated waste water into the water bodies have resulted in deterioration of urban and rural lakes and reservoirs (Chandrashekar *et al.*, 2012). The TG Halli reservoir is no exception and suffers from the problem of untreated waste water.

4.2. Methodology:

To verify and record the status of the TGR catchment and the preservation zones (as per the Government Order dated 18.11.2003), extensive field verifications have been carried out by EMPRI research team of Centre for Lake Conservation (CLC). Remote sensing study by KSRSAC have been taken into account and the EMPRI researchers have documented the existing condition of drainages; water bodies and landscape with reference to village maps including the layouts and apartments, sanitation and solid waste management facilities etc. Further, the unauthorized or illegal activities in the zones as per the Government Order dated 18.11.2003, such as quarries and industries were also documented with photographs and its geographical coordinates with the help of GPS.

4.3. Status of Reservoirs:

4.3.1. Thippagondanahalli Reservoir (TGR):

Foreshore of the TGR is well fenced, but the backshore of TGR has not been adequately fenced which has resulted in free access and soil excavation, sand mining, and also dumping of wastes etc. Influx of sewage water in TGR through the Arkavathi River has degraded the quality of TGR water. Aquatic weed (*Eichhornia* sp.) has spread over some parts of the TGR due to eutrophication as a result of sewage inflow. Seasonal encroachments by the farmers for agriculture (Plate-4.4c) and brick kiln activities were also observed in TGR. The water stored in TGR is presently not being treated by BWSSB and supplied but due to the leaking sluice gate of TGR, the water flows down to Manchanabele dam. The farmers in the surrounding villages have grown Jowar, Finger millet and Lablab (Avarekalu) etc. by drawing water from the TGR. The details of observations made in the 37kms shore length of TGR during the month of December'2014 along with GPS readings are annexed in the Annexure-4.1.

4.3.1a. Biodiversity:

While tracking the entire reservoir the flora and fauna observed have been recorded and given below:

i. Flora:

33 plant species belonging to 22 families have been identified, which include 13 tree species, 08 shrub species and 12 herb species. *Eichhornia crassipes* (Water hyacinth), *Ipomoea fistulosa* and *Lemna* sp. are aquatic plants. Among these, water hyacinth is the major aquatic weed covering parts of the surface water spread area followed by *Lemna* sp. Further, *Ipomoea fistulosa* is wide spread weed in the feeder channels of the reservoir. Apart from the natural vegetation, BWSSB with the help of Karnataka Forest Department (KFD) had planted the *Dodonaea viscosa, Pongamia pinnata, Tectona grandis, Grevillea robusta, Eucalyptus* sp. and *Acacia* sp. in the premises of the TGR. The flora observed in TG Halli reservoir is presented in Table-4.1 and Plate-4.1.

ii. Fauna:

About 22 bird species, two odonate species (dragon fly and blue grass dartlet), beetles, snails, reptiles (snakes and lizards) and fishes were observed. Egrets, Storks (Painted and Wooly necked storks), Heron, Black Drongo are common, whereas Kingfisher, Eagles and Brahminy kites are cited rarely in the TGR premises. But in 2011, Rajashekara and Venkatesha had reported 30 species of aquatic birds in the TGR. The avifauna observed in TG Halli reservoir is presented in Plate-4.2.

4.3.1b. Pollution and other related Issues:

i. Inflow of Sewage:

Reservoir is located in a place where North, East and West directions are elevated and south portion is low lying area. Hence, reservoir receives major portion of water from Arkavathi and Kumudvathi Rivers which are joining the reservoir from North East and North West directions respectively. TGR receives polluted water with foam and debris from various points. Mainly the inflow points are near the Gangenahalli, Nagasandra, Jogerahalli villages of Arkavathi river belt. TGR water is muddy and slurry with algal bloom. Oil spills and dead fishes were observed during ground verification in December'2014. The observations of inflow of polluted water are presented in Plate-4.3.

ii. Rapid Soil Excavation:

TGR is fenced only on the Magadi to Bengaluru highway side. Since the rest of reservoir area is not fenced, free access by people, grazing animals and encroachments for seasonal agriculture are very common within the TGR (Plate-4.4 a-c). Soil excavation and sand mining are the major activities documented in some locations of the reservoir. Adjacent to the present water spread area, mud roads and tracks have been observed that have disturbed the natural channel of water flow into the reservoir. The observations of soil excavation and sand mining in TGR accessed through different villages are presented in Plate-4.4 (d-j).

iii. Other Issues:

One brick kiln (Plate-4.5a) is operating next to the reservoir which is contributing to pollution due to burnt wastes and fly ashes (Plate-4.5 b and c) being dumped immediately adjacent to the reservoir area. Domestic solid wastes such as plastic covers, plastic bottles, glass wastes, waste cloths, detergents covers are observed in the vicinity of the reservoir. The observations are presented in Plate-4.5 (d-g).

4.3.2. Hesaraghatta Reservoir:

The observations documented in the Hesaraghatta reservoir during December'2014 are annexed in the Annexure-4.2. As the water in the Hesaraghatta reservoir is not being utilised for the domestic or irrigation or industrial activities, the local community have utilised for fishing activities. The reservoir is also playing a critical role in recharging the groundwater and the local people are using ground water for their requirements and they are also supplying ground water to nearby villages.

4.3.2a. Biodiversity:

In flora, observations include tree species, herbs, shrubs and aquatic weeds. Two types of aquatic weeds have been documented, namely, *Ipomoea fistulosa* (Plate-4.6a) and *Alternanthera sessilis* (Plate-4.6b), mostly in the Northern East and Northern West of reservoir. The terrestrial plant growth is dominated by Grasses and *Prosopis juliflora*. Other plant species observed are *Parthenium hysterophorus, Lantana camara* (Plate-4.6c), *Calotropis gigantea* (Plate-4.6d), *Prosopis juliflora* (Plate-4.6e), *Eupatorium odoratum* (Plate-4.6f), *Mimosa pudica, Tribulus terrestris, Tecoma stans, Agave americana, Croton sparsiflorus, Peltaphorum inerme, Cassia* sp., *Artocarpus heterophylla, Eugenia jambolana, Tamarindus indica, Punica granatum, Azadirachta indica, Lemna* sp., *Crotalaria juncea, Achyranthes aspera, Argemone mexicana*. Interestingly there was no *Eichhornia crassipes*. This may be indicative of the fact that *Eichhornia crassipes* gets introduced further downstream of the Arkavathi river stretch due to sewage inflow.

Fauna such as Egrets (Plate-4.6g), Black Drongo (Plate-4.6h), Ducks and Herons (Plate-4.6 i-l) are observed all along the reservoir. Butterflies, snakes (Plate-4.6m), insects (Plate-4.6n), odonates, spiders, fishes (Plate-4.6o) and grazing animals are also observed in the reservoir.

4.3.2b. Pollution and other related Issues:

As the entire area is not fenced, unauthorized access was observed. Hesarghatta reservoir has become a popular tourist spot for photography and for picnic. Since there is no management of tourism activities, solid wastes were found to be dispersed in different locations of the reservoir (Plate-4.7 a-c). Aquatic plant debris, poultry wastes, plastic and organic wastes were observed in the Southern part; glass, plastic bottles, waste cloths, cover and paper wastes in the South East; and debris, waste cloths and plastic wastes in Southern West side of the reservoir during the ground verification. Construction of Durggalamma temple is in progress on reservoir main bund and the construction debris is dumped on the bund itself (Plate-4.7 d-f). Apart from this, religious offering activities such as dumping of organic wastes and animal sacrifice are also leading to pollution (Plate-4.7g).

Extensive soil excavations (Plate-4.8) are happening in the South West region in particular. As per the information provided by the local people, soil excavation is regular and daily a lot of soil load is being transported. The Southern part of the Hesarghatta reservoir water has algal growth, but there is no inflow of sewage into the reservoir.

4.4. Existing Status of Zone-2 covering an area of 2 km Around the Reservoir:

A zone of 2 kms from the TGR boundary is notified as the zone-2, as per the Government Order dated 18.11.2003. The zone-2 covers 33 villages located in the districts of Bengaluru Rural, Bengaluru Urban and Ramanagara districts and list of the villages falling in Zone-2 is given in Table-4.2.

Soil excavation in the Gangenahalli village near Arkavathi river bank and sand mining in Goravanahalli village was observed (Plate-4.9 a and b). Stone quarrying was seen in Bidanpalya village (Plate-4.9c). Such activities result in increase in the TDS (Total Dissolved Solids) and siltation in the nearby water bodies. Open dumping of agriculture waste and open defecation in the TGR surrounding villages has resulted in addition of nutrients and also the microbial load in the water during rainfall. Further, sanitary soak pit and improper solid waste management in the Zone-2 villages have also added nutrients and contaminants to the surface water. Brick kiln in ten villages, layouts in six villages, livestock farms for poultry and goat in nine villages and warehouses for LPG were observed in the Zone-2. The details of the locations and observations are presented in Annexure-4.3.

Aquatic weed *Eichhornia crassipes* and *Lemna* sp. were observed in many parts of the Arkavathi River in Zone-2. The possible entry of these weeds to Arkavathi River is from Madanayakanahalli or Siddanahosahalli (Zone-3) village waterbodies through which Arkavathi river passes. The agricultural crops and plantations (Plate-4.9 d-g) observed include the following:

1. *Eucalyptus* sp., *Pongamia pinnata* and *Acacia* sp. are cultivated along the river.
2. Teak, Coconut and Arecanut plantations were observed next to river side in Gangenahalli village.
3. Banana plantations were observed in Goravanahalli village.
4. Agriculture activity by growing Jowar and finger millet was observed in Ganakallu and Hosur villages.
5. Growing of Jowar and finger millet, banana and coconut plantation was observed in Cholanayakanahalli and Motaganahalli villages.

Next to Varthur village, the inflow of sewage from Gangenahalli village was observed. The sewage flows through Nagasandra, Jogerahalli villages (Plate-4.10 a and b) and finally reaches the TGR. In Gangenahalli village, sewage water flowing in the Arkavathi River with foam and aquatic weed *Eichhornia* with the plant debris was observed. Further in Nagasandra and Jogerahalli villages, river bed was found to be encroached for growing horticultural crops, as per the discussion with the local people. In these villages agricultural wastes, plant debris, burned wastes and aquatic weeds were also found to be dumped in the bank of Arkavathi River (Plate-4.10 c and d).

Figure-4.1. A layout formation near Gagenahalli village

Formation of two layouts in the Zone-2 TGR catchment area was found to be completed and layout nearby Arkavathi River and layout in zone-2 was tracked using GPS. (a) Layout near Metipalya village near Arkavathi River (Figure-4.1) and (b) Layout in Ganakallu village, which is constructed for RBI Employees Association, as per the display board. This can be further confirmed from the Revenue department. The observations are presented in Plate-4.11.

4.5. Status of the River Arkavathi and Preservation Zones-3 and 4 around Arkavathi:

4.5.1. Arkavathi Sub-Catchment:

The Arkavathi River is located in the Karnataka State in southern India. The river's catchment overlaps with the western portion of the rapidly growing metropolis of Bengaluru. The region receives approximately 830mm of precipitation annually. The main stem of the Arkavathi River has its origin in the Nandi Hills, north of Bengaluru at Chikkaballapura district. The river Arkavathi flows in the south-westerly direction. The Arkavathi sub catchment has a total area of 376.59 km^2, which includes 137 tanks, Hesaraghatta being the major tank and some of the other tanks are Huskuru kere, Honnasandra kere, Bommashettihalli kere etc. From these series of lakes, water is fed into the river Arkavathi. Presently the river Arkavathi is non perennial and the water flows only when there is continuous rainfall in the region. There is a national highway i.e. NH-4, that passes through the Arkavathi sub catchment.

4.5.2. Hesaraghatta Sub-Catchment:

The first protected water supply to Bengaluru came from the Hesaraghatta Tank which was built across the River Arkavathi and was called the Chamrajendra Water works. In the year 1925, Hesaraghatta tank started drying up and urgent remedial measures were taken. Hence the reservoir was commissioned on river Arkavathi by building a dam (Chamraja Sagar) at TG Halli, downstream of Hesaraghatta tank. The Hesaraghatta sub catchment covering an area of 606.57 km^2 has 197 tanks of varying sizes. Kakolakere, Madhurekere, Doddatumkuru kere, Dodda Hejjije kere, Aradheshanahalli kere etc., are some of the tanks in the catchment. The Hesaraghatta tank has a storage capacity of 19.68 MCM of water. NH 207 is one of the highways that passes through the catchment. Till about few decades back this tank was used as the drinking water source to Bengaluru city. But from past twenty five years the water from Hesaraghatta tank is not flowing down the River Arkavathi because the water in the tank was not sufficient and it is used for local needs. Hence the sluice gates and the syphon were closed by the BWSSB.

The study carried out by Indian Space Research Organization (ISRO) in association with Indian Resources Information and Management Technologies Pvt. Ltd., (IN-RIMIT) revealed that unplanned development in the catchment area is one of the main reasons for the deteriorating quality and reduced inflow into the reservoir. Increasing urbanization and industrialization in the catchment area has altered the drainage pattern in the catchment areas and also has led to overexploitation of groundwater. This in turn has affected the inflow into the Tippagondanahalli Reservoir. The report also said that there are a number of industries in the catchment area, whose effluents also flow into Tippagondanahalli Reservoir affecting the quality of water. Underground leachate from untreated effluent and sewage was also found to be affecting the quality of ground water in this area.

4.5.3. Field Observations in the Zones-3 and 4 of Arkavathi river stretch:

The field visits were carried out in zone-3 and 4 i.e. in and around the Arkavathi river stretch. Till 2012 the Bangalore Water Supply and Sewerage Board relied on the Arkavathi-fed Tippagondanahalli reservoir to supply water to West Bengaluru. By November 2012, the water-level had plummeted to 6 ft. in the reservoir. While the water in the river has risen again, the water is not usable as it is contaminated with sewage and effluents from the surrounding layouts and industries. Field visits were undertaken, covering all the villages in zone-3 and 4 to gather information on the issues concerning these zones within two km buffer area. Also photos and GPS points were taken onsite. Field observations for fifty three (53) villages were completed in the Arkavathi stretch, i.e. from Hesaraghatta tank till TG Halli reservoir. The field visits were conducted in the following villages: Hesaraghatta, Billijaji, Thorenagasandra, Hurullichikkannahalli, Ivarakandapura, Kallenahalli, Kudige Thirumalapura, Tharabanahalli, Thamarasanahalli, Hosallipalya, Guddaddahalli, Dasenahalli, Kallupalya/Muniyanapalya, Heggadadevanapura, Madhanayakanahalli, Siddhanahosahalli, Gowdahalli, Kittanahalli, Sasiveghatta, Dombarahalli, Adaikamaranahalli, Kadaranahalli, Laxmipura, Vaddarahalli, Madavara, Bettahalli, Ravuhathanahalli, Averahalli, Shivanapura, Soldevanahalli, Tammenahalli, Dasanpura, Guddadahalli, Byyandahalli, Narayanappanapalya, Giddannahalli, Honnagannahalli, Kurabarahalli, Sigehalli, Varturu, Mallasandra, Sundekuppa, Balchkuppa, D. Narayanpura, Channamaranpalya, Channehalli, Gattisiddanahalli, Kadabagere, Marenahalli, Honnaganahalli and Kittanahalli.

It was observed that the long course of the river, however, has shrunk over the years. The reduced surface flow of the 33-km stretch of the Arkavathi can be attributed to few major factors, including rampant encroachment, industrial pollution, sand mining, quarrying, unauthorized development etc.

4.5.4 Major environmental issues in the catchment of River Arkavathi:

4.5.4.1. Hesaraghatta Village:

The large Hesaraghatta tank in the village is a source of water to the village and surrounding villages of the district. The Hesaraghatta village being populous has witnessed expansion of habitats around small drains and streams of the river. This has led to encroachment of stream bed that has been subjected to dumping of solid and liquid wastes in the streams (Plate-4.12 a-d). The entire stream stretch in Hesaraghatta village has witnessed intense growth of weeds and grass as the stream has no flow of water. Continuous inflow of sewage into the river might have led to groundwater contamination.

The ground water resources are being tapped to a great extent either for domestic or irrigation purposes, illegal bore wells are distributed throughout the upper catchment i.e. Hesaraghatta catchment, which gives adequate quantity of water only during rainy season. As the dry season advances, and as the water table lowers, most of them become dry during the summer seasons. Therefore villagers have gone in for large number of bore wells. This has led to indiscriminate extraction of ground water in the Arkavathi and Hesaraghatta catchment.

Hesaraghatta tank has two outlet streams, one outlet flows from the sluice gate and the other outlet is a main river from the syphon (which is used to discharge flood water when the reservoir is full) side of the tank. These outlet streams from the tank, flows further down the village and converge near Travellers Bungalow (TB) Cross of the Hesaraghatta village and flows further down as river Arkavathi. The Arkavathi River flows from Hesaraghatta tank till about 5.6 km downstream where the remnant of the brick aqueduct (bridge) to convey water by gravity from tank is situated in Tarabanahalli Village. This entire stretch is totally dry as there is no overflow of water from tank in the past 30 years. As per the discussion with the local villagers during field observation, the sluice gates were closed by the Government on request from these villagers, hence there is no flow of water in this river stretch (Plate-4.12 e-g).

But there are a few blotches of stagnant sewage water in the river course. Adjacent to the stream that is flowing from the sluice gate of Hesaraghatta tank, there's a huge Hesaraghatta settlement, through which a small sewage inlet is let into the stream and a bathroom is constructed at the edge of the same stream (Plate-4.12 h and i). The inflow of sewage into the stream is not so evident since the stream bed is covered with grass and weeds. It is further subjected to dumping of solid and poultry waste, construction debris, black sludge, hence resulting in stream blockage. As the same stream runs down through the main road, waste water inlet is let into the stream from the nearby shops and solid waste was also found to be dumped (Plate-4.12 a-d).

A Green Park Residency Welfare Dhaba (Plate-4.12j), Wood Works, Durgamba and Christ Motors (Plate-4.12k) are located right next to the Arkavathi River which is flowing from the syphon side of Hesaraghatta tank. A drain containing dhaba waste (Plate-4.12l) is let into this river and also there is intense growth of weeds and grass. There is a Hesaraghatta Residency Resort (Plate-4.12m) situated adjacent to the river and it might be encroaching into the river bed, which should be further verified by Revenue Authorities. A small inlet containing waste water from the resort is let into the dry river and also dumping of solid waste from the resort was observed.

The Hesaraghatta Village is home to newly developed layouts around the village. It was specifically noticed that the newer layouts coming up in this village, which are in development stage, have created impediments for the flow of water. Annapoorneshwari layout (Plate-4.12n) is situated right next to the river Arkavathi, where the storm water drain is constructed till the edge of the river. The layout is still in the developing stage.

Prakruthi layout (Plate-4.12o) is coming up right next to the river Arkavathi, where the river is completely dry (Plate-4.12p), with weed growth. Opposite to the layout the river bed is also subjected to encroachment for raising the banana plantation (Plate-4.12q).

Kempegowda layout (Plate-4.12 r-t) is situated right next to the river, encroaching the river bed, storm water drains from this layout is let into the river, and few houses have already come up in the layout while few are still under construction. There's a hollow block factory in the village, as well as poultry and quarry waste has been dumped near the nala (Plate-4.12 u-w). In due course of time during monsoon season, when there is flow in the river and when these layouts are fully developed, more runoff could be generated from these urban locales, which could contaminate the river with sewage and effluents.

4.5.4.2. Dasenahalli Village:

The village came into prominence after the establishment of the CPDO (Central Poultry Development Organization) near Hesaraghatta, in collaboration with the Danish and Irish Governments. CPDO specializes in breeding and raising varieties of cattle and poultry animals.

The village Dasenahalli next to Hesaraghatta village comes under zone-4. The village houses Government institutes like CPDO (Central Poultry Development Organization) and duck unit (Plate-4.13 a-e) that might have encroached part of the Hesaraghatta tank bed (which needs to be verified by concerned revenue authorities) and also massive soil excavation on the Hesaraghatta tank bed was observed. Few layouts in the village are under still under development (Plate-4.13f)

4.5.4.3. Ivarakandapura Village:

The village Ivarakandapura is known for Indian Institute of Horticultural Research, which is spread over 263 hectares. The village has a huge waterbody known as Ivarakandapura Lake. The lake is completely dry and is fenced with barbed wire (Plate-4.14 a and b). As per the information given by local villagers, the reason for fencing the lake could be that the Indian Institute of Horticultural Research (Plate-4.14c), have reserved the water body for cultivation of vegetable and fruit crops. This may further be verified by Lake Development Authority and Revenue Authorities. Few nurseries and plantations have been cultivated around the waterbody and few nurseries have encroached the lake edge (Plate-4.14 d and e). Solid waste has been dumped (Plate-4.14f) in the outlet stream from Ivarakandapura Lake and also few developments have come up next to the outlet stream. The other issue concerning the village is that a number of layouts (Plate4.14g) are coming up and also few poultry farms (Plate4.14h) which are causing nuisance, by dumping poultry waste (Plate4.14i) in the vicinity of the village and also in the water body and massive soil excavation (Plate4.14j). The Revenue Authorities and the concerned Planning Authorities should verify the permissibility of such developments.

4.5.4.4. Kittanahalli and Giddenahalli Villages:

Both the villages are subjected to extensive quarrying. Though the government has banned quarrying in Arkavathi catchment, it was observed during field verification. Presently quarrying (Plate-4.15 a-d) is in progress just 500m away from the River Arkavathi. The

Department of Mines and Geology may further look into the matter and take necessary action. Quarrying can generate a number of environmental effects through blasting, excavation, crushing, and transport of aggregates. Illegal quarry disturbs the ecology and drainage pattern in the river. It also reduces water inflow to the TG Halli Reservoir and has reduced the groundwater table. The water also gets polluted due to quarrying activities. The villages and residential colonies in the area are feeling the effects of uncurbed quarrying activity. Further quarry waste has been dumped in the river stretches (Plate-4.15 e and f) as well as near the culverts and bridges.

There are two granite factories (Plate-4.15 g-i). One of the granite factories is adjacent to the river, just about 50m away and the other is around 200m away from the river, where cutting and cleaning of granites are done. The granite waste is let into the water causing water pollution and also the dust particles from cutting the granite, causes air pollution. The river flowing in force under the bridge, is foamy in nature, carrying the polluted water. The river bed is fenced i.e. encroached for plantation (Plate-4.15 j-l).

4.5.4.5. Varthuru Village:

Construction of Gayathri residency/D K Residency layouts etc. (Plate-4.16 a-d) are coming up right next to the river Arkavathi within a distance of 100m in Varthuru village. There was a small waterbody present in this area till 2012, but by 2014 this waterbody has been encroached for layout development. There is further clearing of land going on for layout development (Plate-4.16e) near the river course. Other issues in this village are brick factory and poultry farms (Plate-4.16f), where brick waste and poultry waste are discarded into the river, causing contamination in the river. The Revenue Authorities and Town Planning Department should further look into these developments and take suitable action. The river bed has been fenced, i.e. encroached for plantation and also soil excavation by local people has been observed (Plate-4.16 g and h). Growth of water hyacinth has been observed in the river, which indicates that river water is polluted (Plate-4.16 i and j) and quarry waste has been dumbed near the lake (Plate-4.16k).

4.5.4.6. Kadabagere Village:

This village is known for the issues concerning the river from few industries like Cement industry, Power Plus Pvt. Ltd., Nutri Food Farm Pvt. Ltd. (Plate-4.17 a-c) and also few godowns, brick factories (Plate-4.17d) and poultries. The KSPCB may further inspect with regards to the pollution levels due to the industrial units and take suitable action. Layout development, granite factories, sand mining are some of the issues observed in this village (Plate-4.17 e-h).

4.5.4.7. Tarabanahalli Village:

In Tarabanahalli, houses built adjacent (Plate-4.18a) to the stream are letting the grey water into the storm water drains which in turn are entering the stream. Some houses have directly connected the pipes into the stream. Srigiri Convention Hall (Plate-4.18b) has been built close to the river (within 100m). New Anjanadri layout has come up close to the stream. The river Arakavathy is completely dry with weed growth and also polluted with solid waste, construction debris, poultry waste, cloth waste etc (Plate-4.18 c-f). Brick factory and layout development in the village (Plate-4.18 g and h) are also some of the other issues.

4.5.4.8 .Thorenagsandra Village:

There are several layout developments coming up in this village. Few of the layouts are still in early developmental stage where as few others have come up. Two to three layout developments have taken place very close to the river Arkavathi.

4.5.4.9. Alur Village:

Alur village is falling partly within the zone-3 and zone-4 and also zone-1. During ground verification disposal of solid waste into the river was observed (Plate-4.19a). The sewage water from the broken man hole adjacent to the river was found to be entering the river (Plate-4.19b). Further down the river Nilgiri plants were observed in middle of the river bed (Plate-4.19c). The width of the river has narrowed due to the agricultural encroachment of the river bank from either side. This may further be verified by Revenue Authorities. Layout has been developed adjacent to the river (Plate-4.19d). Lakes in Alur, forming a part of the river course are subjected to severe abuse evident from layouts developed adjacent to the lakes (Plate-4.19 e and f). Further, solid waste dumping near Pan Parag India Ltd. into drain close to the stream was observed (Plate-4.19g). A sand filtering unit (Plate-4.19h) with a drain connected to the stream and layout (Plate-4.19i) are present adjacent to the stream.

4.5.4.10. Heggadadevanapura Village:

Heggadadevanapura village has totally three lakes. Of the two lakes one lake has been completely converted to layout (Plate-4.20 a and b). Few houses are present in the layout. The other lake has been encroached by the godown – Future Consumer Enterprises Ltd. (Plate-4.20 c and d). This may be further verified by revenue authorities. The storm water drain carrying the grey water from the settlement is entering the river (Plate-4.20e). Puddle of stagnant polluted water was found in the river (Plate-4.20f). Growth of duck weeds, ipomoea and others are seen. Close to the river, borewell and houses are present. Many godowns (Plate-4.20g) and layouts (Plate-4.20h) within 1 km from the river are present in the village.

4.5.4.11. Makali Village:

NH-4 High way is passing right through this village. The village has grown tremendously along the river Arkavathi. Golden Seams Textile Pvt. Ltd. is situated around 520 mts away from the river (Plate-4.21a). Himalaya Drug Company is situated around 300 mts away from the river (Plate-4.21b). A temple named Sri Anjanaiah temple having the impression of foot of Lord Hanuman on the rock is present inside the river giving the place a status of holiness (Plate-4.21c). During ground verification storm water drain carrying the grey/ wastewater from the settlement was found to be joining the river (Plate-4.21d). On the river bed human defecation was found. A single lake present in the village is found to be encroached by the godown. The godown is under Writ Petition (WP No 38737/2013, Survey No. 13) owned by Mr. Srilakshmikantha (Plate-4.21 e and f). The godown is rented to Himalaya Drug Company for storage of finished goods. This may be further verified by concerned authorities. The village has large number of godowns, commercial buildings, hotels; shops etc., that have come up close to the river all within 1km from the river. Few godowns are found to be built on the river bank and have constructed drains leading into the river for carrying grey water, floor washing etc. (Plate-4.21g). These godowns are rented to Sabic Innovatic Plastics, Zydus–Candial Health care Ltd. (Plate-4.21h) and for MRF tyres (Plate-4.21i). One godown is empty and is under Writ Petition (WP No. 38793/2013, Sy.No.14) owned by Mr. C.S. Puttegowda (Plate-4.26j). Further many godowns are present within 1km from the river.

4.5.4.12. Madhanayakanahalli Village:

The village has developed tremendously on either side of the NH 4 highway in form of commercial buildings and gowdowns. Godowns coming under Writ Petition (WP No. 39940/2013, Sy.No. 50) owned by Mr. H Ravi, apparently appeared to be encroaching the river bank (Plate-4.22a). This may be further verified by concerned authorities. The godowns are rented to Bata India Ltd., Inland World Logistic, Shri Sai Enterprises, etc. These godowns have constructed drains leading into the river to carry the grey or waste water from their godowns (Plate-4.22b). Wastewater in the storm water drains located adjusent to the godowns (Sri Venkata Raghavendra Enterprises, Reliance Fresh and RCPL Logistics (P) Ltd.) are entering the river (Plate-4.22 c and d). Further the godowns situated in this village are used by Jaipur Golden Transport Ltd., Lloyd Electric and Engineering Ltd., RCPL, Usha, Parle, etc. LT Karle & Co Garment stitching Unit–II is found to be present around 700 mts from the river (Plate-4.22e).

The stream flowing through the village was found to be carrying the greywater which was entering the river. The wastewater is forming the puddle of polluted water with the growth of duck weeds, *Ipomea* and others (Plate-4.22f). In the village the boulders found adjacent to the river near NH4 was broken and the low lying land has been filled with broken rocks and solid waste dump (Plate-4.22g).

Huge dumping of solid waste including construction debris, bio medical waste, and organic waste, agricultural waste (from agricultural based activities) and burning of waste was observed all along the stretch of the river bank (Plate-4.22 [h-j]).

4.5.4.13. Adaikamaranahalli Village:

The village consists of large number of godowns. The stream flowing through the village is subjected to solid waste dump and a number of godowns including the Himalayan drug Company and its godown and other godowns are constructed adjacent to it. Further small shops have also been established adjacent to the stream. The godowns are rented to Fed Ex, Smart Retail Pvt. Ltd., Camlin, Dow Chemical International Pvt. Ltd., Spot on, etc. Further small shops selling steel, automobile garage are present close to the stream. Few godowns are present within 1km from the river while others are beyond one km from the river.

4.5.4.14. Harokyathanahalli Village:

The stream, flowing via Dhombarahalli joins the river in Harokyathanahalli. A small (fabric dying) shed is found adjacent to the stream and is letting the washed water into the stream (Plate-4.23 a-c). Till Harokyathanahalli only puddle of water is found but from the confluence point the sewage water is found to be continuously flowing in river downstream (Plate-4.23d). Huge construction debris and burning of solid waste were found adjacent to the stream. Soil mining in the river bed was found during the field visit (Plate-4.23f). In the village the storm water drain carrying the grey/ wastewater from the settlement was entering into the lake (Plate-4.23g). A lake was found to be encroached by the houses and temple (Plate-4.23 h and i). This may further be verified by Revenue Authorities. The godowns present are Idea cellular Ltd warehouse, Castrol India Pvt. Ltd., Kvehne Nagel, ware house of Godrej & Boyco, Supreme Transport Solutions (P) Ltd., etc.

4.5.4.15. Gowdahalli and Kammasandra Villages:

Layout developments are adjacent to the river in Gowdahalli (Plate-4.24 a and b) and Kammasandra villages. The agricultural fields adjacent to the river was found to be growing banana, coconut, maize, chilly etc. These agricultural fields were found to draw the sewage water flowing in the river for cultivation purposes (Plate-4.24c). Eventually similar activity was observed in Kammasandra also. Further in Kammasandra a small lake was completely filled with granite sludge (Plate-4.24d). Layout development (Plate-4.24e), Brick kiln and poultry were found in the village of Kammasandra.

4.5.4.16. Ravuthanahalli Village:

Apart from the layouts an unusual activity of dumping of granite sludge waste close to the river was noticed. A lorry carrying the slurry was found to be emptying the sludge which eventually flowed into the river (Plate-4.25 a and b). A poultry is present adjacent to the river and stream (Plate-4.25c).

4.5.4.17. Dhombarahalli Village:

The only lake in the village has been converted to a layout (Plate-4.26 a and b). This may be further verified by concerned authorities. Few houses are present in the layout adjacent to the river. Few godowns are present in the village. The godowns – Nilkamal Ltd., Volvoline Cummins Ltd., etc. are near to the stream. Highly polluted stream from Madavara village (Plate-4.27g) further flows through the Dhombarahalli village (Plate-4.26c). Storm water drain carrying waste water is joining this stream. The stream further joins the river at Harokyathanahalli. Large layout with few houses was found adjacent to the stream (Plate-4.26d). A poultry farm is also present near the stream (Plate-4.26e).

4.5.4.18. Byyandahalli and Bettahalli Villages:

A stream flowing from the lake in the Machohalli via Vaddarahalli is flowing adjacent to the villages Byyandahalli and Bettahalli. Algal bloom was found in the stream indicating nutrient enrichment. The stream confluences with the river Arkavathi (Lat. 13°00′36.7″N and Long. 77° 25′55.4″E), down this confluence point fishing was observed (Plate-4.27a). Further adjacent to the river in the Bettahalli sand filtering was being carried out (Plate-4.27b). In Bettahalli poultry was found, while brick kilns were found in Byyandahalli.

4.5.4.19. Siddhanahosahalli Village:

Glory Boys Apparel Pvt. Ltd. garment stitching unit is present (around 700 mts from the river) (Plate-4.27d). Few other godowns are also present. Huge dumping of solid waste adjacent to the river was found.

4.5.4.20. Avverahalli Village:

The village falls in zone-4. The lake in the village is completely surrounded by the development of the layouts all around which would cause hindrance to the normal functioning of the lake and to the ecosystem (Plate-4.27h).

Some of the other issues concerning the Arkavathi river course from the villages Hessarghatta (Plate-4.12), Dasenahalli (Plate-4.13), Ivarakandapura (Plate-4.14), Kittanahalli, Giddannahalli (Plate-4.15), Varthuru (Plate-4.16), Kadabagere (Plate-4.17), Tharabanahalli (Plate-4.18), Billijaji, Thorenagasandra, Thirumalapura (Plate-4.28), Hurullichikkannahalli (Plate-4.29), Kudige Thamarasanahalli, Guddaddahalli, Honnagannahatti (Plate-4.30), Kallenahalli (Plate-4.31a), Kurabarahalli (Plate-4.31 b-d), Mallasandra (Plate-4.31 e and f), Sigenahalli (Plate-4.31g), Hosahallipalya (Plate-4.31h), Sondekuppa (Plate-4.31i), Balchkuppa, De Narayanpura, Channamaranpalya, Channehalli, Gattisiddanahalli, Alur (Plate-4.19) Kallupalya/ Muniyanapalya, Heggadadevanapura (Plate-4.20), Makali (Plate-4.21), Madhanayakanahalli (Plate-4.22), Harokyathanahalli (Plate-4.23), Gowdahalli, Kammasandra (Plate-4.24), Sasiveghatta, Ravuhathanahalli (Plate-4.25), Adaikamaranahalli, Dhombarahalli (Plate-4.26), Kadaranahalli, Laxmipura, Vaddarahalli, Madavara, Siddhanahosahalli, Byyandahalli, Bettahalli, Averahalli (Plate-4.27), Shivanapura, Soldevanahalli, Tammenahalli, Dasanpura, Guddadahalli, Byyandahalli, Narayanappanapalya and Nagarur are given below:

i. Dumping of solid, poultry, agricultural and biomedical waste, construction debris, etc. which has led to chocking the passage of river water flow in the culverts and bridges, and also disrupting the water flow in the river. There are few brick units and poultry farms in and around the River Arkavathi.

ii. The Arkavathi bank is a veritable goldmine for real estate developers, are now dotted with layouts, houses and commercial structures as rapid development is taking place along the river stretch, which has damaged the rivers. Many layouts, many of them unauthorized, have come up in the Arkavathi upper catchment area, some of them have also encroached into the river beds, obstructing the river. Few layouts have come up right next to the river, encroaching the river beds, i.e. the storm water drains are built till the edge of the river, few houses have been already constructed in these layouts and few layouts are still under development. During monsoon, when there is flow in the river, sewage and other effluents from these developing layouts flow into the river, further polluting the water quality and also percolating slowly into water flowing below the ground, hence in turn polluting the groundwater as well.

iii. It is noted that intense tapping of ground water near the surface river courses are causing local depletion of water level, reducing surface water storage and hence the flow of the river water course is steeply declining. Stagnation of polluted water has led to contamination of ground water. Hence the Arkavathi River has become non-perennial, flowing only during rainy season. There are a number of tanks within the area that store rain water but due to excess silting the storage capacity has reduced. Due to scarcity of water in Hessarghatta as well as the nearby villages, many bore wells have been dug, leading to over exploitation of groundwater. Water in these open wells is unfit for human consumption.

iv. Agriculture was one of the main occupations in these regions but over the last decade the land use pattern has drastically changed due to conversion of agriculture lands to layouts and commercial areas.

v. The other issues in these villages are that the lakes are almost dry with rapid soil excavation taking place. Encroachment of few lakes was found to be for agriculture in some cases and layout development in some other cases. There are few poultry farms and brick factories close to the lakes, where poultry and brick waste are dumped into the water body. Many bore wells in and around the lake have been dug up, hence the water retention, quality and quantity of ground water is decreasing. Also solid waste, agriculture waste and construction debris are dumped into the lake causing water pollution.

vi. Agricultural activities were predominantly found in Kallupalya/Muniyanapalya village adjacent to the river. A Reserve forest is located adjacent to the river. During the field visit it was observed that the compound wall, made of stone, constructed by Forest Department, was destroyed badly due to the heavy flow of the river water during monsoon (Plate-4.18 i and j). A bridge constructed across the river during Sir M Vishweshwariah period as per the villagers has markings of High Flood Level (HFL) of water in the river. Based on the markings it was roughly calculated as 30ft of High Flood Level (Plate-4.23b). A borewell was present adjacent to the river in the agricultural field and one adjacent to the forest. A puddle of muddy water was present in the river. During visit to the village of Sasiveghatta a bore well adjacent to the river was found to have failed. As per the villagers the ground water was available only beyond 1000ft. A borewell adjacent to the river itself did not have water. Hence some agricultural lands have been converted into the layouts but halted waiting for further court orders. The river stretch in this village was completely dry.

vii. <u>Layouts</u>: In the villages of Tarabanahalli, Alur, Heggadadevanapura, Madhanayakanahalli, Siddhanahosahalli, Gowdahalli and Harokyathanahalli (Plate-4.23e) some layouts are developed adjacent to the river. The developed layouts included storm water drain, roads (metallic or non-metallic) and electric poles. The storm water drains of such layout are directed towards and are leading into the river. The layouts – Aishwaraiah and SLV layouts are also encroaching the stream apart from being developed adjacent to the river in Gowdahalli (Plate-4.24a). While Sri Gajanana Enclave-3 with few houses in Alur village is present adjacent to the stream (Plate-4.19i). These findings may be further verified by Revenue Authorities.

viii. In few layouts, buildings had already come up while some were under construction in the villages of Madhanayakanahalli, Tarabanahalli, and Heggadadevanapura (Plate-4.20h), while bore-wells are present in the layout of Madhanayakanahalli village (Plate-4.22k) near the water stagnant river. Similarly borewell and houses near the river was noticed in Heggadadevanapura village. These findings may be further verified by Revenue Authorities.

ix. Layouts developed closer to the river falling within 1 km of the river were found in Tarabanahalli, Alur, Sasiveghatta, Kuduregere, Harokyathanahalli, Gowdahalli (Plate-4.24b), Kammasandra (Plate-4.24e), Hanumanthasagara (Plate-4.27c), Ravuthanahalli, Kadaranahalli, Bettahalli, Kittanahalli, Shivanapura, and similarly layouts have developed beyond one km in Laxmipura, Averahalli, Vaddarahalli, Thammenahalli and Guddadahalli. Further building was found to be constructed adjacent to the streams in villages of Vaddarahalli and Kadaranahalli (Plate-4.27 e and f).

x. Solid waste was found to be dumped on the river banks in the villages of Alur, Makali, Madhanayakanahalli, Siddhanahosalli and Heggadadevanapura. Solid waste included inorganic waste, construction debris, organic waste, agricultural waste from agricultural based activities, paper cups, bio medical waste etc. In Makali (Plate-4.21 k and l) and Madhanayakanahalli the solid waste was found to be burnt. Also, plastic covers, solid waste was found to be burnt adjacent to the river in Heggadadevanapura.

xi. Godowns are found in the villages of Makali, Madhanayakanahalli, Heggadevanapura (Plate-4.25g), Adaikamaranahalli in clusters and some in Siddhanahosahalli, Harokyathanahalli and Dasanpura, and few are found in Madavara, Gowdahalli, Narayanappanapalya**,** Kuduregere, Soladevanahalli, Lakshmipura and Nagarur villages. These godowns could not be individually visited since there was no cooperation from the owners, except for godowns which were involved in writ petitions, which have been covered separately in Chapter-6. Only from the activities around the godowns and from the name boards, observations have been recorded.

The detailed field observations in the villages of Zone-3 and 4 of Arkavathi River are annexed in Annexure-4.4 and Plate-4.12 to 4.31.

4.6. Existing Status of Zone-3 and 4 of Kumudvathi Course:

Kumudvathi River originates from Shivagange hills and beyond Thymgondlu town covering a catchment area of about 462.6 Km^2 of Nelamangala taluk of Bangalore rural district and Magadi taluk of Ramanagara district of Karnataka. In zone-3 and 4 of the catchment, there are around 98 villages from Benegere in North to Bidanpalya and Motaganahalli in the South. Until Kuluvanahalli village, the water flows through a series of cascading lakes of varied sizes connecting each other and further downstream, Chikkannayyana kere near Dodderi on NH-4, the river flows at a stretch till it converges with River Arkavathi at Chamarajasagar Reservoir in Thippagondanahalli.

4.6.1. Field Observations in the Zones-3 and 4 of Kumudvathi River Course:

Some of the major issues and observations concerning the river are

i. The catchment has witnessed increase in population in few villages, which has resulted in encroachment of small streams that furnish water to the river. In the upper catchment, above Thymagondlu village, most of the small streams have been encroached for agricultural activity and also the streams are clogged by deposition of silt and sand. Some of the lakes like Niduvanda and Dasenahalli kere are subjected to seasonal agricultural encroachment (Plate-4.32 a and b). The lake bed of Hajipalya is completely encroached for establishment of brick manufacturing unit (Plate-4.32c).

ii. The extension of Sompura Industrial area in adjacent Niduvanda village of zone-4, has led to construction of new industries in the catchment leading to industrial development (Plate-4.32 d and e). The storm-water drains from this developing industrial area are directed to the Niduvanda kere (Plate-4.32f).

iii. In the river stretch of Zone-3 and 4, there are around 33 poultries and 34 brick manufacturing units (including cement block manufacturing units) and few of them are not in working condition.

iv. There is no definite solid waste management system in the villages of this catchment area, hence in these settlements, solid waste is dumped in backyard of the houses, outside villages and nearby lakes/streams, therefore solid wastes are found scattered randomly in the catchment area (Plate-4.32 g and h). The putrescible organic waste generated from kitchen, straws, garbage, waste earth and cow dung is piled up and when composted, it is utilised as manure in agricultural fields. In most of the places, the culverts carrying water to the streams under the road and railroad has been choked up by weed growth, scattered solid waste and by deposition of waste earth and stones etc.

v. The distinctive feature of River is that it flows through number of lakes in the catchment. The major lakes of this sub-catchment area are Manne kere, Hirekere, Kalalaghatakere, Sondilvadikere and Niduvandakere near Thymagondlu, Chikkannayyanakere and T.Begurkere on NH-4, and Yelechagerekere of Yelechagere village. As per field observation, the status of lakes situated in the river catchment are in poor state and the sluice gate are not in working condition, hindering the water flow in fringes of drains connecting these lakes. Majority of lakes are subjected to soil excavation (Plate-4.32i) and bore wells have been dug in the lake bed and on lake bund as well. Storm-water drainages were letting sewage water into the Lakes of Benegere, Karimane, Heggunda, and Motaganahalli villages (Plate-4.32j). Most of the storm water drains in Zone-3 and 4 were carrying the domestic wastewater (Plate-4.32k).

vi. The entire river stretch had stagnant water in small blotches. This stagnant water was found in Basavenahalli of magadi taluk, Doddakarenahalli, Kodihalli, Tippadabegur, Dodderi and Chikkamaranahalli of Nelamangala taluk. The water spread in the river stretch was approximately around 108m in Chikkamaranahalli, 805m in Doddakarenahalli and from Lingenahalli to Basavenahalli is 663 m. The Dodda-Begurkere of zone-1, Bidlurukere and Dodderi Lake of zone-3 was moderately filled with water. The Lakes had muddy water where as in streams; water was green in colour at Doddakarenahalli, Lingenahalli and Basavenahalli villages, blackish green water behind Cadbury factory (Plate-4.32l) and putrid water in Chikkamaranahalli village was recorded (Plate-4.32m). During field visits by EMPRI team, a check dam was spotted in Chikkamaranahalli village (Plate-4.32n).

vii. Water available in the lakes and stream is utilised for animal washing, animal feeding, washing clothes in Lekkenahallikere and Chikkannayyanakere. Water is pumped to agricultural plots in Basavenahalli (Plate-4.32o), Lingenahalli and also in Yelechagere from the Yelachagerelake villages (Plate-4.32p). Due to scarcity of water in the catchment, groundwater abstraction is comparatively high as the villagers mostly depend on the groundwater for their domestic purpose. The excessive use of this water has resulted in groundwater depletion.

viii. Sand washing in the river bed was observed near Chowdasandra village where sand loaded in a tractor was washed by pumping out the water available in the stream (Plate-4.32q). In Balaguruvanpalya, soil excavation was noticed and this soil was crammed in a tractor for transportation (Plate-4.32r). These activities in river bed induces suspended solid, turbidity, instability and slumping of river banks, rise in rate of soil erosion and damages to flora/fauna.

ix. Quarrying was predominant activity, reported in Basavenhalli, Kadukarenahalli and Vannasandra villages near Chamarajasagar Reservoir. In Basavenhalli (Plate-4.32s) and Kadukarenahalli (Plate-4.32t) villages, a group of people were involved in stone cutting and few of them were loading these stones into a lorry. The hill in Vannasandra is subjected to immense quarrying. Behind the stone crusher located at Basavenahalli village (Plate-4.32u), quarrying was observed and the cut stones were heaped near the crusher, due to this, the surrounding trees and plants were found to be covered with white dust. The ugly scars and pits due to quarrying, alters natural runoff pattern diminishing the water availability for groundwater recharge and surface water flow, which ultimately decreases the moisture content of soil, thus shrinking the level of groundwater table, thus exploiting the aquifer of the region.

x. The river stretch in few places has been encroached for various purposes. In Aralasandra village, Amma Naturopathy and Yoga center has been established very next to stream, which has also constructed a pathway on the stream (Plate 4.32v). A layout has come up immediately next to stream bed in Kempohalli at the converging point of two streams; one emerging from Thyamagondlu and another from Tippadabegur Doddakere (Plate-4.32w).

xi. Industries like Kirlosker Electricals and Fosroc Chemicals India Pvt. Ltd. (Plate-4.32 x and y) etc., have been established in Zone-3 and 4. Kemwell Pvt. Ltd. (a Pharmaceutical industry) on NH-4 and Cadbury industry on NH-48 has been established adjacent to the stream and few pipe outlets from Kemwell industry have been let into the stream (Plate-4.32z). The Pepsi industry located behind Kemwell Pvt. Ltd. has been collecting the effluent in an artificially constructed basin/pond near the stream.

xii. Quarrying and sand washing are the major environmental damaging activities which are practiced in the villages beyond the Bangalore Mangalore Highway (NH-48) up to Bidanpalya village in the south.

The above points are few of the major issues witnessed along the river course. The detailed field observations in the villages of Zone-3 and 4 of Kumudvathi River are annexed in Annexure-4.5 and Plate-4.32.

4.7. Existing Status of Zone-1:

Zone-1 of TGR catchment area covers 550 villages apart from the villages of Zone-2, 3 and 4. There are three distinct sub-catchments for the TGR, with aerial extend of 606 sq. km (Hesaraghatta), 376.6 sq. km (Arkavathi) and 462.6 sq. km (Kumudvathi). The following are the field observations in Zone-1 summarised sub-catchment wise.

4.7.1. Hesaraghatta Sub Catchment Area:

The Hessarghatta tank situated in the upstream of TGR divides the catchment area into two sub-catchments are Hesaraghatta and Arkavathi sub-catchments. Hesaraghatta sub-catchment covers an area of 606.57 sq. km. with 197 tanks in the catchment. Kakola kere, Doddatumkur kere, Ardeshanahalli kere, Madhure kere, Dodda Hejjajji kere, etc. are some of the large tanks in the catchment, while Hesaraghatta tank is the largest as per the ISRO-INRIMT report. Water from these tanks is used mainly for irrigation and also for domestic purposes. The filling up of these tanks mainly depends on the pattern of rainfall in the catchment. NH-207 is one of the highways that pass through the catchment. Doddabalapur Industrial area is situated in the catchment. Annie Besant Park is next to Doddabalapur, having a length of 2.39 kilometers. The villages that come under Hesaraghatta sub-catchment area are given in Table-4.3.

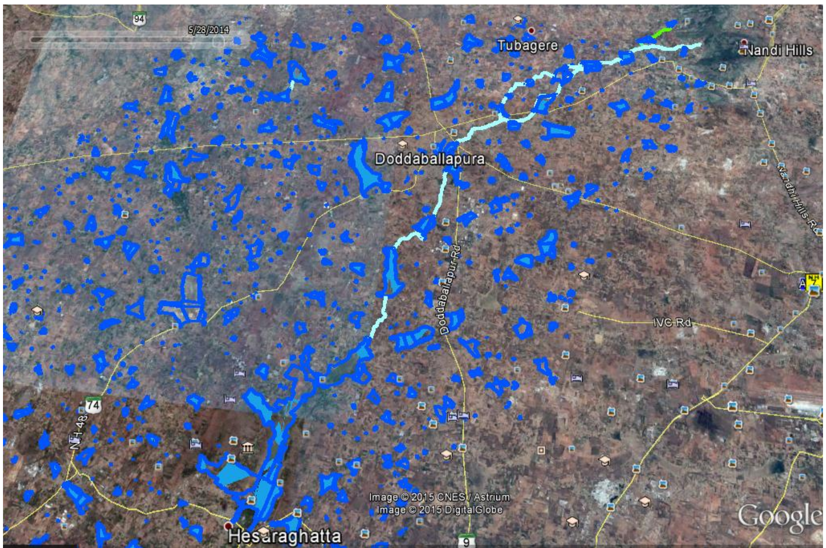


Figure-4.2: The main stem of the River Arkavathi originates from Nandi

The main stem of the River Arkavathi originates from Nandi Hills, flowing past Doddabalapur town through a series of cascading lakes, which feeds the Hesaraghatta tank and further flows downstream as Arkavathi River. The series of cascading tanks that feed Hesaraghatta tank starting from Nandi hills are Doddarayappanahalli kere, Melekote kere, Gantiganahalli kere, Beedikere kere, Kanchiganala kere, Thimmasandra kere, Shivapura kere, Khas Bhag kere, Veerapura kere, Dodda Tumakuru kere and Kakolu kere. These cascading lakes were feeding Hessarghatta tank years back, but now these lakes no longer overflow, as the drains that carry the overflowing water from these lakes are narrowed/ blocked (Figure-4.2). Also the outflow of water and retention of water has come down due to blocking of feeder channels, lack of maintenance etc. These water bodies face some of the major issues like rapid soil excavation, dumping of solid waste, construction debris, plastic waste etc. slight encroachment for agricultural activities, and hence most of the lakes are partially dry.

4.7.1a. Major Environmental Concerns:

Lakes and tanks are known to be ecological barometers of the health of the city. The presence of a lake in any region greatly influences the life of people living in the region. Some of the major issues observed in Zone-1 of the Hesaraghatta sub catchment area during the field visits are quarrying, rapid soil excavation, storm water drains carrying wastewater from households and industries to the nearby waterbodies in few villages, dumping of solid waste, construction debris, etc. in the lakes as well as storm water drains, encroachments for agriculture activities or raising of plantation in lakes and also bore-wells drilled in and around the lakes.

4.7.1a.i. Quarrying:

Quarries disrupt the existing movement of surface water and groundwater; they interrupt natural water recharge and can lead to reduced quantity and quality of water for residents or downstream from a quarry site. Adjacent eco-systems are affected by noise, dust, accumulation of silt in nearby waterbodies leading to pollution and contamination. In addition, sliding of unconsolidated material near waterbodies can introduce large quantities of sediment and rocks into the aquatic environment. As a quarry becomes deeper, water inflows generally increase but when the quarry closes it must be ensured that the site is fully reclaimed and it doesn't pose a danger in the future. Active quarrying has been observed in few villages like Obadevanahalli, Managondanahalli, Koyira, Chikkobanahalli and Varadhanahalli (Plate-4.33). Also quarrying in Bacchahalli, Varadhanahalli and Byrapura villages was found to be taking place very close to the lake.

Quarries in Thimmasandra, Alurududdanahalli and Gulyanandhigundh villages have been stopped few years back, but they are not reclaimed rather they are left as it is, with water filled in these quarry pits posing danger to the public.

4.7.1a.ii. Soil excavation:

One of the major issues commonly observed in most of the lakes is soil excavation. Most of the lakes are subjected to rapid and excessive soil excavation like the lakes in madhuranahosahalli, Beerasandra, Dodda Tumakuru, Gejjagadhahalli, Muppadighatta, Chikkavadagere, Sonnenahalli, Kannamangala, Madhure, Gulya, Honnavara, kakola, Bhairapura, Challahalli, Buddamanahalli, Dibbur, Linganahalli, Beerasandra, Thirumagondanahalli, Ittagalapura, etc. (Plate-4.34). It is found that excavation activities have induced damages to the water bodies, by discharging sediments into the water body. Soil excavation generate high levels of turbidity from colloidal sediment particles, which reduces the amount of light reaching the lower depths, which can inhibit growth of submerged aquatic plants and consequently affect species which are dependent on them. Soil excavation also leads to air pollution.

4.7.1a.iii. Encroachment:

Many lakes in the catchment are dried up as the 'Raja Kaluves' (the major streams) and other drains that carry rainwater to the lakes are blocked or narrowed and hence rendering these dried lakes vulnerable to encroachments. On the other hand, the lakes are drying up due to reduction in rainfall. As per the discussion with villagers, most of the lakes are dry round the entire year and hence they utilize the lake for agricultural activities, mainly for growing seasonal crops. Few of the lakes in Koluru Rayanahalli, Byatha, Gulya, Honnavara, Honnadevipura, Kadanur, Byrasandra, Gejjagadhahalli, Doddagollahalli, Madhagondanahalli, Obadevanahalli, Arakere, Kadathamale, Sadenahalli, etc. (Plate-4.35) villages are subjected to encroachment for raising plantations like Nilgiri, coconut, etc. and also for agriculture.

4.7.1a.iv. Waste Dump:

Solid waste generated in the villages includes degradable waste and non-degradable waste like plastic. The villagers use degradable waste for manure while most of the lakes in the catchment area have become dumping grounds for plastic waste, construction debris, burning waste, agricultural waste, poultry waste, etc. which are scattered in and around the lake and they are also dumped in storm water drains, as there is no scientific method of disposal system in the villages. These wastes if not treated on time, produces leachate which might contaminate the groundwater, surface waterbodies, soil, etc. Some of the villages where dumping of solid waste in the lakes are observed in Suradenapura, Rajankunte, Ammanipalya, Ramanathapura, Gejjagadhahalli, Doddagollahalli, Buddamanahalli, Madhure, Ramadevanahalli, Kakola, etc. (Plate-4.36).

4.7.1a.v. Groundwater Exploitation:

Groundwater resources are being tapped in the catchment area to a great extent for both domestic and irrigation purposes. Bore-wells are drilled in and around the lakes and water is supplied to households through mini water schemes, which are setup in most of the villages. Most of the bore wells drilled in this catchment, goes up to a depth of 800 ft. or much below. This indicates that water is drawn for extensive irrigation and for domestic purposes due to population increase (Plates-4.37). Due to this the groundwater recharge gets accelerated because of induced recharge by continuous pumping of groundwater and the surface storage also gets reduced at faster rate.

4.7.1a.vi. Wastewater Discharge to the Lakes:

In few of the villages like Suradenapura, Adhiganahalli, Bashettihalli, Majara Hosahalli, Madhure, Shanubhoganahalli, Haniyur, Adde Viswanathapura, etc. small sewerage lines are directly connected to the lakes as settlements, layouts and apartments have come up close to the lake boundaries. Sewage in water leads to water contamination i.e. eutrophication and major health hazards. Also the sewage leaches into the groundwater leading to groundwater contamination.

4.7.1b. Pollution in Major Lakes:

4.7.1b.i. Kakola Kere:

Kakola lake is one of the large tanks after Hesaraghatta tank situated in the village Kakola. As per the discussion with local people the lake has been dry for many years but in the past two years the lake has been partially filled. The overflow from this lake flows to Hesaraghatta tank but as the sluice gate is closed, water doesn't overflow; hence the other side of kakola lake i.e. Hesaraghatta tank is not getting water from Kakola kere. Some of the issues threatening this lake are major soil excavation, major growth of weed and trees in the lake. A fishing tent was constructed inside the lake where small boats were used for fishing. Plastic waste was dumped in the lake.

4.7.1b.ii. Dodda Tumakuru Kere

Dodda Tumakuru kere is another big lake in Zone-1, which covers three villages i.e. Dodda Tumakuru, Byrasandra and Bacchahalli. The water is muddy and slightly greenish mainly due to excessive soil excavation in the lake. Coconut, arecanut and growth of other plantations were observed inside the lake. Excessive weed growth was also seen in the lake. The lake is slightly encroached by grape plantation. Agriculture waste and construction debris were dumped in the lake. Bore-well was located inside the lake, which shows that lake water is being drawn for agriculture purpose and also a pipe has been installed inside the lake for drawing water. A hut was seen inside the lake, used for fishing.

4.7.1b.iii. Ardeshanahalli kere

Ardeshanahalli kere is situated in the village Ardeshanahalli. Rapid soil excavation, solid waste dumping, brick waste, construction debris was found to have been dumped in the lake. There is a brick factory adjacent to the lake, hence brick waste has been dumped inside the lake. Three bore-wells were dug inside the lake, used for drawing lake water directly for irrigation and other purposes in the village. Growth of plantation was also observed inside the lake.

4.7.1b.iv. Madhure Kere:

Madhure Ammanikere is one of the large lakes in the region covering six villages i.e. Madure Amanikere, Kanasavadi, Channadevi Agrahara, Honnavara, Isthur and Mallohalli. The lake is almost filled with water and consists of five small islands. The lake has been subjected to rapid soil excavation, drawing of lake water into tankers, washing clothes, bore wells near the lake and also there is a small sewage drain from the settlements which is let into the lake, polluting the lake (Plate-4.38a). There is a Choultry in Kanasawadi village adjacent to the outlet of the lake, this has led to dumping of solid waste, construction debris, burning waste, cloth waste etc. into the lake. There are few graveyards on the lake bed. Plantations have slightly encroached the lake in Honnavara, and Isthur village and also there are few trees and weed growth inside the lake.

4.7.1b.v. Dodda Hejjajji Kere

Dodda Hejjaji kere, one of the large lakes in Hesaraghatta sub catchment covers Dodda Hejjaji, Chikka Hejjaji Amanikere, Doddabelavangala and Sonnenahalli villages. The lake is facing degradation due to excessive soil excavation, dumping of agriculture waste, burning of waste, etc. in the lake and encroachment by coconut and other plantations in part of the lake in Doddabelavangala village.

4.7.1b.vi. Bashettihalli Kere:

Bashettihalli kere is shared between two villages i.e. Areguddadhahalli and Ba Shettyhalli. The Central Effluent Treatment Plant (CETP) set up by the Karnataka Industrial Areas Development Board (KIADB) to treat the effluents from the Doddaballapur Apparel Park is situated at the edge of the lake (Plate-4.39). As per the discussions with people in the treatment plant, all the pipelines from the industries carrying industrial waste water is brought to the treatment plant and after treating, the treated water is taken back to the industries but the plant has not been functional from past few days. But as per the discussion with villagers and an article (Deccan Chronicle, 10th June'2015), the treatment plant is no longer operational, **reportedly because the private agency roped in to run it, found it financially unviable to keep it functional and shut it down in 2010.** Industries that claimed to have their own treatment plants did not send their effluents to it even when it was operational, but the others that depended on it took the easy way out and began releasing their effluents into the Bashettihalli Lake, polluting its water and damaging the health of the villagers who used it.

As per the field visit, it was observed that a small drain containing industrial waste from Bombay Rayon Fashions Limited (BRFL), which is situated adjacent to the lake, is entering the lake. There's a small pond in the edge of the lake that contains industrial waste, which is stagnant (Plate-4.38 b-d). The lake is almost dry due to the evaporation of waste water, and high rate of weed growth is observed due to heavy pollutant load. Soil excavation was also observed in the lake.

4.7.1b.vii. Majara Hosahalli Kere:

Majara hosahalli kere is shared by Veerapura and Majara Hosahalli villages. A drain carrying sewage from the village is connected to the lake, hence polluting it (Plate-4.38e). Drain containing waste from Birla Cement factory is entering the lake (Plate-4.38f). The lake is completely dry with heavy growth of weeds. A sewage treatment plant is being constructed inside the lake. A small treatment plant of 12MLD capacities is under construction (Plate-4.40). Also huge walls of cement and gravel materials are under construction. As per the discussion with villagers, these walls are being constructed to store waste water that is received from the villages. The contractor for the treatment plant is Raus Construction Pvt. Ltd., and the total area is 37 Acres. There is a small patch of coconut plantation inside the lake.

Polluted Shanubhoganahalli, Haniyur, Adhiganahalli and Suradenapura lakes are shown in Plate-4.38 (g-j). The detailed field observations in the villages of Hesserghatta sub-catchment area (Zone-1) is annexed in Annexure-4.6.

4.7.1c. Doddaballapura Industrial Area:

Doddaballapura is a town and municipal council in Bangalore Rural district in the state of Karnataka. The Karnataka Industrial Areas Development Board [KIADB] developed the Doddaballapura Industrial Area (Figure-4.3) which is about 40km from Bangalore towards North on Bangalore to Hindupur state highway. This town was once known for weaving silk. Many families in Doddaballapura depend on power looms. Doddaballapura Industrial Area is stretched in four villages - Areguddadhahalli, Ba Shettyhalli, Veerapura and Yellapura (Plate-4.41). There is a very big industrial area in Bashettihalli, which is around 6km from Doddaballapura. The Doddaballapur apparel park is on the outskirts of Bangalore and is being developed by the Karnataka Industrial Areas Development Board (KIADB). Few industries in the industrial area are Raymond's Ever Blue Apparel Ltd., Bombay Rayon Fashions Ltd., Himatsingka Seide Ltd., Amtek Industries etc. This industrial area houses a large number of industries. The site of the upcoming, 12,000 Acre (49 km^2) BIAL IT Investment Region is the largest IT region in India and one of the largest infrastructure projects in history of Karnataka.

Figure-4.3: Layout Map of Doddaballapur Industrial Area

4.7.2. Arkavathi Sub-Catchment Area:

The Arkavathi sub-catchment area extends from south of Hesaraghatta tank to Thippagondanahalli Reservoir which covers parts of Hesaraghatta, Dasanapura, Yelahanka, and Yeshwanthpur hobli of Bangalore Urban district and Nelamangala hobli of Bangalore Rural district. As per ISRO-INRIMT report, the aerial extent of the catchment area is 376.6 sq.km and there are about 137 tanks in the catchment. Some of the large tanks of the catchment are Honnasandra, Nagarur, Huskuru, Mukturu and Bommashettihalli. Around 119 villages falls under Arkavathi sub-catchment area and are as tabulated in Table-4.4.

The North and South Eastern part of Arkavathi sub-catchment and along the National Highway (NH4), the catchment has witnessed extensive development of industrial area, layouts and massive expansion of the settlements due to intensive population growth. Peenya Industrial Area is one of the Asia's largest industrial areas is located in this catchment. The major concerns of this region are management of solid waste, treatment of effluents from small to large scale industries and treatment of domestic wastewater (sewage and sullage). Most of the storm-water drains are carrying industrial and domestic wastewater to the nearby waterbodies. And also solid-wastes have been dumped in these water bodies. The major water bodies in this vicinity have witnessed huge spread of invasive species of Hydrophytes i.e, *Eichhornia crassipes* (water hyacinth) due to heavy pollutant load.

4.7.2a. Major Environmental Concerns:

4.7.2a.i. Domestic and Industrial Wastewater Discharge:

The domestic wastewater contains nitrogen, phosphorous, potassium, micronutrients and organic matter which are normally required for agricultural crop production and when not managed properly, the pathogens such as bacteria, viruses, protozoa and helminths can cause potential health hazards especially when it is discharged into natural water bodies. The wastewater is highly dangerous when it loses dissolved oxygen due to warm climatic condition to become stale or septic in nature. It also releases hydrogen sulphide which produces offensive odour. Due availability of these nutrients, the plant (water hyacinth) growth is increased which basically depends on nutrient contents of waterbodies. Thus the trophic state of water bodies gets transformed from oligotrophic/ mesotrophic stage to eutrophic (hyper eutrophic) stage. In the Arkavathi sub-catchment, the industrial effluent and domestic sullage are discharged to nearby village drains (Plate-4.42). Most of the lakes have witnessed the growth of aquatic weeds as well (Plate-4.43).

Industrial wastewater contains toxic chemicals and metals depending on the raw materials that are used in the manufacturing process and they pose great threat as these chemicals reacts in the environment based on various factors like temperature, pH, etc., the wastewater when let into waterbodies, alters the basic profile of waterbodies by inducing alkaline/ acidic contents. This activity causes highly unfavourable conditions for the living organisms of waterbodies. In the catchment, most of the drains are receiving coloured wastewater from surrounding industrial outlets and it is difficult to trace particular industry which is responsible to this.

The discharge of domestic sewage/sullage and industrial wastewater into drains of the catchment will ultimately reach to tanks and river as most of the waterbodies are connected to each other by natural drainage system.

4.7.2a.ii. Solid Waste Disposal:

When solid waste is not treated at the time of generation, it produces leachate which has potential to contaminate soil, water bodies and ground water aquifers. In this catchment, lakes and drains are treated as dumping yard of waste such as garbage, poultry, construction and demolition debris, plastic wastes generated by various purposes which can severely pollute waterbodies. Such pollution also creates an un-aesthetic environment. Almost all the lakes and drains are subjected to waste dump in this region (Plate-4.44).

Ramky Landfill Site:

Survey No. 8 of Mavallipura village has been used for dumping Bangalore's garbage for several years. Bruhat Bengaluru Mahanagara Palike (BBMP – Bruhat Bangalore Municipal Corporation) had outsourced the task of managing this landfill site to M/s Ramky Environmental Engineers, a Hyderabad based company. Huge piles of untreated garbage were found to be dumped at the site. The seepage of the toxic leachate water generated from this site had seriously contaminated the groundwater aquifer of that region. Hence this dumping site is currently not being used to dump the waste (Plate-4.44a) due to the various possible threats associated to it.

4.7.2a.iii. Soil Excavation and Quarrying:

Soil excavation induces turbidity and increases total suspended solids in the water bodies. Most of the lakes in the Arkavathi sub-catchment are subjected to soil excavation (Plate-4.45).

Quarrying causes environmental disturbance by the process of aggregate extraction and processing. It changes the geomorphologic features of particular land ultimately leading to conversion of land use pattern. When it rains, the pollutants and sediments from quarrying site may reach to nearby water bodies in runoff. The rainwater which is stored in quarry pits lessens the inflow to the natural drains which feeds immediate and also surrounding water bodies of the region. Due to this soil moisture is reduced in surrounding area and reduces the ground water recharge of the aquifer.

Quarrying was observed in Mallasandra, Hunnegere, Lakkenahalli, Mantanakurchi, Byregowdanahalli, Guddadhahalli, Thotagere, Hadhripura and Bettahalli villages of Zone-1 of Arkavathi sub-catchment area (Plate-4.46). In Hadhripura village extensive quarrying was observed.

4.7.2b. Pollution in Major lakes and villages:

4.7.2b.i. Madavara Kere:

The Madavara kere covers three villages- Madavara, Chikkabidarakallu and Thirumalapura. Pipeline conveying foamed wastewater and the coloured wastewater from surrounding is passing through the lake and is discharging this wastewater into the drain which continues to flow ultimately to River Arkavathi (Plate-4.42 a and b). Garbage waste, construction and demolition debris, poultry waste and the wastes from barber shop was dumped in the lake premises (Plate-4.44 b-e). During the field visit it was observed that the lake bund was being diverted.

4.7.2b.ii. Doddabidarakallu Kere:

This Lake covers two villages- Doddabidarakallu and Nagasandra. In Doddabidarakallu village, there is a 20MLD sewage treatment plant located next to the bund of Doddabidarakallu kere (Plate-4.47). The lake was entirely covered by water hyacinth (Plate-4.43a) and only stale/septic black coloured water can be seen in the lake (Plate-4.42f). A drain from Nagasandra village is carrying stale wastewater which is directed to the lake. Garbage, construction and demolition waste was found to be dumped in the lake and also in and around the drains of these villages. And also burning of the waste was observed in the lake. The lake is surrounded by factories like Lorman Kitchen Equipments Pvt. Ltd.

4.7.2b.iii. Dasarahalli Kere:

The Dasarahalli kere is located in a portion of Dasarahalli and Chokkasandra villages. The garbage waste is discarded on the bund and around the lake. The inlet drain of lake from Chokkasandra is hauled with wastewater. The treated wastewater from the Sewage Treatment Plant (Plate-4.48) is let into Dasarhalli kere. A drain passing from Texport Syndicate India (P) Ltd. and Dynomic Airospace Technology industries are carrying wastewater.

A number of small drains feed the aforementioned lakes, and they are connected to a drain which runs almost 7.5 km to convey water to River Arkavathi. Initially this drain carries water from Dasarahalli kere to Daddabidarakallu kere and then to Madavara kere and from Madavara kere it finally discharges water to River Arkavathi. Thus entry of any toxic and hazardous contaminants in any one of the aforementioned lakes or drain connected to these cascading tanks in turn pollutes River Arkavathi. The overflow from Madavara kere is currently blocked.

4.7.2b.iv. Kammagondanahalli Kere, Chikkabanavara Kere and Abbigere Lake

The Kammagondanahalli kere covers three villages- Kammagondanahalli, Mydharanahalli and Shettyhalli and is entirely covered with water hyacinth.

The Chikkabanavara Kere receives the overflowing water from Kammagondanahalli lake and also from the Abbigere lake through a drain. This lake covers four villages- Chikkabanavara, Somashettyhalli, Guddadhahalli and Ganigarahalli. Varieties of birds were spotted in Chikkabanavara kere. The lake is dumped with large quantities of poultry waste, garbage, construction and demolition debris and waste from barber shop etc. Domestic wastewater is also let into this lake.

A drain connects Abbigere lake to Chikkabanavara kere. The overflow from Abbigere feeds Chikkabanavara kere. Abbigere lake covers two villages- Abbigere and Singapura village. The waste from barber shop, garbage waste, construction and demolition debris is dumped in and around this lake (Plate-4.44 f-i) and also drain carrying stale wastewater is let into the lake.

4.7.2b.v. Bagalakunte Kere and Kachohalli Kere:

Huge amount of construction and demolition debris is dumped in the Bagalakunte lake (Survey No. 113). Stale wastewater carried by storm water drain is let into this lake. Garbage waste is also discarded randomly in the lake (Plate-4.44m).

The Kachohalli kere is surrounded by industries, Kachohalli settlement and hollow block manufacturing units. The drain passing through the factories like Sai Packing, Colour flex, Life Star Pharma Pvt. Ltd. and hallow block manufacturing unit is carrying wastewater to the Kachohalli lake. The garbage and poultry waste is discarded in the lake. Also these wastes are burnt in the lake premises (Plate-4.44x).

4.7.2b.vi. Sondekoppa Kere and Nelamangala Kere

The Sondekoppa lake of this village is polluted by inlet of wastewater (Plate-4.42j) and plastic waste, construction and demolition debris which are dumped in the lake. Lake is surrounded by granite factories and settlement in the North West direction.

Water hyacinth is spread in the Nelamangala lake indicating that the lake is polluted (Plate-4.43d). Lake is surrounded by settlement and Brick manufacturing units. Garbage is dumped in and around the lake (Plate-4.44y).

4.7.2b.vii. Dasanapura Kere and Arasinakunte Kere:

Dasanapura lake is surrounded by layout, apartment and agriculture land. The sewer outlet is found in this lake, though wastewater flow from this sewer was not observed on the day of field visit by EMPRI team (Plate-4.42m). Garbage is dumped in the lake.

Arasinakunte lake seems to be highly polluted and water hyacinth is spread in the lake (Plate-4.43e). Huge quantity of waste is dumped in the lake such as garbage, plastic, construction and demolition debris.

4.7.2c. Rejuvenation of Lakes:

The deteriorated lakes are generally rejuvenated to improve water quality and to beautify the lake environs. During the field visits conducted by EMPRI team in the Arkavathi sub catchment, it was observed that the lakes of Lingadeeranahalli (Figure-4.4), Handrahalli and Karihobanahalli are under rejuvenation process and the lake of Herohalli is also rejuvenated and is under BBMP jurisdiction. Though the lake is rejuvenated, more quantity of solid waste was discarded in and around the lake creating an-aesthetic environment (Figure-4.5).

The detailed field observations of villages in Arkavathi sub-catchment area are annexed in the Annexure-4.7.

Figure-4.4: Lingadeeranahalli lake under rejuvenation process

Figure-4.5: Waste dumped in rejuvenated Herohalli lake

4.7.2d. Peenya Industrial Area:

Peenya is one of the largest industrial areas in Bengaluru. Peenya industrial area comprises of Phase-1 to 4 developed by Karnataka Industrial Area Development Board (KIADB) and Stage-1 to 3 developed by Karnataka State Small Industries Development Corporation (KSSIDC). Phase-1 and Stage-1 of Peenya Industrial Area is located in Peenya village. Stage-2, Stage-3 and Phase-4 are established in Nelakadharanahalli. Phase-3 was accommodated partly in Chokkasandra, Laggere and Peenya village. Phase-2 of Peenya industrial area has occupied a portion of Chokkasandra, Nelakadharanahalli and Peenya village (Figure-4.6). Peenya industrial area has sheltered small, medium and large scale industries which belong to red, orange and green categories of industries. Shivapura kere, Karihobanahalli kere and Dasarahalli kere are the three major waterbodies of this area and are fed by a number of streams running through Peenya Industrial Area.

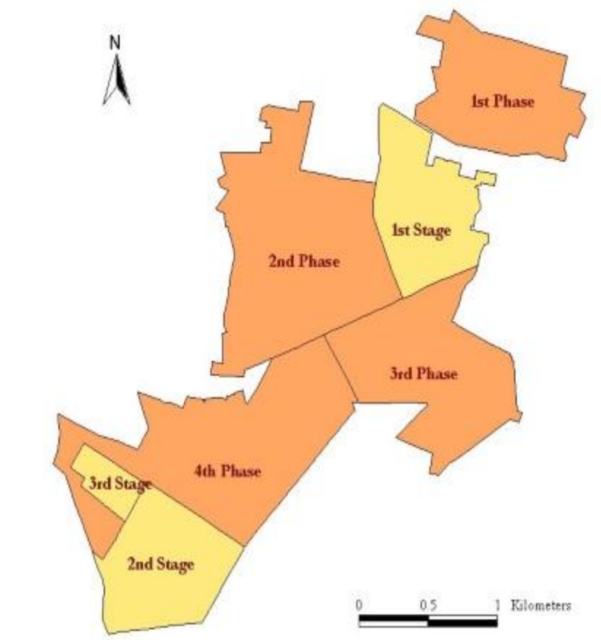


Figure-4.6: Layout Map of Peenya Industrial Area
(Source: Environmental Database for Peenya Industrial Area, Bangalore)

As per field observations, most of the drains in this industrial area are carrying wastewater and subjected to solid waste dumping as well (Plate-4.49). In Phase-3, clothes were discarded opposite to Sreeshwari Textile process industry and waste was dumped randomly in this lane. Waste was also dumped near Paper industry, Lakshmi Metals & Alloys Pvt., Heat controls, Bremers Rubber, Shahi Export Pvt. Ltd. and Sankhila Polymers industries. The waste dump was noticed in phase-4 as well. The two main feeder drains of Karihobanahalli Lake, passing through Stage-2 and 3 are carrying wastewater from surrounding area and solid wastes are dumped in and around these drains.

4.7.2c.i. Nelakadharanahalli

Nelakadharanahalli is a portion of Peenya Industrial Area and has three lakes. One of the lakes (Survey No. 59) joints outlet of huge drain carrying wastewater from the settlement. Solid waste is dumped in this lake.

Another lake called Shivapura kere (Survey No. 63) has highly polluted black coloured stale wastewater in small drains inside the lake (Plate-4.49 m-o). As per field observation, apart from small drains carrying waste water inside the lake, rest of the area had turned to blackish grey, because of repeated discharge of wastewater which clogs the pores of soil, preventing oxidation and causing obnoxious smell. The Milimines Agro Chemical Industry and other industries are located around this lake.

Karihobanahalli kere covers two villages- Nelakadharanahalli and Karihobanahalli. This lake is under rejuvenation process.

4.7.3. Kumudvathi Sub-Catchment Area:

Kumudvathi sub-catchment area forms the western portion of the TGR Catchment having aerial extent of 462.6sq km. The sub-catchment area covers around 154 numbers of villages falling with in Nelamangala taluk of Bengaluru Rural district and Magadi taluk of Ramanagara district. In addition to these villages few villages fall under Zone-2, 3 and 4. National Highways such as NH-4, NH-48 and NH-207 passes through the catchment area. As per ISRO-INRIMT report in catchment area 207 seasonal tanks are present, of which Mannekere, Hirekere near Tyamagondalu and Chikkannayyana kere near Kulvanahalli are very large tanks in the catchment while large tanks include Begur kere, Kalalaghatta kere, Sondilvadi kere, Niduvanda kere, Kodihalli kere, Kenchapura kere, and Billanakote kere. Villages of the Kumudvathi sub-catchment area are given in Table-4.5.

The environmental issues observed during the field visit are solid waste dumping in and around the lakes, liquid waste disposal from the residential area/ industries, extraction of ground water through bore-wells (both working and non-working), soil excavation/ sand mining in the lake bed and quarrying in the catchment area. Further encroachment of lake bed and check dams in the streams, and also some good practices such as Rain Water Harvesting systems (RWH) were noted in the villages during the field visit.

4.7.3a. Major Environmental Concerns:

4.7.3a.i. Groundwater Extraction:

In most of the villages it was found that major source of water for domestic use was the ground water. Bore wells were drilled inside the lakes or at the edge of the lake by the Mandal as per the discussions with villagers for the purpose of providing drinking water to the villagers (Plate-4.50a). The bore well water was supplied through Mini Water Scheme (MWS) to the villagers (Plate-4.50 b and c). During the field visit most of the lakes had been dried up. As per the discussion with few villagers it has been decades since the lakes such as Nidavanda kere have been filled completely. Even though few bore wells are drilled inside lakes, there is no water. The water level in the bore wells has decreased and the availability of the groundwater is beyond 1000ft. and many bore wells dug ended up as a failure as per the villagers.

In the villages such as Lakkuru, Nidavanda (also falls in Zone-3 and 4), Biragondanahalli (also falls in Zone-4) and Halenahalli, encroachement of the lake bed for the agricultural activity was observed. The villagers said that since there was no water in the lake they grew crops such as ragi, maize, horse gram inside the lake. If the government imposed any restriction on this they are willing to stop cultivation.

In few villages there was some amount of water in the lake. But the villagers depended on MWS for their domestic needs. In village of Hemapura private tankers were found to draw water from the lake (Plate-4.50d).

4.7.3a.ii. Soil Excavation and Sand Mining:

Extensive soil excavation was seen in the Pemmanahalli kere and Yedehalli kere. In the Yedehalli kere the soil was excavated and was taken to the adjacent field and dumped there (Plate-4.50e). Sand was also being mined in the lake bed during the field visit (Plate-4.50f). In all the villages soil excavation was observed, in addition sand mining was also found in the lakes of Avverahalli (Plate-4.50g), Alur, Udikunte, Kenchanapura and Machonayakanahalli villages.

4.7.3a.iii. Solid and liquid Waste:

Dumping of solid waste inside and around the lakes was observed. The solid waste included clothes, plastic, decomposable waste, agricultural waste (Plate-4.50h), garbage, biomedical waste (Plate-4.50i), bottles, construction debris, ash, broken brick waste etc and burning of waste was also observed.

Huge amount of solid waste dumped in and around the Sompura lake was observed (Plate-4.50j). As per the discussion with villagers dumped solid waste was generated due to the fare conducted adjacent to the Sompura lake every week (Plate-4.50k). Further there was discharge of waste water (Plate-4.50l) into the lake from the adjacent building (choultry) which was also dumping all the solid waste generated adjacent to the lake. Solid waste disposal unit of Nelmangala Town Municipal council is established in Kangondanahalli (Plate-4.50m).

In the villages of Maragondanahalli, Bommanahalli Kangondanahalli and Byadarahalli waste water was being discharged into the lakes. The waste water is entering the lake (Plate-4.50n) directly or through storm water drains which end up near the lakes (Plate-4.50o).

4.7.3a.iv. Quarrying:

Quarrying was observed in the villages of Lakkenahalli, Marikuppe, Koramangala, Billanakote and Hosahalli (Plate-4.50p), Mahimapura (Plate-4.50q), Narayanaraopalya (Plate-4.50r), Thyagadahalli, Kodagibommanahalli and Machonayakanahalli. In the village of Machonayakanahalli (Plate-4.50s) quarry was observed near the lake edge itself.

While in villages of Agalakuppi, Avverahalli, Kambala, Narayanapura, Arebommanahalli, Mallapura, Vadhakunte, Lakkappanahalli, Kanugondanahalli, Obanayakanahalli, Dasanpura, Kachanahalli villages during the field visit no activity in the quarry place was found. In Laxmanapura village abandoned quarry pit was found. The quarry pit is very deep and large without any warning signs or boards and hence is posing danger to the wanderers near to it (Plate-4.50t). Similarly, the quarry pit found in the village of Kanugondanahalli is also posing danger to the safety of local people (Plate-4.50u).

4.7.3b. Industrial Areas:

Karnataka Industrial Area Development Board (KIADB) a wholly owned infrastructure agency of Karnataka Government has formed the industrial area namely Sompura Industrial Area and Dabbaspet Industrial Area in Nelamangala taluk, Bangalore Rural district (Figure-4.7). The layouts are being allotted to industries ever since 1995. Further KIADB is expanding these industrial areas under different stages and developing new phases such as Avverahalli 5Th phase. The combined layout is of 3870.425 Acres. The industrial area includes villages such as Sompura, Pemmanahalli, Thimmanayakanahalli, Nidavanda, Bharatipura, Lakshmanapura, Biragondanahalli, Hosahalli, Yedehalli, Chandanahosahalli, Honnenahalli, Avverahalli and Makanakuppe (Figure-4.8). Industries of all categories – Red, Orange and Green are established in this industrial area. The detailed field observations in the villages of Kumudvathi sub-catchment area (Zone-1) is annexed in Annexure-4.8.

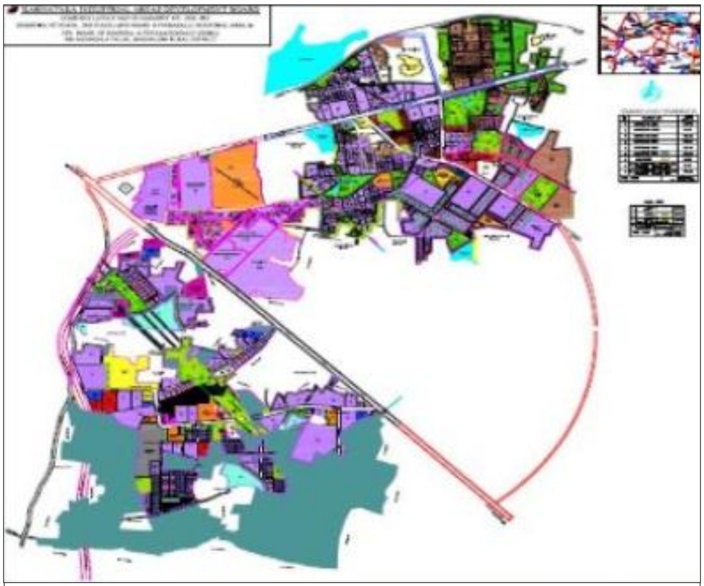


Figure-4.7: Combined layout map of Dabaspet 1st-3rd (Sompura 1st and 2nd Stage) (4th phase Avverahalli Industrial Area) & 5th Phase of Sompura and Thyamagondalu

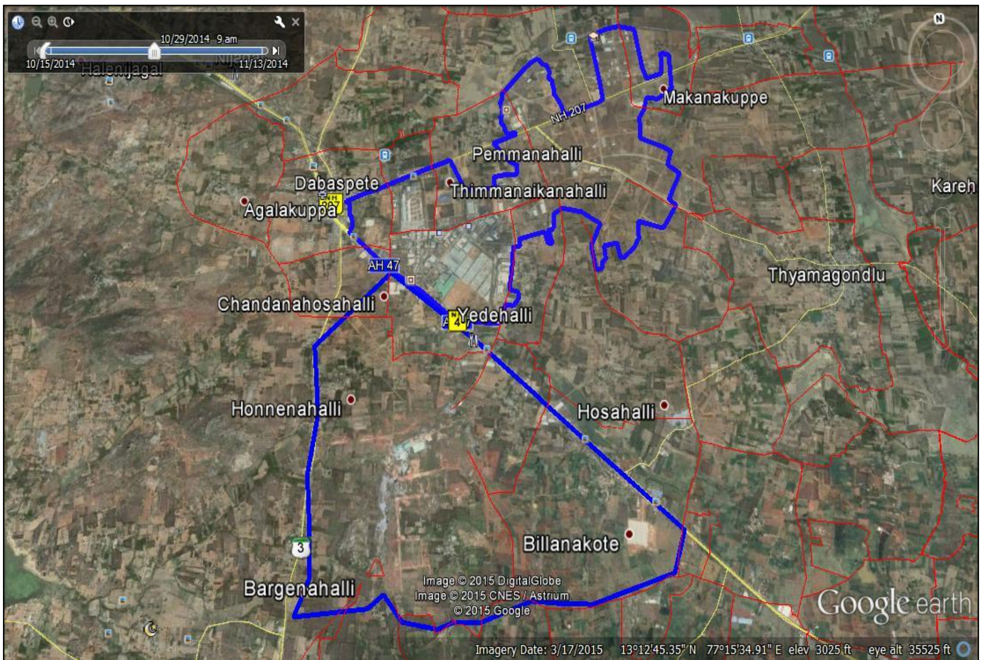


Figure-4.8: Combined Industrial Area Layout map in Google Image

Industries of red and orange (large, medium and small) categories apart from the above mentioned villages are also established in the villages of Aladahalli, Visheshwarapura, Budihaal, T.Begur, Kachanahalli, Bommanahalli, Mylanahalli, Bavikere, Gangadaranapalya, Mallapura, Tonachinakuppe, Kempalinganahalli, Devaganahalli, Basavanahalli, Veeranjinipura, Hanumanthapura, Geddalahalli, Minnapura and Yelachegere.

The lakes coming within the industrial area, Nelamangala were visited. The streams or drainage flow path was observed in the industrial area. Few streams were observed to be enclosed by the compound of industries (Plate-4.50v). Hazardous Waste Treatment Storage and Disposal Facility have been established adjacent to the stream/ drain with the outlets opening into this stream (Plate-4.50w). Rapid extensive soil excavation was observed in the Pemmanahalli kere. Solid waste was found dumped inside the stream near the culvert in Pemmanahalli village (Plate-4.50x).

4.7.3c. Other Observations:

- Check dams were found in the streams of the villages of Varadhanayakanahalli, Pemmanahalli (Nelmangala Taluk) and Narayanaraopalya (Plate-4.50y).
- Structures such as buildings (offices, institutions, etc), godowns adjacent to the lakes might be encroaching the lake bed in the villages of Honnenahalli, Kammasandra (Plate-4.51a), Billanakote (Plate-4.51b) and Byadarahalli. This may be further verified by the conserned Authorities.
- Layout development was observed near lakes in villages of Byadarahalli (Plate-4.51c), KSSIDC layout in Narasimhapalya, Veerananjipura and Byranayakanahalli
- Industries were found near by the lakes in villages of Minnapura, Tippadabegur, Budhihaal (Plate-4.51d), Bommanahalli and Sompura.
- Good practice of Rain water harvesting was observed in a new commercial building (Lat.13°14′05.0″ N; Long.77°14′28.5″E) of village of Lakkuru (Plate-4.51e) and in a farm (Lat.13°16′51.3″N; Long.77°14′03.4″E) in the village of Halenahalli (Plate-4.51f). Near by the Bommanahalli village lake (Sy.No. 61), the rain water harvesting project was implemented by the Union Brewers Limited (Plate-4.51g).

4.7.4. General Concerns:

4.7.4a. Waterbodies and its drain:

Waterbodies (lake, *kere*, *katte*, pond, tank and *kunte*), which are the feeder tanks for the Arkavathi and Kumudvathi rivers are most threatened in the zone-1. The problems and issues observed in zone-1 includes encroachment on waterbodies as well as on drains, soil excavation, sand mining, solid waste dumping, sewage influx, etc. Further due to the nutrition loads in the waterbodies, aquatic weeds, algal bloom, etc. are observed in the waterbodies.

4.7.4b. Pollution of the River Course by Industries:

Four industrial areas are developed by KIADB (Karnataka Industrial Area Development Board) in the villages of Doddaballapur, Peenya, Dobaspet and Sompura of zone-1. The cluster of industries in the industrial area has established the CETP (Common Effluent Treatment Plant), which are monitored by the KSPCB. But there may be industrial units operating without necessary consent. Sewage is found to be entering into Stream of Arkavathi River from the Peenya Industrial Area. As per the discussions with the local people, industrial effluents are discharged into the river course during night time and also into storm water drains during rainfall. Some local people have also informed that effluents are injected into the dry bore wells by the industries. However such information needs to be verified by KSPCB.

4.7.4c. Settlements and water demand and supply situation:

Due to natural growth, all the old settlements have expanded. But the rapid urbanisation has led to booming of layouts and apartments. As few of the layouts and apartments are unplanned, the wastewaters generated from these superstructures are reaching the river course through the connecting streams. In existing settlements, the absence of UGD in some of the habitations, has forced the community to use the storm water drain for discharge of sewage waste. In 2007, 110 villages were added to the BBMP area, but as these areas were not under the jurisdiction of BWSSB, the sewage generated by these villages are being released to the nearby waterbodies and to the river. Further, in few village settlements, sanitary pits are used to dispose the sanitary waste, which also reach the nearby waterbody through the rainfall runoff. Open defecation near the settlement area, which resulted in water contamination through rain, can be reduced by implementation of Swachh Bharat Abhiyan guidelines. Another source of pollution is solid wastes since there is no proper management of solid wastes in TGR catchment area villages.

4.8. Conclusion:

Urbanization/development of Bangalore city has put a lot of pressure on water resources of TGR catchment in the following manner:

i. Granite quarrying, going on in the catchments of tanks and streams, is causing silting up and pollution of water bodies.
ii. Sand mining and sand filtering are harming the natural valley system in the area.
iii. Villages are dumping solid waste to the catchments of the river. Solid waste and sewage water from Bangalore city and townships around the city is contaminating the water.
iv. Use of chemicals/pesticides in commercial crops is harming the water quality.
v. Ground water is overexploited for both industrial and agricultural activities; hence the ground water level has gone down beyond 800 ft in some areas.
vi. Land prices have gone up around the catchment due to the growth of Bangalore city, which has resulted in real estate developers/cultivators encroaching tanks, streams and grazing lands.

Due to unplanned growth of human habitations and lack of proper waste disposal, the environment in the entire catchment area is getting degraded rapidly, more so the waterbodies such as lakes, streams, etc. The waste generated by industries is highly toxic and hazardous having serious implications for the local people unless suitable remedial measures are undertaken.

Though the observations have been recorded during field verification further its encroachments etc. can be confirmed once again by the concerned authorities through detailed survey.

Table-4.1. Documented flora in the TGR premises

Sl. No	Name of plant	Common name	Family
Trees			
1	*Acacia* sp.	Acacia tree	Fabaceae
2	*Atrocarpus heterophylla*	Jack fruit tree	Moraceae
3	*Azadirachta indica*	Neem tree	Meliaceae
4	*Cassia* sp.	Cassia tree	Fabaceae
5	*Eucalyptus* sp.	Eucalyptus tree	Myrataceae
6	*Eugenia jambolana*	Jambul tree	Myrtaceae
7	*Grevillea robusta*	Silver oak tree	Proteaceae
8	*Peltophorum inerme*	Yellow Poinciana	Fabaceae
9	*Pongamia pinnata*	Pongamia tree	Fabaceae
10	*Prosopis juliflora*	Algaroba	Fabaceae
11	*Punica granatum*	Pomegranate	Lythraceae
12	*Tamarandus indica*	Tamarind tree	Fabaceae
13	*Tectona grandis*	Teak	Lamiaceae
Shrubs			
14	*Agave americana*	Century plant	Agavaceae
15	*Calotropis gignatea*	Crown flower	Asclepidaceae
16	*Crotalaria juncea*	Sunhemp	Fabaceae
17	*Dodonaea viscosa*	Hop bush	Sapindaceae
18	*Eupatorium odoratum*	Catweed	Asteraceae
19	*Ipomoea fistulosa*	Ganesh kaddi	Convolvulaceae
20	*Lantana camara*	Lantana	Verbenaceae
21	*Tecoma stans*	Yellow bell plant	Bignoniaceae
Herbs			
22	*Achyranthes aspera*	Prickly Chaff flower	Amaranthaceae
23	*Alternanthera sessilis*	Sessile Joy weed	Amaranthaceae
24	*Argemone mexicana*	Mexican Prickly Poppy	Papaveraceae
25	*Croton sparsiflorus*	Banatulasi	Euphorbiaceae
26	*Dolichos lablab* (Agricultural)	Lablab bean	Fabaceae
27	*Eichhornia crassipes*	Water hyacinth	Pontederiaceae
28	*Eleusine coracana*(Agricultural)	Finger millet	Poaceae
29	Grasses	Grass	Poaceae
30	*Lemna* sp.	Lesser Duck weed	Araceae
31	*Mimosa pudica*	Touch Me Not plant	Fabaceae
32	*Parthenium hysterophorus*	Parthenium	Asteraceae
33	*Tribulus terrestris*	Puncture Wine	Zygophyllaceae

Table-4.2. List of villages falling in the zone-2 as per 2003 notification

Sl. No	District	Taluk	Hobli	Villages
01	Bengaluru Rural	Nelamangala	Nelamangala	Banasvadi
02				Nagasandra
03				Narasimhapalya
04				Kanavanahalli
05				Goravanahalli
06				Hosahalli
07				Avalkuppe
08				Kotanahalli
09				Soladevanahalli
10				Bidanpalya
11				Chowdasandra
12	Bengaluru Urban	Bengaluru North	Dasanpura	Mallasandra
13				Sondekoppa
14		Bengaluru South	Tavarekere	Jogerahalli
15				Gangenahalli
16				Nagenahalli
17				Devamachohalli Narayanapura
18				Marenahalli
19				Devamachohalli
20				Ganakallu
21				Puradapalya
22				Cholanayakanahalli
23				Kempagondanahalli
24				Gangappanahalli
25				Tavakadahallli
26				Kutlu
27	Ramanagara	Magadi	Magadi	Kalluru
28				Shanbhoganahalli
29				Varadenahalli
30				Bachenahatti
31			Solur	Mummenahalli
32				Gollahalli
33				Motaganahalli

Table-4.3. List of villages falling in the Hesaraghatta sub-catchment area (Zone-1) as per 2003 notification

S.No.	Village Name	S.No.	Village Name
1	Chennapura	46	Kasaba Kundhana
2	Chikkarayappanahalli	47	Sulakunte
3	Kotturu	48	Pandithapura
4	Madakuhosahalli	49	Doddachimanahalli
5	Gulyanandhigundhi	50	Raghunathapura
6	Karahalli	51	Shivapura
7	Heggadihalli	52	Pindakura Thimmanahalli
8	Melekote	53	Thindlu
9	Kurubarahalli	54	Kamenahalli
10	Chougandanahalli	55	Kasavanahalli
11	Ramanathapura	56	Basavanahalli
12	Masthimmanahalli	57	Sadhenahalli
13	Kachahalli	58	Sriramanahalli
14	Hireguddadhahalli	59	Byrapura
15	Beedikere	60	Budamenahalli
16	Chikkobanahalli	61	Ittagalapura
17	Nagadenahalli	62	Madhappanahalli
18	Rajaghatta	63	Linganahalli
19	Alurududdanahalli	64	Kadathanamale
20	Venkatapura	65	Nellukunte
21	Lingadheeragollahalli	66	Hosahudya
22	Kolipura	67	Gowdahalli
23	Dyavarahalli	68	Sonnenahalli
24	Obadevanahalli	69	Kamakshipura
25	Govindapura	70	Kukkanahalli
26	Muthsandra	71	Kannamangala
27	Machagondanahalli	72	Kenjigadhahalli
28	Doddarayappanahalli	73	Marasandra
29	Thapashipura	74	Chikkavaddagere
30	Thapashipura	75	Halenahalli
31	Sonnamaranahalli	76	Purushanahalli
32	Thylagere	77	Isthuru
33	Misaganahalli	78	Gulya
34	Dandadasakodagenahalli	79	Muppadighatta
35	Beedikere Agrahara	80	Chennadevi Agrahara
36	Marahalli	81	Kadanuru
37	Kabbanahalli	82	Tharabanahalli
38	Dinnenahalli	83	Kasagatta
39	Yadhlahalli	84	Katthihosahalli
40	Kuruvagere	85	Kamana Agrahara
41	Managondanahalli	86	Doddabelavangala
42	Doddagollahalli	87	Bheemaravuthanahalli
43	Konagatta	88	Shankarasanahalli
44	Kanchiganala	89	Madeshwara
45	Adinarayana Hosahalli	90	Madure

91	Karepura	140	S.M.Gollahalli
92	Chikkanahalli	141	Kesthuru
93	Galibilikote	142	Kodigehalli
94	Mandibyadarahalli	143	Dargajogihalli
95	Narasayyana Agrahara	144	Majara Hosahalli
96	Kuntanahalli	145	Dargapura
97	Dyavarahalli	146	Areguddadhahalli
98	Aradeshanahalli	147	Veerabhadrana Palya
99	Varadhanahalli	148	Palanijogihalli
100	Chikkannanahosahalli	149	Sonnappanahalli
101	Maragondanahalli	150	Vaddarahalli
102	Adde Viswanathapura	151	Koluru
103	Kakolu	152	Hanabe
104	Shanubhoganahalli	153	Bedarajakkasandra
105	Rajanukunte	154	Kamaluru
106	Honnenehalli	155	Byrapura
107	Mathkuru	156	Chilenahalli
108	Kakkenahalli	157	Karenahalli
109	Masandra Amanikere	158	Hadonahalli
110	Bacchahalli	159	Tubagere
111	Haniyuru	160	Mayasandra
112	Byatha	161	Koyira
113	Junnasandra	162	Ardeshanahalli
114	Shastripalya	163	Kabbanahalli
115	Uddhinachikkanahall	164	Udhanahalli
116	Nagenahalli	165	Jogandahalli
117	Puttenahalli	166	Linganahalli
118	Doddavaddagere	167	Nandigunda
119	Nallenahalli	168	Aruvanahalli
120	Shimpadipura	169	Kavalahalli
121	Honnadevipura	170	Mutthagadhahalli
122	Kagepura	171	Karanala
123	Mallohalli	172	Gantiganahalli
124	Challahalli	173	Beerasandra
125	Madhagondanahalli	174	Byradevanahalli
126	Chikka Hejjaji	175	Dasagondanahalli
127	Agrahara	176	Chapparadhahalli
128	Venkateshapura	177	Binnamangala
129	Thubakunte	178	Chinnakempanahalli
130	Chikkabelavangala	179	Sunnaghatta
131	Akkathammanahalli	180	Bacchahalli
132	Konenahalli	181	Gollahalli
133	Bhuchanahalli	182	Thammashettyhalli
134	Bhaktarahalli	183	Siddhenaikanahalli
135	Mallanayakanahalli	184	Thimmasandra
136	Basavanapura	185	Nagasandra
137	Shravanuru	186	Kakkenahalli
138	Huskuru	187	Alahalli
139	Bokipura	188	Veerapura

189	Yellapura	232	Srinivasapura
190	Mutthuru	233	Chikkatumakuru
191	Gangadharapura	234	Thippapura
192	Hasamagatta	235	Ba Shettyhalli
193	Thogarigatta	236	Khas Bhag
194	Thirumagondanahalli	237	Rojipura
195	Anthrahalli	238	Mallatthahalli
196	Somashettyhalli	239	Medahalli
197	Maralenahalli	240	Thapasihalli
198	Talagawara	241	Neralagatta
199	Kadabyadarahalli	242	Vanigarahalli
200	Galipuje	243	Shiravara
201	Kantanakunte	244	Thippuru
202	Lakshmidevipura	245	Gundasandra
203	Sothenahalli	246	Nellukunte
204	Jalige	247	Subrayanagenahalli
205	Juttenahalli	248	Naraganahalli
206	Bettanahalli	249	Jakkasandra
207	Suradenapura	250	Aralu Mallige
208	Tharahunase	251	Shyakaladevipura
209	Arakere	252	Karimsonnenahalli
210	Sheethakempanahalli	253	Gejjagadhahalli
211	Chokkanahalli	254	Dodda Hejjaji
212	Dhibburu	255	Mutthugadahalli
213	Shinganayakanahalli	256	Mugenahalli
214	Koluru Rayanahalli	257	Kolagere
215	Dodda Tumakuru	258	Kolladu
216	Kuntanahalli	259	Gollahalli
217	Byrasandra	260	Chikkakalenahalli
218	Channasandra	261	Lingapura
219	Shiresandra	262	Rampura
220	Kodihalli	263	Naranahalli
221	Kallodu	264	Bommanahalli
222	Thimmasandra	265	Kugonahalli
223	Ramadevanahalli	266	Hadhripura
224	Kanasawadi	267	Kalludevanahalli
225	Honnavara	268	Ekasipura
226	Bhadrapura	269	Menasi
227	Gandragulipura	270	BaShettyhalli
228	Aambalagere	271	Madhuranahosahalli
229	Karenahalli	272	Thigale Bhagaythu
230	Hesaraghatta grass farm	273	Gurutimmanahalli
231	Hesaraghatta grass farm		

Table-4.4. List of villages falling in the Arkavathi sub-catchment area (Zone-1) as per 2003 notification

Sl.No	Village Name	Sl.No	Village Name
1	Kondekoppa	43	Agraharapalya
2	Irigenahalli	44	Hyadalu
3	Gollanapalya	45	Byrashettyhalli
4	Hunnegere	46	Bolamaranahalli
5	Mantanakurchi	47	Arjunabettahalli
6	Goranabele	48	Gollarahalli
7	Kempalinganahalli	49	Gopalapura (Sayappanahalli)
8	Lakkenahalli	50	Shamabhattarapalya
9	Kengenahalli	51	Kukkalahalli
10	Hullegowdanahalli	52	Thotagere
11	Venkatapura	53	Guddadhahalli
12	Byregowdanahalli	54	Linganahalli
13	Kodappanahalli	55	Mutthukadhahalli
14	Vaddarapalya	56	Shivakote
15	Shivanapura	57	Mylappanahalli
16	Gajagadahalli	58	Krishnarajapura
17	Dasanapura	59	Krishnasagara
18	Arasinakunte	60	Avalahalli
19	Mallapura	61	Jarakabandekaval/Ramagondanahalli
20	Mallarabanasavadi	62	J.I.Lingarajapura
21	Jakkasandra	63	Mavallipura
22	Kasaba Nelamangala	64	Lingarajasagara
23	Koolipura	65	Kondashettihalli
24	Vajarahalli	66	Kasaghattapura
25	Narasipalya	67	Byalakere
26	Nagaruru	68	Shyamarajapura
27	Pillalli	69	J.I.Medi Agrahara
28	Kodipalya	70	Kalathammanahalli
29	Sheshagiriraopalya	71	Veerasagara
30	Mariyanapalya	72	Kempapura
31	Vadarahalli	73	Ganigarahalli
32	Mutthahalli	74	Somashettyhalli
33	Hucchanapalya	75	K.G.Gune Agrahara
34	Ramapalya	76	K.G.Vaderahalli
35	Betthanagere	77	Doddabettahalli
36	Saidamipalya	78	Chikkabettahalli
37	Krishnarajapura	79	S.I.Singapura
38	Hadhripura	80	K.G.Lakshmipura
39	Srinivasapura	81	Ganigarahalli
40	Bommashettihalli	82	Chikkabanavara
41	Huskuru	83	Guddadhahalli (Guledhahalli)
42	Honnasandra	84	Abbigere

85	K.G.Ramachandrapura	105	Chokkasandra
86	Jarakabandekaval	106	J.I.Doddabidarakallu
87	J.I.Kammagondanahalli	107	Kodagi Thirumalapura
88	J.I.Shettyhalli	108	K.G.Srikantapura
89	Myadharahalli	109	Gangondanahalli
90	Hosahalli Gollarapalya	110	Karihobanahalli
91	Chikkasandra	111	K.G.Nelakadharanahalli
92	Shidedhahalli	112	Laggere
93	Thotadhaguddadahalli	113	K.G.Hegganahalli
94	Bagalakunte	114	Srigandhakavalu
95	J.I.Mallasandra	115	Herohalli
96	K.G.Srikantapura (Anchepalya)	116	K.G.Handrahalli
97	Madavara	117	Lingadeeranahalli
98	Chikkabidarakallu	118	Gangondanahalli
99	Peenya Plantation	119	Bylakonenahalli
100	Peenya	120	Machohalli
101	Dasarahalli (Peenya)	121	Kachohalli
102	Nagasandra	122	Myakala Channenahalli
103	Madhapatna	123	Doddamaranahalli
104	Ajjanapalya		

Table-4.5. List of villages falling in the Kumudvathi sub-catchment area (Zone-1) as per 2003 notification

S.No.	Village Name	S.No.	Village Name
1	Halenahalli	46	Kasaragatta
2	Bettadahosahalli	47	Naryanapura
3	Madhenahalli	48	Dasanpura
4	Pemmanahalli	49	Mallapura
5	Chandanahosahalli	50	Bhairasandra
6	Kengalkempohalli	51	Shantapura
7	Avverahalli	52	Honnarayanahalli
8	Malekattiganuru	53	Palanahalli
9	Shivagange	54	Bhairapura
10	Gantehosahalli	55	Goruru
11	Kodigebommanahalli	56	Lakkenahalli
12	Mylanahalli	57	Solur
13	Kallupalya	58	Lingenahalli
14	Rangenahalli	59	Hosahalli
15	Kempapura	60	Uddanahalli
16	Kankenahalli	61	Garageshwara
17	Rangenebetta	62	Kottaganahalli
18	Chikkanahalli	63	Bantarakuppe
19	Ramenahalli	64	Balagere
20	Chikkasolur	65	Gulapura
21	Koramangala	66	Kammasandra
22	Gudemaranahalli	67	Byranaikanahalli
23	Byalakere	68	Thyagadahalli
24	Tirumalapura	69	Krishnarajapalya
25	Bommanahalli	70	Mylanahalli
26	Krishnarajapura	71	Kachanahalli
27	Tadasighatta	72	Byranahalli
28	Kenchanapura	73	Bommanahalli
29	Lakkappanahalli	74	Manchenahalli
30	Bardhi	75	Obanayakanahalli
31	Minnapura	76	Visheshwarapura
32	Moolenagathihalli/Hosuru	77	Bennegere
33	Yeramanchanahalli	78	Imachenahalli
34	Narayanaraopalya	79	Agalakuppa
35	Budihal	80	Hosahalli
36	Bolamaranahalli	81	Yedehalli
37	Kempalinganahalli	82	Kerekottiganuru
38	Viraraghuvanapalya	83	Machenahalli
39	Bugadihalli	84	Kambalu
40	Channohalli	85	Guruvanahalli
41	Lakkuru	86	Mooganahalli
42	Timmanayakanahalli	87	Shriganahalli
43	Srinivaspura	88	Udukunte
44	Gundenahalli	89	Banavadi
45	Gottikere	90	Kuppemala

91	Channohalli	123	Geddalahalli
92	Engere	124	Basavapatna
93	Gangenapura	125	Maragondanahalli
94	Kannasandra	126	Arebommanahalli
95	Turbara Palya	127	Aluru
96	Kudaluru	128	Hemapura
97	Marikuppe	129	Narasapura
98	Somadevaranahalli	130	Billasandra
99	Naganahalli	131	Muppenhalli
100	Torechanahalli	132	Tattekere
101	Bharatipura	133	Vaddarahalli
102	Kodigehalli	134	Parvathapalya
103	Vadhakunte	135	Kalyanapura
104	Isuvanahalli	136	Biravara
105	Hasurahalli	137	Hakkinalu
106	Bettahalli	138	Byadarahalli
107	Chikkanahalli	139	Kodihalli
108	Marohalli	140	Malluru
109	Ahobalapalya	141	Hulikunte
110	Machonaikanahalli	142	Mavinakommenahalli
111	Veeranjipura	143	Nimbenahalli
112	Hanchipura	144	Guddegowdanachannohalli
113	Ghandragulupura	145	Jakkanahalli
114	Gangadaranapalya	146	Mandigere
115	Narasipura	147	Varadanayakanahalli
116	Nijagal Kempohalli	148	Ananthapura
117	Sompura	149	Narasimhapalya
118	Billanakote	150	Devaganahalli
119	Honnenahalli	151	Kangondanahalli
120	Aladahalli	152	Bavikere
121	Baragenahalli	153	Byadarahalli
122	Sidganahalli	154	Veerapura

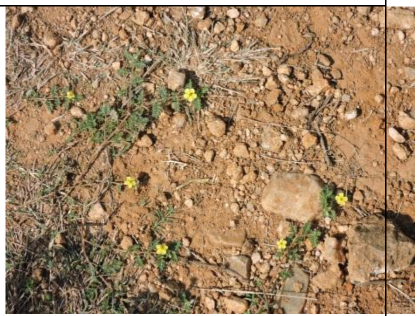
Plate-4.1: Flora observed in the TGR premises


(a & b): *Eichhornia crassipes* in different locations of reservoir

(c) *Eichhornia* with *Lemma* sp.

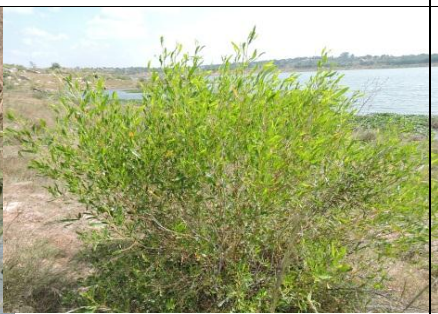
(d) *Eupatorium odoratum*

(e) *Acacia* sp.



(f) *Tribulus terrestris*

(g) *Pongamia pinnata*



(h) *Doddanea viscosa*

(i) *Grivellia robusta*

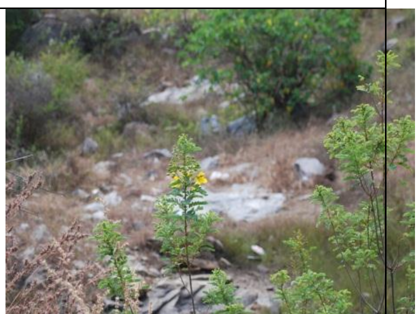
(j) Grasses

(k) *Tecoma stans*

(l) *Dolichos lablab*

(m) *Azadirachta indica*

(n) *Lantana camara*



(o) *Cassia* sp.

		
(p) *Mimosa pudica*	(q) *Argemone mexicana*	(r) *Ipomoea fistulosa*
		
(s) *Parthenium hysterophorus*	(t) *Alternanthera sessiles*	(u) *Agave americana*
Plantations by BWSSB with the help of Karnataka Forest Department		
		
(v) *Grevillea robusta* plantation	(w) A*cacia* plantation	(x) *Eucalyptus* plantation
		
	(y) *Dodonaea viscosa*	

Plate4.2: Fauna observed in TGR premises


(a) Black kite


(b) Heron


(c) Brahminy kite


(d) Darter


(e) Grey Heron


(f) Large egret


(g) Stork

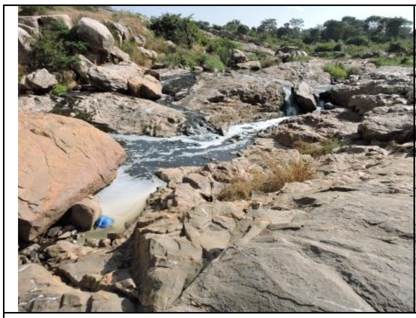

(h) Black drongo


(i) Little egret


(j) Bue eared Kingfisher


(k) Painted stork

Plate-4.3: Inflow of sewage and muddy water in TGR




(a & b) Waste water entering into TGR from Jogerahalli

(b) Muddy water with weeds at Varadenahalli


(c) Slurry water entering in different locations of TGR at Mummenahalli & Avalkuppe

(d) Water with oil spills at Goravanahalli

(e) Algal growth at Gangappanahalli

Plate-4.4: Free access by people, grazing animals and encroachment (seasonal) in TGR


(a) Free access by people at Goravanahalli


(b) Grazing animals Tavakadahalli


(c) Encroachment for seasonal agriculture at Goravanahalli

Sand mining and soil excavation observed during the ground truth verification


(d) Avalkuppe


(e) Soladevanahalli


(f) Narasimhapalya


(g) Goravanahalli


(h) Naganahalli


(i) Kanuvanahalli


(j) Tavakadahalli

Plate-4.5: Brick kilns, dumping of wastes and other solid wastes at different locations of TGR

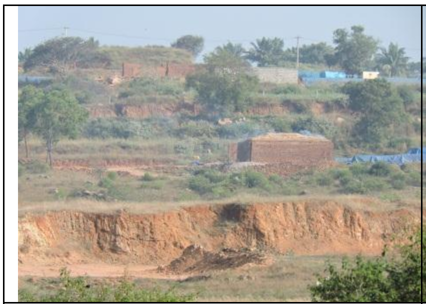
		
(a) Soil excavation and brick kiln at Jogerahalli	(b) Ash dumped in reservoir area at Jogerahalli	(c) Lorry (HMVs) used to carry bricks at Marenahalli
		
(d) Plastic bottles thrown by local people at Kanuvanahalli	(e) Tin wastes at Goravanahalli	(f) Insecticide tin in reservoir area at Gangappanahalli
		
	(g) Rubber tubes (waste) at Naganahalli	

Plate-4.6: Flora and Fauna of Hesaraghatta Reservoir premises


(a) *Eupatorium odoratum*


(b) *Lantana camara*


(c) *Alternanthera sessilis*


(d) *Calotropis gigantea*


(e) *Prosopis juliflora* with Grass


(f) *Ipomoea fistulosa*


(g) Intermediate Egret


(h) Black drongo


(i) Wooly necked stork


(j) Heron


(k) Red wattled lapwing


(l) Coot & ducks


(m) Snake


(n) Insects


(o) Cat fish

Plate-4.7: Solid wastes and various pollutants observed in Hesaraghatta reservoir premises

		
(a) Paper wastes	(b) Glass wastes	(c) Paper wastes
		
(c) Construction of temple on tank bund (11 Dec. 2014)	(d) Construction of temple on tank bund (02 Jan. 2015)	(e) Construction debris is dumped on the bund
		
(f) Religious offerings- wastes dumped and animal sacrifice Temple construction debris		

Plate-4.8: Soil excavation at Hesaraghatta Reservoir

	
(a) North- east region	(b) South West region 1
	
(c) South West region 2	(d) South West region 3
	
(e) Water with algal growth at Southern part	

Plate-4.9: Observations in Zone-2

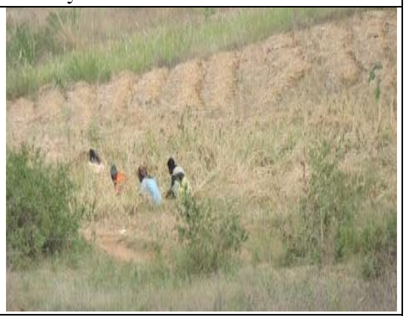
		
(a) Soil excavation at Gangenahalli village	(b) Sand mining at Goravanahalli village	(c) Stone quarrying at Bidanpalya village
Agriculture activities observed during the study		
		
(d) Teak and Coconut plantations at Gangenahalli village	(e) Banana plantation at Goravanahalli village	(f) Harvesting Finger millet at Ganakallu village
		
	(g) Growing Jowar at Cholanayakanahalli village	

Plate 4.10: Wastewater entry and wastes dumped in the stream

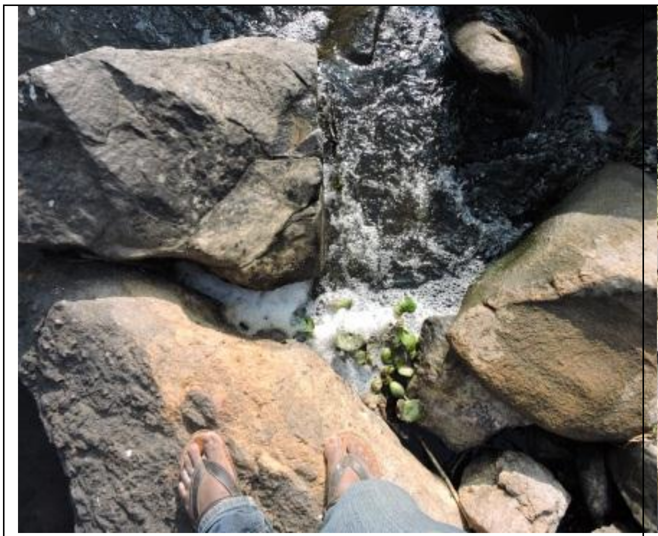
	
(a) Polluted water entry with foam and debris at Nagasandra village	(b) Polluted water entry at Jogerahalli village
	
(c) Dried up Arkavati stream burnt wastes dumped at Cholanayakanahalli village	(d) Wastes dump at Nagasandra village

Plate-4.11: Layouts in Zone-2

Metipalya		
		
(a) Layout development	(b) Dumping soil in channel for developing layout	(c) Layout development
		
(d) Centre City layout	(e) SLV Developers	(f) Saptagiri layout
		
(g) Shrisha residential layout at Soladevanahalli village	(h) Lakshmivenkateshwara layout (Soladevanahalli- Tandya)	(i) SLV Layout at Soladevanahalli village
		
(j) RS Murthy layout in Soladevanahalli village	(k) Jinamba Enclave in Nagasandra village	(l) Layout near to Kanavanahalli village

		
(m) Jinamba Enclave-3 in Kanavanahalli village	(n) Layout near garment factory in Ganakallu village	(o) Saibaba layout Gankallu village
		
	(p) Layout development in Jogerahalli village	

Plate-4.12: Hesaraghatta Village of Arkavathi River Course (Zone-1)


a: Solid waste dumped in the stream from the sluice gate side of the Hesaraghatta tank


b: Solid waste dumped in the stream from the sluice gate side of the Hesaraghatta Tank


c : Solid waste dumped in the river


d: Solid waste dumped next to the river


e: Dry river stretch


f: Check dam in the dry river

g: Dry Arkavathi River next to the Dhaba

h: Sewage from the settlements to the stream near the sluice gate side of the tank

i: Public toilet constructed next to the stream

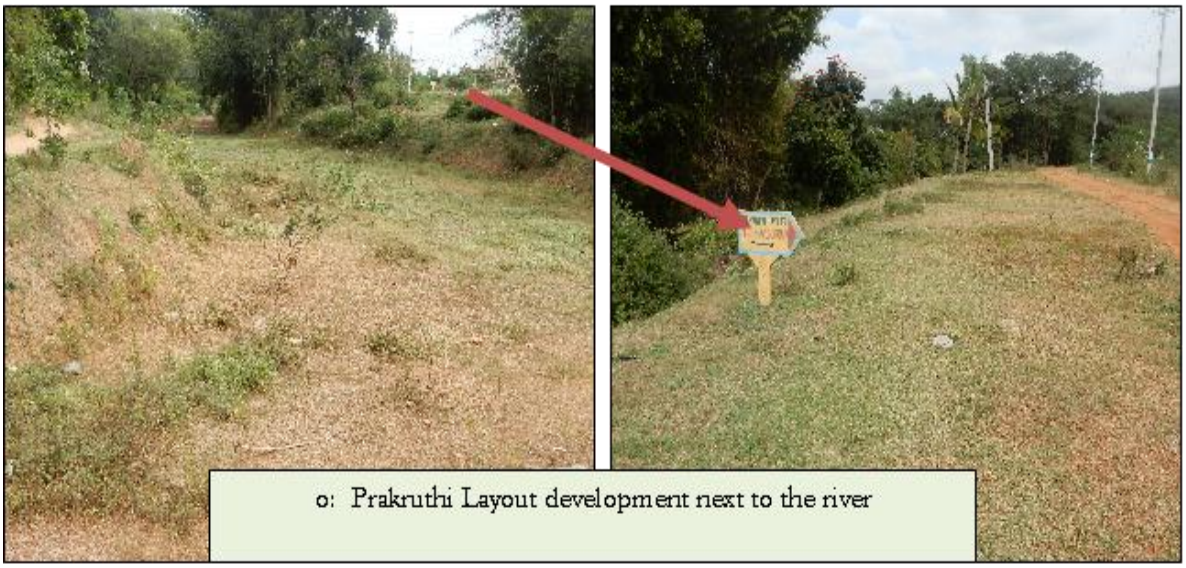
j: Green park residency welfare dhaba, right next to the river

k: Christ motor and durgamba office next to river

l: A drain containing waste from the dhaba is let in the stream from syphon side of the tank

m: Hesaraghatta Residency Resort next to River

n: Annaporneswara layout next to the river



o: Prakruthi Layout development next to the river

p: Dried up river

q: Banana plantation encroaching the river bed

r: Cement washing near the Kempegowda layout next to the river

s: Kempegowda Layout next to the river Arkavathi

t: Storm water drain from Kempegowda layout letting out into the river

u: Poultry waste in the culvert

v: Hollow block factory

w: Quarry waste next to one of the nala

Plate-4.13: Dasenahalli Village of Arkavathi River Course (Zone-4)

a: Encroachment of Hesaraghatta tank bed by CPDO

b: Layout development

c: Institutes next to the Hesaraghatta Tank and the river

d: Poultry farm

e: Poultry Unit

f: CPDO Institute

Plate-4.14: Ivarakandapura Village of Arkavathi River Course (Zone-3 & 4)


a: Outlet from Ivarakandapura lake is dry


b: Ivarakandapura lake is dry and fenced

c: Indian Institute of Horticulture Research


d: Nursery encroaching the edge of Ivarakandapura lake


e: Nursery encroaching edge of Ivarakandapura lake


f: Solid waste dumped in Ivarakandapura lake outlet

g: Layout development

h: Poultry opposite to the river

i: Poultry waste in the outlet

j: Soil excavation in the lake

Plate-4.15: Giddenahalli Village of Arkavathi River Course (Zone-3)

a: Active quarry within 200 m from the river

b: Active quarry

c: Active quarry

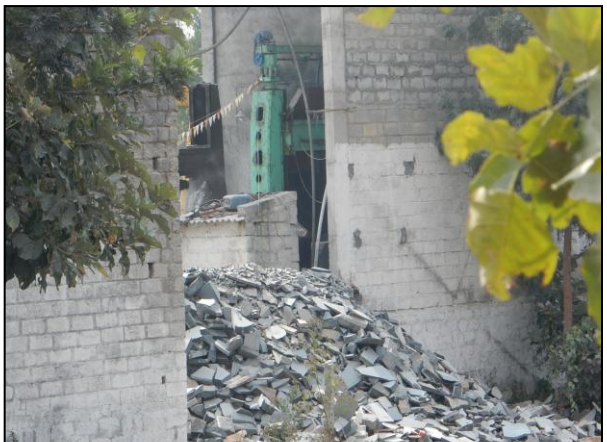
d: Active quarry

e: Quarry waste dumped next to the river

f: Quarry waste dumped next to the river

g: Granite factory within 50-100m from the river

h: Lakshmi Venkateshwara granites factory next to the river



i: Lakshmi Venkateshwara granite factory next to river

j: Foam water flowing in the river

k: Fencing the plantation on the river bed

l: Wastewater flowing in the river bed

Plate-4.16: Varthur Village of Arkavathi River Course (Zone-3)

a: Layout development next to river Arkavathi

b: Layout development

c: Layout development near the river

d: Layout development near the river

e: Clearing the area next to the river bed for layout formation

f: Poultry farm close to the river

g: Fencing the Plantation on the river bed

h: Soil exaction on the river bed

i: Waste water flowing in the river

j: Waste water flowing in the river, growth of water hyacinth

k: Quarry waste and stone dumped near the river

Plate-4.17: Kadabagere Village of Arkavathi River Course (Zone-3 & 4)

a: Cement Industry

b: Power Plus industry

c: Nutri Farms and feeds

d: Brick factory

e: Layout development

f: Granite factory

g: Granite factory

h: Sand mining

Plate-4.18: Tharabanahalli Village of Arkavathi River Course (Zone-3)

a: storm water drain carrying waste water from households into the stream

b: Sri giri convention hall next to the river

c: Solid waste dump in the river

d: Construction debris in the river

e: Poultry waste in culvert

f: Poultry waste next to the river

g :Brick factory

h: Layout development

i: Kallupalya Reserve Forest compound damaged due to heavy flow of water in river

j: Bridge having HFL marking

Plate-4.19: Alur Village of Arkavathi River Course (Zone-3 & 4)

a: Solid waste dump inside the river

b: Sewage water entering the river

c: Nilgiri plants in the river bed

d: Layout adjacent to the river

e: Layout adjacent to the lake (Sy No 132)

f: Layout adjacent to the lake (Sy. No. 117)

g: Solid waste dumped in to the drain near to Pan Parag India Ltd.

h: Sand filtering unit adjacent to the stream

i: Sri Gajanana Enclave-3 adjacent to the stream

Plate-4.20: Heggadadevanapura Village of Arkavathi River Course (Zone-3 & 4)

a: Lake encroached by layout – Google image 2014

b: Lake Sy. No. 59 encroached by layout

c: Lake encroached by godowns – Google image 2014

d: Lake Sy. No. 52 encroached by the godown

e: Waste water from storm water drain entering the river

f: Puddle of stagnant water

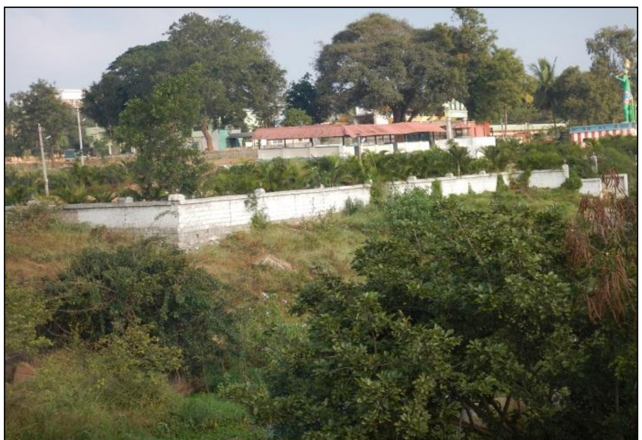
g: Godowns

h: Layout-Sri Gajanana Enclave-2 adjacent to the river

Plate-4.21: Makali Village of Arkavathi River Course (Zone-3)

a: Goldenseams Textile Pvt. Ltd.

b: Himalaya Drug Company



c: Sri Bhimanjanaiah temple

d: Waste water entering the river through storm water drain

e: Lake (Sy. No. 13) encroached by godown

f: Lake encroached by godown –Google image 2014

g: Godowns with outlets into the river

h: Godowns on the river bank

i: Godowns on the river bank

j: Godowns on the river bank

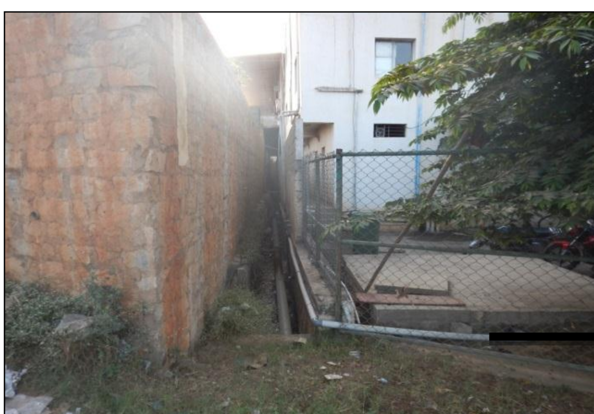
k: Slaughter waste

l: Solid waste dump

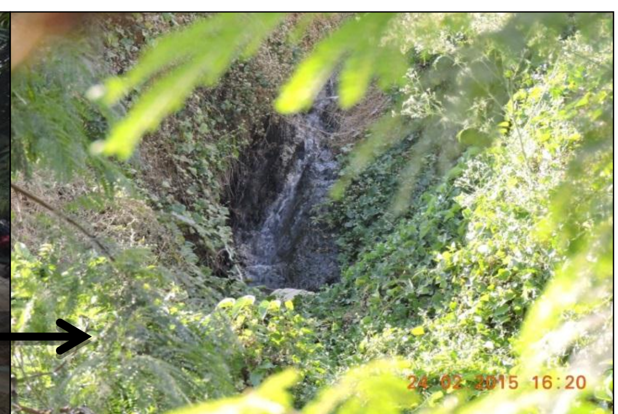
Plate-4.22: Madhanayakanahalli Village of Arkavathi River Course (Zone–3)

a: Gowdowns on the river bank

b: Godowns have constructed outlets from their godowns into the river



c: Storm water drain with waste water adjacent to godowns



d: Waste water from the storm water drain entering the river

e: LT Karle & Co Unit –II (building is situated around 700 m from the river)

f: The grey or waste water is entering the river and forming pool of stagnant water inside river

g: The boulders at the river bank are broken and the low lying area filled using the broken boulders, soil and solid waste adjacent to the river


h: Burning of solid waste & agricultural waste from the agriculture based activities

i: Biomedical waste

j: Construction debris

k: Borewell inside the layout and adjacent to the river

Plate-4.23: Harokyathanahalli Village of Arkavathy River Course (Zone–3 & 4)


a: A shed (fabric dying) located adjacent to the stream and is letting out the waste water outside which is entering the stream

b: Waste water from shed is entering the stream

c: Stream carrying the waste water is joining the river

d: Coloured Waste water flowing in the river

e: Jai Maruthi Enclave-Layout adjacent to the river and the stream

f: Sand mining in the river bed

g: The waste water is let into the lake via storm water drains

h: Lake encroachment – Google map 2014

i: Lake (Sy. No. 108) encroached by the residential buildings

Plate-4.24: Gowdahalli and Kammasandra villages of Arkavathi River Course (Zone-3)

a: Layout adjacent to the river

b: Development of layout

c: Drawing of waste water from the river

d: Lake filled with granite sludge in Kammasandra village

e: Layout near the river in Kammasandra village

Plate-4.25: Ravuthanahalli Village of Arkavathi River Course (Zone-3)

a: Lorry dumping the granite sludge

b: Granite Sludge entering the river

c: Poultry farm set up adjacent to the stream and the river

Plate-4.26: Dhombarahalli Village of Arkavathy River Course (Zone -3 & 4)

a: Lake encroachment, 2014 Google image

b: Lake encroached by the layout

c: Stream carrying waste water

d: Layout and dry stream near

e: Poultry farm

Plate-4.27. Villages of Arkavathi River Course (Zone-3 & 4)

a: Fishing in the river in Byyandahalli village

b: Sand filtering adjacent to the river in Bettahalli village

c: Vidyasri Badavane-Layout close to the river in Hanumanthasagara village

d: Glory Boys Apparel Pvt. Ltd. In Siddhanahosahalli village

e: Building adjacent to the stream in Vaddarahalli village

f: Building adjacent to the stream in Kadaranahalli village

g: Stream with waste water flowing adjacent to the BIEC in Madavara village

h: Layouts adjacent to the lake in Avverahalli village

Plate-4.28: Thirumalapura Village of Arkavathi River Course (Zone-3 & 4)

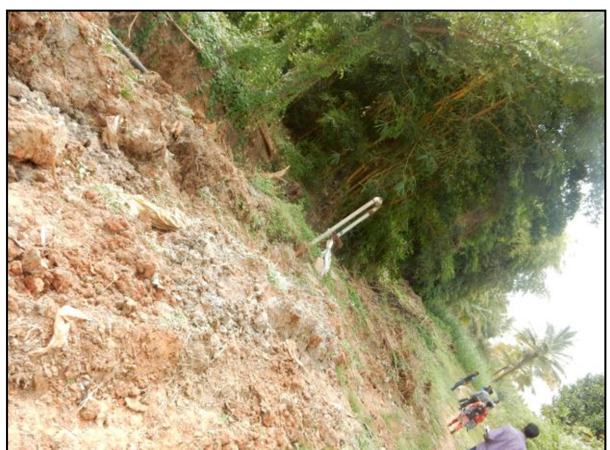
a: Medical waste in the stream

b: Stream running next to the settlement

c: Pipelines in the stream

d: Sewage water entering the river through stream

e: Sewage water from settlements entering stream

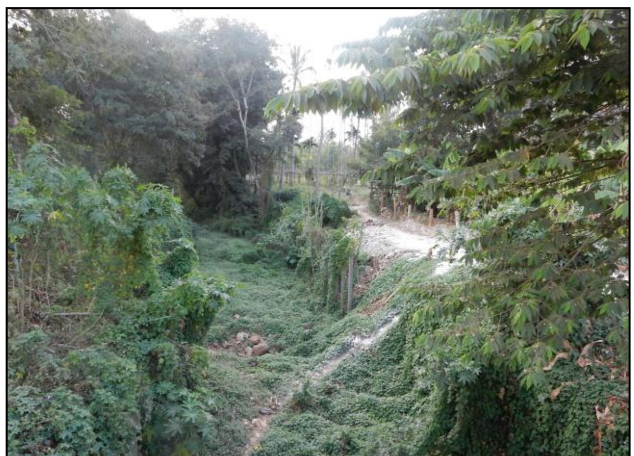


f: Bore well next to the stream

g: Layout development

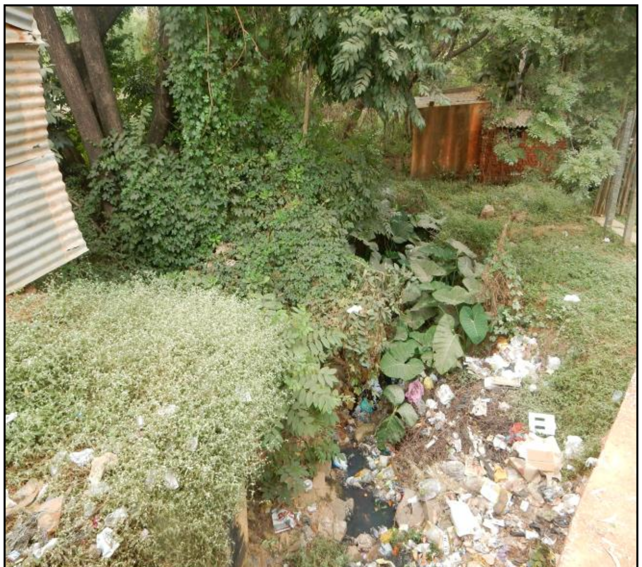
h : Layout Development

i: Layout Development



j: Quarry waste next to stream

Plate-4.29: Hurlichikkanahalli Village of Arkavathi River Course (Zone–3 & 4)



a: Solid waste in the culvert

b: Layout development

c: Layout development

Plate-4.30: Honnaganahatti Village of Arkavathi River Course (Zone-3 & 4)


a: Quarry stopped at present


b: RMX Cement factory


c: Hollow blocks


d: Layout development

e: Granite Factory

Plate-4.31: Villages of Arkavathi River Course (Zone-3 & 4)

a: Encroachment of the stream by plantation in Kallenahalli village

b: Layout development in Kurubarahalli village

c: Layout development in Kurubarahalli Village

d: Club development in Kurubarahalli village

e: Soil excavation in Mallasandra Village

f: Quarry stopped at present in Mallasandra Village

g: RMX Cement industry in Sigenahalli Village

h: Layout development in Hosahallipalya village

i: Encroachment of stream by a house in Sondekoppa Village

Plate-4.32: Kumudvathi River Course Villages (Zone-3 & 4)

a: Agricultural encroachment in Niduvanda Kere

b: Complete Lake encroachment in Dasenahalli village

c: Brick manufacturing unit established in the lake bed of Hajipalya village

d: View of industries under construction from Niduvanda Kere

e: Industrial view from Niduvanda Kere

f: Stormwater drains from Industrial area directed to Niduvanda Kere

g: Solid waste dumped near lake in Mudlinganahalli village

h: Solid waste dumped road side in Niduvanda village

i: Soil excavation in T.Begur Chikkakere

j: Stormwater drain outlet connected to lake in Motaganahalli village

k: Wastewater flow in the storm water drain of Thymgondlu village

l: Blackish green water behind Cadbury industry in Sitaramabhattapalya

m: Kumudvathi River in Chikkamaranahalli

n: Check dam in Chikkamaranahalli village stream

o: Water extraction from stream in Basavenahalli village

p: Water pumping from Yelachagere kere for agriculture plots

q: Sand washing in stream bed of Chowdasandra Village

r: Soil excavation in stream bed of Balaguruvanpalya village

s: Quarry in Basevanahalli village

t: Stone cutting in Kadukarenahalli village

u: Stone crusher of Basavenahalli village

v: Stream encroachment by Amma Naturopathy and yoga center in Aralasandra village

w: Layout next to Dry River Kumudvathi in Tore-Kempahalli village

x: Kirlosker Electricals industry in Govenahalli village

y: Fosroc Chemicals (India) Pvt. Ltd. in Kulvanahalli village

z: Pipe outlets into stream on NH-4 from Kemwell Pvt. Ltd. industry

Plate-4.33: Quarrying in Hesaraghatta sub-catchment area (Zone-1)

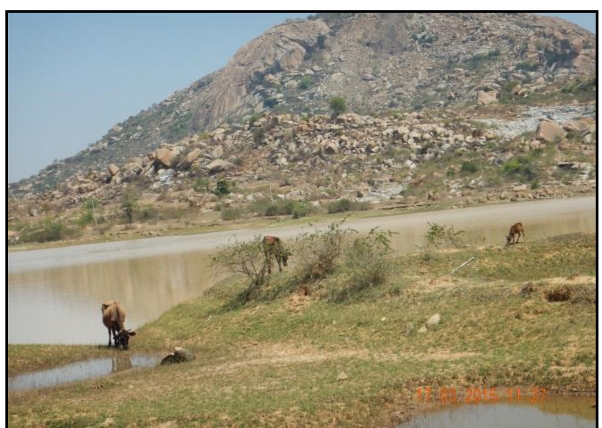
a: Quarry in progress in Chikkobanahalli village

b: Quarry pit not reclaimed in Koyira village

c: Quarry in progress in Managondanahalli village

d: Quarry in progress in Koyira village

e: Quarry currently stopped in Varadhanahalli village



f: Bacchahalli lake next to quarry site

Plate-4.34: Soil excavation in lakes of Hesaraghatta sub-catchment area (Zone-1)

a: Soil excavation in Kannamangala lake

b: Soil excavation in Madhure lake

c: Soil excavation in Honnavara lake

d: Soil excavation inside Gulya lake

e : Construction debris dumped in Sonnenahalli kere

f: Soil excavation and fishing in Chikkavadagere lake

g: Soil excavation in Muppadighatta lake

h: Soil excavation in Gejjagadhahalli lake

i: Tractor for excavating soil and MSW in side Gejjagadhahalli lake

j: MSW and soil excavation inside Dodda Tumakuru lake

k: Soil excavation in Beerasandra lake

l: Soil excavation by tractors in Madhuranahosahalli lake

m: Soil excavation in Kakola lake

n: Soil excavation and the lake is completely dry in Bhairapura

o: Soil excavation and fishing in Buddamanahalli kere

p: Rapid soil excavation in Challahalli lake

q: Dibbur lake is almost dry and soil excavation

r: Rapid soil excavation in Linganahalli kere

s: soil excavation in Ammanikere

t: Soil excavation in Beerasandra lake

u: Soil excavation in Thirumagondanahalli lake

v: brick work inside Thirumagondanahalli lake

Plate-4.35: Encroachment on lakes for agriculture in Hesaraghatta sub-catchment (Zone-1)

a: Encroachment by grape plantation in Koluru Rayanahalli kere

b: Sri Lakshmi Breading Poultry Farm on the Byatha lake bed

c: Slight encroachment by Nilgiri plantation and soil excavation in Honnavara lake

d: Ragi separation and fencing of the Gulya lake

e: Honnadevipura lake is completely dry with slight encroachment by areca plantation

f: Saplings planted inside Kadanur lake


g: Nigiri and grape plantation has slightly encroached Byrasandra lake


h: Encroachment by Nilgiri plantation in Gejjagadhahalli lake


i: Encroachment of areca plantation inside Madhagondanahalli lake


j: Nilgiri plantation inside Doddagollahalli lake


k: Compound constructed in Obadevanahalli lake


l: Cat fish raring in Madhagondanahalli lake

m: encroachment by agriculture in arakere lake

n: Apartment built on the Kadathamale lake bed

o: Poultry on Sadenahalli lake bed

Plate-4.36: Wastes Dumped in Lakes of Hesaraghatta sub-catchment area (Zone-1)

a: Solid and burning waste dumped in the outlet of Madhure lake

b: Fishing tent and plastic waste in the Kakola kere

c: Ramadevanahalli lake is completely dry

d: Solid waste dumped in culvert in Madhure village

e: Construction debris dumped in Buddamanahalli kere

f: Solid and burning waste in culvert of Doddagollahalli village

g: Agriculture and burning waste in Gejjagadhahalli lake

h: Solid waste and construction debris in Ramanathapura lake

i: Garbage dump in ammanipalya lake

j: Solid waste dumped in Rajankunte lake from nearby houses

k: garbage dump in Suradenapura lake

Plate-4.37: Groundwater exploitation in lakes of Hesaraghatta sub-catchment area (Zone-1)

a: MSW and inspection man hole in Koluru Rayanahalli kere

b: Bore well drilled inside Dibbur lake

c: Bore well drilled on the lake bed

d: Bore well drilled inside Kukkanahalli lake

e: MSW and bore well on Madhure lake bed

f: Drawing Madhure lake water into tankers

g: A pipe has been installed inside the Dodda Tumakuru

h: MSW and bore well inside Aruvanahalli lake

i: MSW and bore well inside Masandra Ammani lake

j: Underground pipe in Suradenapura lake used for agricultural purposes

Plate-4.38: Wastewater discharged to the lakes of Hesaraghatta sub-catchment area (Zone-1)

a: Drain carrying sewage into Madhure lake

b: A small pond in the edge of the Bashettihalli lake that contains industrial waste

c: A pipe connecting to the storm water drain from BRFL, carrying to Bashettihalli lake

d: A small drain containing industrial waste from BRFL entering the dry Bashettihalli lake

e: Drain containing sewage from the village is entering Majara Hosahalli lake

f: Drain containing waste from Birla Cement factory is entering Majara Hosahalli lake

g: Small puddle in Shanubhoganahalli lake is filled with sewage from close by houses

h: Solid waste dumped and waste from village entering Haniyur lake

i: Vehicle and cattle washing in Adhiganahalli lake

j: sewage inlet into Suradenapura lake from houses next to the lake

Plate-4.39: Central Effluent Treatment Plant next to Bashettihalli kere in Hesaraghatta sub-catchment (Zone-1)

Sewage treatment plant and (BRFL) next to Bashettihalli kere

Plate-4.40: STP Construction in Majara Hosahalli lake in of Hesaraghatta sub-catchment (Zone-1)

a: Construction of sewage treatment plant inside Majara hosahalli lake

Plate-4.41: Doddaballapura Industrial Area in Hesaraghatta Sub-catchment area (Zone-1)

a: Doddaballapura Industrial area

b: Doddaballapura Industrial area

c: Bombay Rayon Fashions Ltd (BRFL) Areguddadhahalli village

d: Birla Super Bulk Terminal in Ba Shettyhalli village

e: Sri Vasavi granite in Bacchahalli village

Plate-4.42: Wastewater discharged into water course of Arkavathi sub-catchment area (Zone-1)

a: Thirumalapura wastewater carried in a concrete pipe by pass beneath Madavara kere and discharge wastewater into drain further connected to river Arkavathi

b: Effluent let into drain of Thirumalapura village

c: Wastewater drain in Singapura village

d: Drain carrying wastewater in Dasarahalli village

e: Sullage in Hunnegere village

f: Polluted Doddabidarakallu Kere

g: Nagasandra drain

h: Koolipura drain

i: Drain carrying stale wastewater in Handarahalli village

j: Stale wastewater flow to Sondekoppa Lake

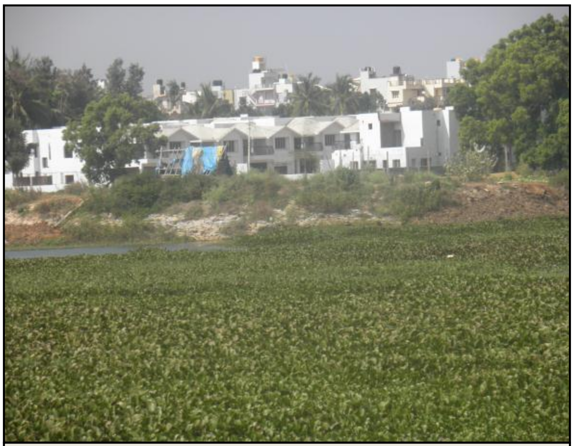
k: Manhole and inspection chamber near Bagalakunte Lake

l: Sewage flowing near Bagalakunte Lake

m: Sewer outlet found in Dasanapura Lake

Plate-4.43: Aquatic weeds in lakes of Arkavathi sub-catchment area (Zone-1)

a: Water Hyacinth spread in Doddabidarakallu kere



b: *Eichhornia crassipes* spread in Arasinakunte lake

c: Water hyacinth spread in Kammagondanahalli Lake

d: Water hyacinth in Nelamangala kere

e: Water hyacinth in Arasinakunte lake

f: Aquatic weed and Solid waste dump in Nelakadhrenahalli Kere (sy.no. 59)

Plate-4.44: Solid waste disposal in lakes of Arkavathi sub-catchment area (Zone-1)

a: Ramky Dumping Site in Mavallipura village

b: Construction and demolition waste in Madavara Lake

c: Barber shop waste in Madavara Lake

d: Poultry waste in Madavara Lake

e: Waste dumped in Madavara Lake

f: Construction and demolition waste in Abbigere Lake


g: Garbage Waste dump in the Abbigere Lake


h: Barber shop waste in Abbigere Lake


i: Waste dumped in the Abbigere Lake


j: Burning of waste in Byalakere Lake


k: waste floating in Gangaondanahalli lake


l: Organic waste and cow dung piled up in Bylakonenahalli kere

m: waste dump near Bagalakunte Lake

n: Construction and Demolition waste in Byalakere Lake

o: Construction and Demolition waste dumped in Arasinakunte Lake

p: Waste discarded in Dasarahalli kere

q: Construction & Demolition waste in Bagalakunte Lake

r: Burning waste in Lakshmipura Lake


s: Waste dump in Mallasandra Lake


t: Waste dump in Lakshmipura Lake


u: Waste floating in Nagaruru-Pillahalli Lake


v: Waste dump in Shettyhalli kere


w: Waste dump in Vaddarahalli village


x: Burning waste and poultry waste dump in Kachohalli Lake


y: waste dump in Nelamangala village

Plate-4.45: Soil excavation in lakes of Arkavathi sub-catchment area (Zone-1)

a: Soil excavation in Byalakere Lake

b: Soil excavation in Hunnegere lake

c: Soil excavation in Kengenahalli Lake

d: Soil excavation and Construction and demolition waste dump in Sondekoppa Lake

e: Soil excavation in Koolipura Lake

f: Mallapura Lake

Plate-4.46: Quarrying in Arkavathi sub-catchment area (Zone-1)

a: Quarrying in Byregowdanahalli village

b: Quarrying in Mallasandra village

c: Quarrying in Hadhripura village

d: Quarrying in Hadhripura village

Plate-4.47: STP in Nagasandra village of Arkavathi sub-catchment area (Zone-1)

a: Doddabidarakallu kere

b: STP of Nagasandra village

c: Fine bar screen chamber of STP in Nagasandra village

Plate-4.48: STP of Dasarahalli village in Arkavathi Sub-catchment area (Zone-1)

a: Dasarahalli kere

b: STP in Dasarahalli village

Plate-4.49: Peenya Industrial Area in Arkavathi sub-catchment area (Zone-1)

a: Drain carrying wastewater and waste dump in Stage 2

b: Waste dump in phase-3

c: Waste dump next to drain in Stage-2

d: Waste dumped in Phase-4

e: Clothes discarded opposite to Sree Eshwari Textiles

f: Waste dumped in Phase-3

g: Volvo industry located in Phase-1

h: Waste dump in Stage-2

i: Waste dump in Phase-3

j: Phase-3 drain

k: Phase-2 drain

l: Stage-2 drain

m: Stagnant wastewater in Shivapura kere

n: Black coloured wastewater in Shivapura kere

o: Shivapura kere

Plates-4.50: Environmental Concerns in the Kumudvathi sub-Catchment area (Zone-1)

a: Borewell inside the lake (sy. No. 46) of Machonayakanahalli village

b: Mini water supply (MWS) in Naganahalli village

c: Mini water supply (MWS) in Kottaganahalli village

d: Drawing of water from the lake by tankers in Hemapura village

e: Excavation of soil from the Yedehallikere and dumping in the opposite field in Yedehalli village

f: Sand mining in the Yedehalli kere in Yedehalli village

g: Sand mined in Avverahalli kere in Avverahalli village

h: Agricultural waste in the lake of Narasipura village

i: Burning of biomedical waste near the lake in Geddalahalli village

j: Solid waste dumped in and around the Sompurakere in Sompura village

k: Adjacent to the Sompura kere in Sompura village

l: Waste water entering the Sompurakere in Sompura village

m: Solid waste disposal unit is established by Nelmangala Town Municipal Council in Kangondanahalli village

n: Wastewater from the settlement in entering the lake in Bommanahalli village

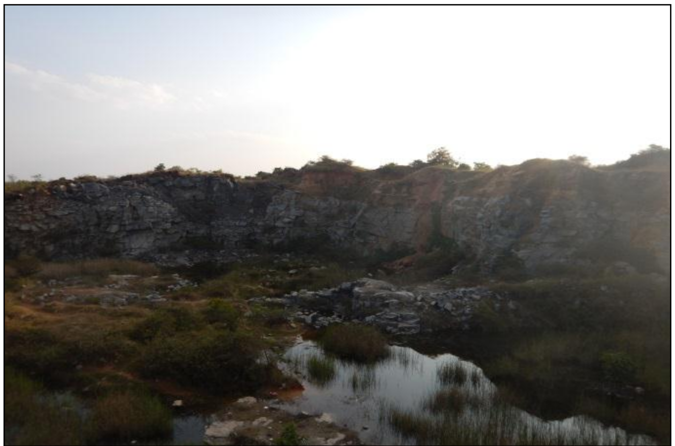
o: Waste water through storm water is entering lake in Margondanahalli village

p: Quarry in Billanakote village

q: Quarry in Mahimapura village

r: Preparation for quarry in Narayanaraopalya village

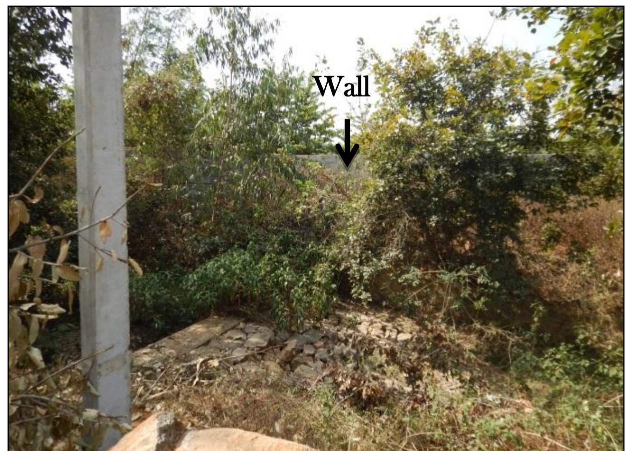
s: Quarry at the edge of the lake (sy. No. 46) in Machonayakanahalli village



t: Abandoned quarry in Laxmanapura village

u: Abandoned quarry in Kanugondanahalli

v: Stream within the compound and adjacent to the industries in Sompura and Dabbaspet Industrial area in Yedehalli village



s: Attached to stream is Hazardous Waste Treatment storage and Disposal facility in Pemmanahalli village

x: Solid waste dumping inside the stream within the Industrial Area in Pemmanahalli village

y: Check dam inside the stream in Narayanaraopalya village

Plates-4.51: Observation in the Kumudvathi sub-Catchment area (Zone-1)

a: SM College of Engineering adjacent to the lake in Kammasandra village

b: Godown adjacent to the Billanakote kere in Billanakote village

c: Layout and compound adjacent to the lake in Byadarahalli village

d: Industries close to the lake (Sy. No. 153) in Budhihaal village

e: Rain water harvesting in a commercial building in Lakkuru village

f: Rain water harvesting in the farm in Halenahalli village

g: Rain Water Harvesting project near the Bommanahalli village lake (Sy. No. 61) by UBL

CHAPTER-5: Change in Landuse/ Landcoverfor the Period 2003-2014

5.1. Introduction:

The entire geographical area drained by a river and its drainage network system is known as river catchment area. The catchment areas vary in shape and size. Catchment area of river includes many sub-catchment areas which are otherwise also known as watersheds. The characteristics of any river (physical, chemical and biological) are determined by the nature of the catchment and human activities happening in that area. Our stream and rivers have been changed dramatically because of rapid and unplanned urbanization. Catchment area has also been greatly modified for several human purposes like agricultural activity, urban development, introduction of exotic plants etc. Vegetation and wetlands act like sponges to slow down and absorb water and when these are replaced with impervious surfaces (buildings, roads, pavement, parking areas etc.), the infiltration rate decreases and ground water recharge also decreases which ultimately lead to depletion in ground water table and increase in runoff. So whatever happens even in the small drainages also affects the main river. Both positive and negative impacts attribute to the main river. Understanding the river system, assessment and analysis of the current situation and its comparison with the past situation is the main concern of the present study.

Source: http://www.waterprotection.ca/images/watershedb.jpg

In this chapter, attempt has been made to address the Terms of Reference (ToR) 2, 3 and 4 given by Hon'ble High Court of Karnataka for identifying the changes in landuse/ landcover and understanding the present situation of the TGR catchment area.

- The 2nd Terms of Reference for the study requires a comprehensive study of the present status of TGR catchment area and to provide the details of superstructures and infrastructure that have come up post notification no. FEE 215 ENV 2000 dated 18/11/2003 issued by the Government of Karnataka (the '2003 Notification'), clearly depicting the changes in landuse/ landcover pattern in the entire area and with particular focus on conservation Zone-2, 3 and 4.
- The 3rd Terms of Reference aims at identification and providing survey numbers in which each of the superstructures and any other infrastructure had come up, including details of the permissions given by concerned authorities.

- The 4th Terms of Reference aims at identification of superstructures and the purpose for which they are presently utilized.

It is submitted here that complete identification of all superstructures within the various zones is a gigantic task that requires total station survey/ DGPS survey. Hence an attempt has been made to provide the required information using remote sensing as well as field verification. In the previous chapter, observations have been summarized zone wise for all the four zones. Also GPS readings have been provided for each of the recorded observation. In this chapter, the analysis using remote sensing and GIS with regards to the change in landuse/ landcover has been provided.

5.2. Study Area:

The TG Halli catchment area is segregated into four zones i.e. Zone-1, 2, 3 and 4 (Figure-5.1). The entire Zone-1 is known as TG Halli Catchment area, the Zone-2 covers the TGR reservoir with 2 km buffer around the reservoir. Zone-3 is the area covered within the distance of 1 km buffer on both sides of the main rivers, Arkavathi river up to Hesaraghatta tank and Kumudvathi river and Zone-4, consists of the area covered within 1 to 2 km on both sides of the main rivers.

5.3. Methodology:

As per the Hon'ble High Court order dated on 02-02-2015, the remote sensing and GIS analysis has been carried out by Karnataka State Remote sensing Application Centre (KSRSAC) which is the nodal agency of the State Government for remote sensing and GIS work. The change detection analysis for landuse and landcover (LU/LC) has been carried out by KSRSAC using LISS (Linear Imaging Self Scanner) IV satellite imageries of the month of December for both the years 2003 and 2014. LISS IV imageries have a resolution of 5.8 meters.

The materials used for the present study are

a. LISS IV data for the years 2003 (IRS Resourcesat-1) and 2014 (IRS Resourcesat-2), ortho-corrected and geo-referenced
b. ArcGIS platform
c. Survey of India topographic maps
   Datum used: WGS84
   Projection: UTM

The methodology that has been followed for the present analysis is as follows

The landuse/ landcover type classes were delineated by using on-screen visual interpretation technique on the basis of image elements such as colour, tone, texture, pattern, association, shape and size. The Survey of India topomaps were used for locational reference. The classification is done for both 2003 and 2014. The entire area is classified into the following categories of landuse and landcover classes (Table-5.1) that have been identified using LISS IV imageries.

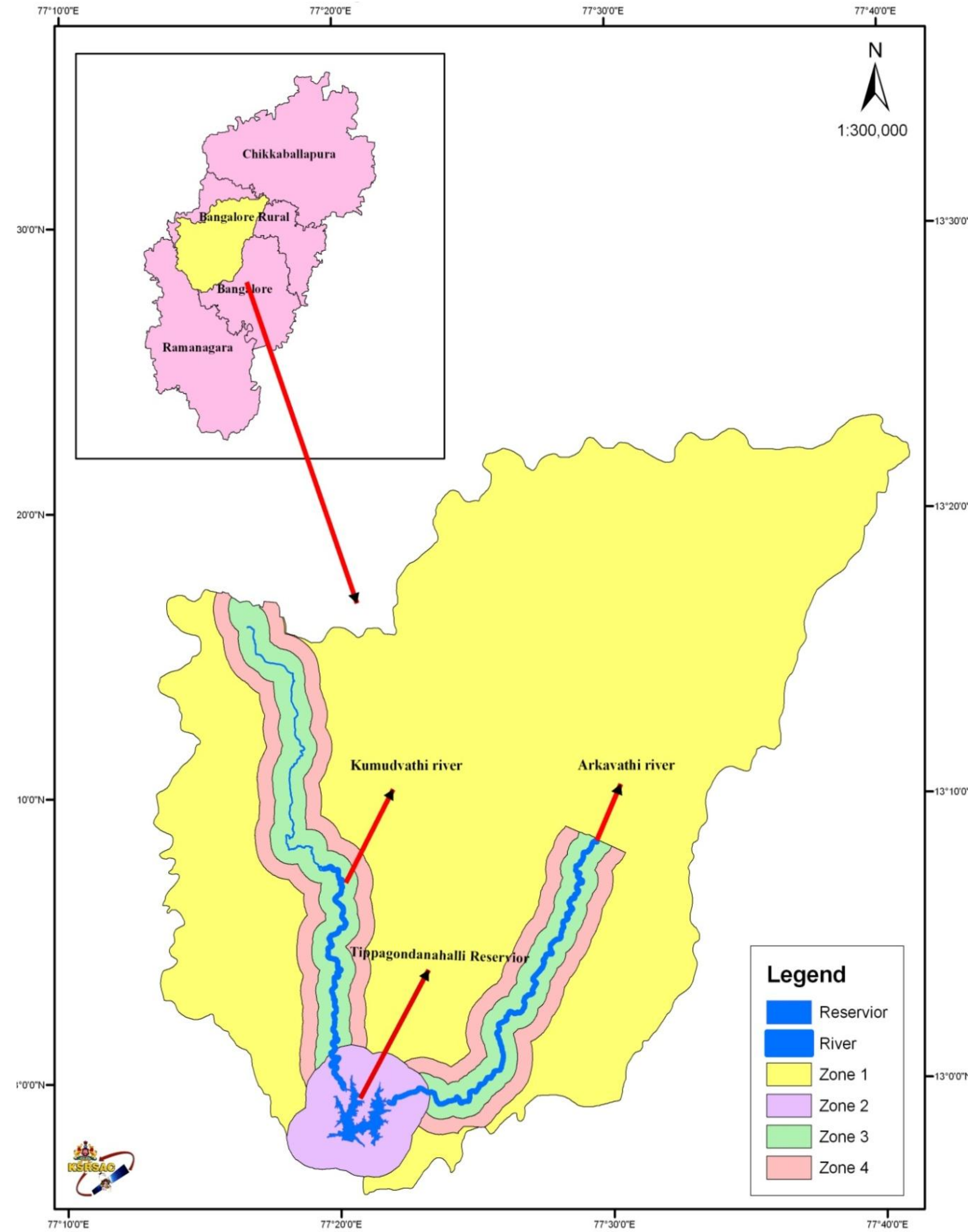


Figure-5.1. TGR catchment area

i. Agricultural land

These are the lands primarily used for farming and for production of food, fibre and other commercial and horticultural crops. It includes land under crops (irrigated and un-irrigated, fallow, plantations, etc.).

In TGR catchment the agriculture lands are further classified into crop land (which includes fallow lands), Horticultural plantations (includes garden crop, vegetables and orchards), Agricultural plantation (includes *Eucalyptus*/*Acacia,* etc.).

- ***Aquaculture/ Pisciculture*:** These are the areas where fish are bred and reared for commercial purpose.

ii. Built-up land:

In the catchment area the built-up category includes mostly urban/rural settlements/Mining/Quarrying/Industry/Roads.

iii. Forest:

Scrub forests are the areas where trees and thorny bushes/scrubs are noticed.

- ***Forest plantation*:** These are the areas of tree species for forestry raised and managed especially in the notified forest areas.

Table-5.1: Landuse classification used in the present study

SI. No	Level-1	Level-2	Level-3
1	**Agricultural land**	Crop land	Crop land
		Plantation	Horticulture Plantation/ Agriculture Plantation
		Aquaculture/ Pisciculture	Aquaculture / Pisciculture
2	**Built-up**	Built up(Urban)	Built up
			Layout
		Built up(Rural)	Village /Hamlet
		Mining /Industrial	Industrial/ Godowns/ Sheds
			Mining /Quarry
		Transportation	Road
3	**Forest**	Forest	Forest
			Forest plantation/ Eucalyptus
4	**Wastelands**	Scrub land	Scrub land(Land with or without scrub)
		Gullied /Ravinous land	Gullied/ Ravinous land
		Barren rocky	Barren rocky
5	**Water bodies**	Reservoir / Tanks / Pond	Reservoir / Tanks / Pond
		River/Stream/Drain	River/Stream/Drain

iv. Wasteland:

These are described as degraded lands which can be brought under vegetative cover with reasonable effort and which is currently under-utilized and land which is deteriorating for lack of appropriate water and soil management on account of natural causes. These lands are again categorized into Scrub land (Land with or without scrub), gullied land and barren rocky.

- ***Scrubland (Land with or without scrub):*** These are lands which are generally prone to deterioration due to erosion. Such lands generally occupy topographically high locations, excluding hilly/mountain regions. Scrub lands are associated with moderate slope in plains and foot hills and generally surrounded by agricultural lands.

- ***Barren rocky***: These are rock exposures of varying lithology often barren and devoid of soil and vegetation cover.

v. Water bodies:

This category comprises area with surface water, either impounded in the form of ponds, tanks, reservoir or flowing as river/streams etc.

5.4. Limitations of the Present Study:

The limitation of using LISS IV is that it is not possible to identify individual superstructures as LISS IV images of Resourcesat have a spatial resolution of 5.8m. The structure identified generally as built-up may be a shed or industrial building or residential building or a godown. Accurate identification of these structures has to be carried out by field survey. Hence the present study provides the details about the total area under built-up in the Zones-1, 2, 3 and 4, but is not able to provide the details of individual superstructure. However the changes are indicative of the developments that have happened in the period between the year 2003 and 2014.

5.5. Results:

The remote sensing and GIS analysis carried out by KSRSAC, gives the following results for various zones of the TGR catchment area and the change in landuse/ landcover of the area under study.

5.5.1. Zone-1 of TGR Catchment Area:

The area occupied by different units of landcover in the TGR Catchment (Zone-1) is given in Table-5.2; Figure-5.2a and 5.2b. The result indicates that in the year 2003 (year of notification) agriculture occupied 77.82% area of the catchment and it has reduced to 70.44% in the year 2014. Correspondingly, there is an increase of Built-up area (used in the report to refer housing/ industry/ mining/ layout/ roads etc.) from 9.24% in the year 2003 to 16.26% in the year 2014 (Figure-5.3). The area under other land cover units viz. forest, wastelands and water bodies has not changed significantly.

5.5.2. Zone-2 of TGR Catchment:

The area occupied by different units of landcover in the Zone-2 is given in Table-5.3 and presented in Figure-5.4a and 5.4b. The area under agriculture and wastelands has decreased marginally whereas the area under built-up class has increased significantly from 171.67 ha (2.93%) in 2003 to 239.95 ha (4.10%) in 2014 (Figure-5.5). Area under forest and Water bodies did not change significantly in this period.

5.5.3. Zone-3 of TGR Catchment:

The area occupied by different landcover classes in the Zone-3 is given in Table-5.4 and Figure-5.6a and 5.6b. The area under agriculture has come down from 10113.02 ha (81.62%) in the year 2003 to 8993.12 ha (72.58%) in the year 2014 due to increase of activities in the sector Built-up. The Built-up area increased drastically from 962.12 ha

(7.76%) in the year 2003 to 2039.73 ha (16.46%) in the year 2014 (Figure-5.7). The area under forest, wastelands and water bodies has not changed significantly.

Table-5.2. Landuse/ Landcover classes of Zone-1

Year				2003		2014	
Sl. No	Level-1	Level-2	Level-3	Area in Ha	% of Total Area	Area in Ha	% of Total Area
1	Agricultural land	Aquaculture/ Pisciculture	Aquaculture/ Pisciculture	2.36	0.00	18.55	0.01
		Crop land	Crop land	75000.68	50.99	62086.18	42.21
		Plantation	Horticulture Plantation	9196.06	6.25	11711.73	7.96
			Plantation/ Eucalyptus	30259.17	20.57	29781.98	20.25
Sub total				**114458.28**	**77.82**	**103598.45**	**70.44**
2	Built-up	Built up (Urban)	Built up	3293.88	2.24	6896.59	4.69
			Layout	1851.89	1.26	6654.79	4.52
		Built up(Rural)	Village /Hamlet	5190.83	3.53	5268.23	3.58
		Mining /Industrial	Industrial/ Godowns/ Sheds	1588.18	1.08	3066.91	2.09
			Mining /Quarry	897.32	0.61	1105.97	0.75
		Transportation	Road	766.12	0.52	916.29	0.62
Sub total				**13588.21**	**9.24**	**23908.77**	**16.26**
3	Forest	Forest	Forest	1218.54	0.83	1256.50	0.85
			Forest plantation	1327.90	0.90	1196.53	0.81
Sub total				**2546.44**	**1.73**	**2453.03**	**1.67**
4	Wastelands	Barren rocky	Barren rocky	1897.58	1.29	1734.18	1.18
		Gullied /Ravinous land	Gullied/ Ravinous land	26.40	0.02	26.68	0.02
		Scrub land	Scrub land (Land with or without scrub)	7543.48	5.13	8088.64	5.50
Sub total				**9467.46**	**6.44**	**9849.50**	**6.70**
5	Water bodies	Reservoir / Tanks / Pond	Reservoir / Tanks/ Pond	6837.86	4.65	7088.91	4.82
		River/Stream/ Drain	River/ Stream/ Drain	185.99	0.13	185.59	0.13
Sub total				**7023.85**	**4.78**	**7274.50**	**4.95**
Total area: 147084.25 Ha							

5.5.4. Zone-4 of TGR catchment:

Area under different landcover units is given in Table-5.5 and Figure-5.8a and 5.8b. The area under agriculture has decreased significantly from 9491.21 ha (82.88%) in the year 2003 to 8145.49 ha (71.13%) in the year 2014. This kind of negative impact on productive landuse has occurred due to increasing activities in the built-up sector and some lands going to the class wastelands. Built-up area increased two and half times in the period, that is, 934.81 ha (8.16%) in the year 2003 and 2226.56 ha (19.44%) in the year 2014. The wastelands increased from 661.84 ha (5.78%) in the year 2003 to 723.05 ha (6.31%) in the year 2014 (Figure-5.9).

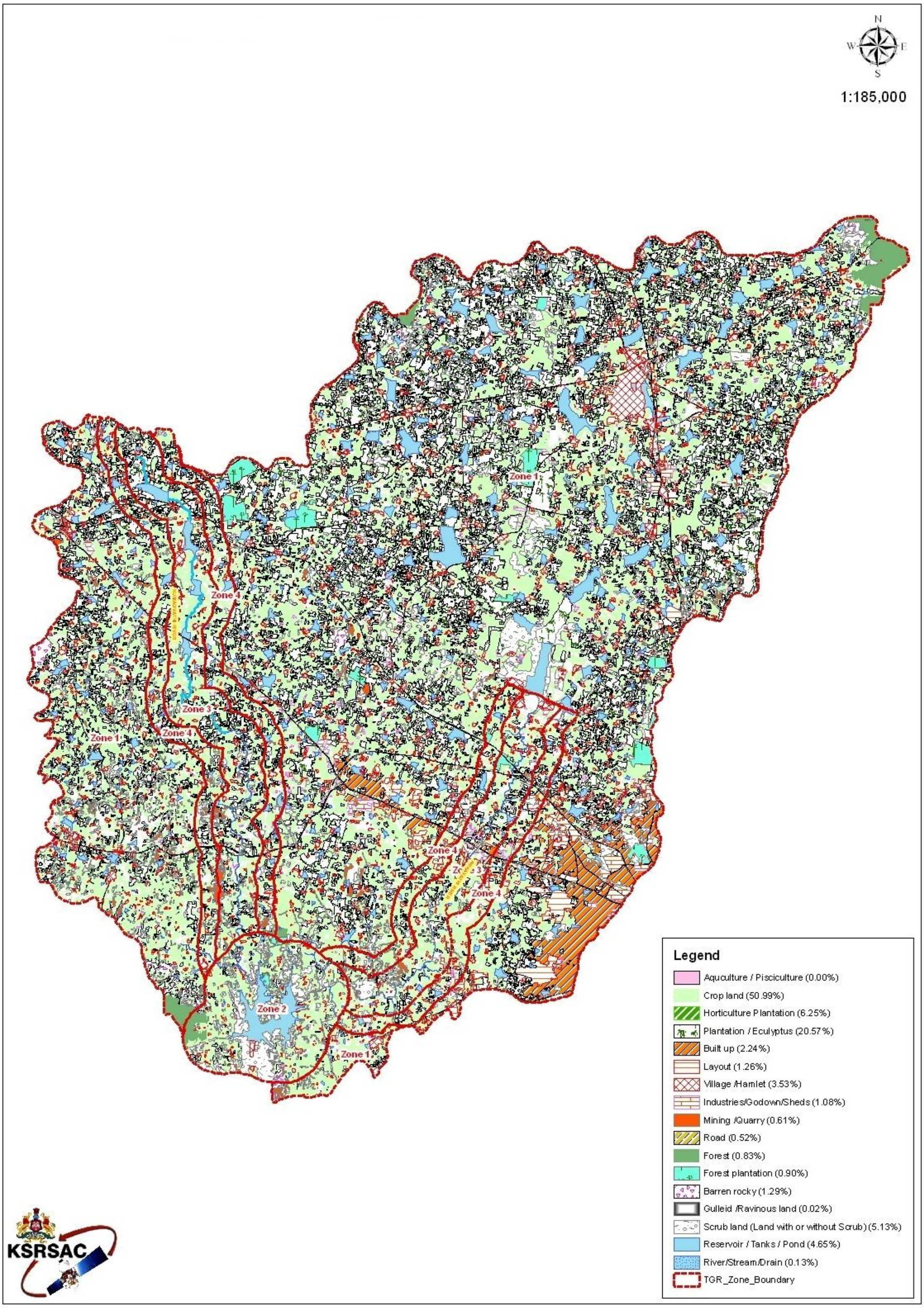


Figure-5.2a.Landuse/landcover map of TGR catchment area (2003)

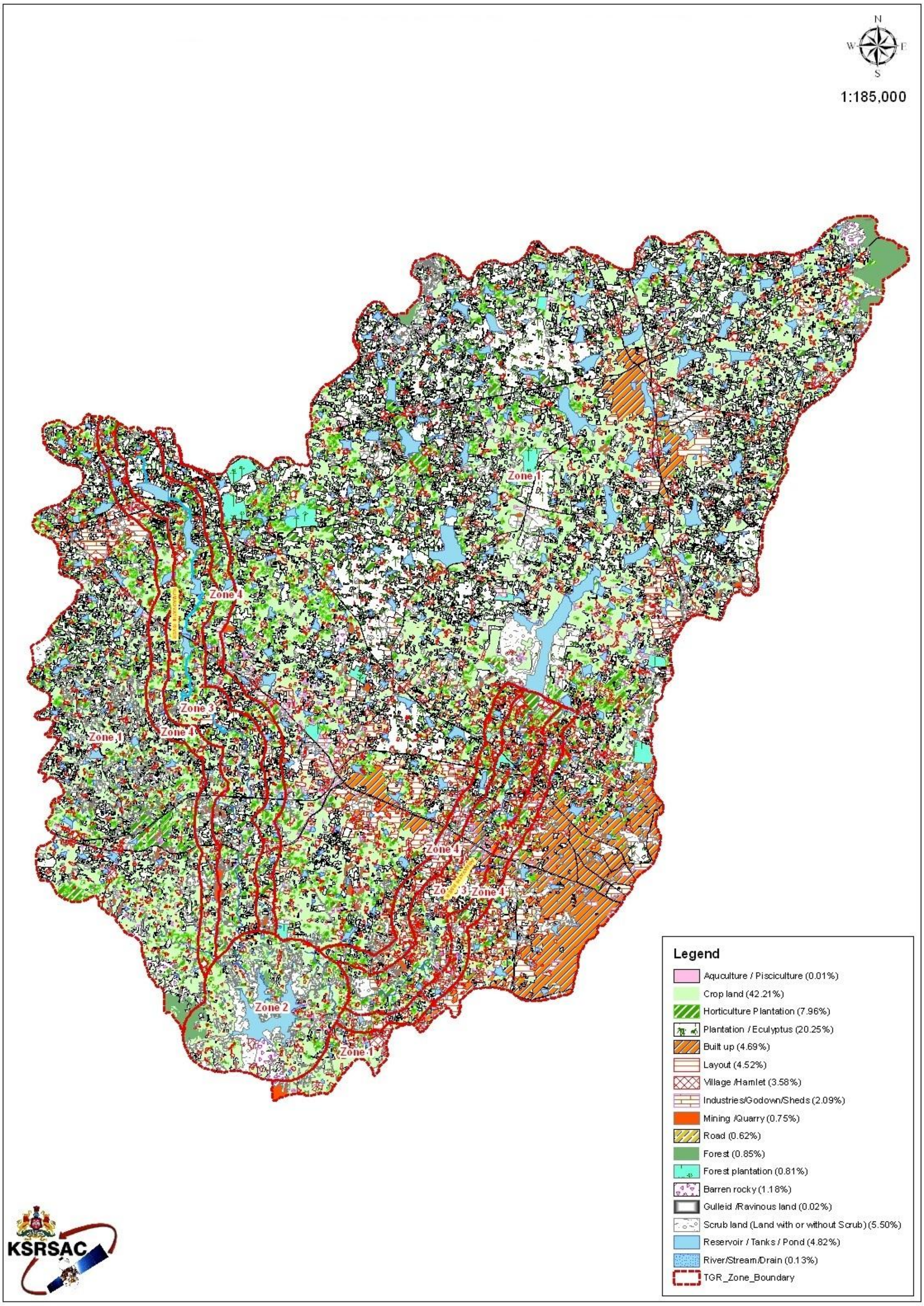


Figure-5.2b.Landuse/landcover map of TGR catchment area (2014)

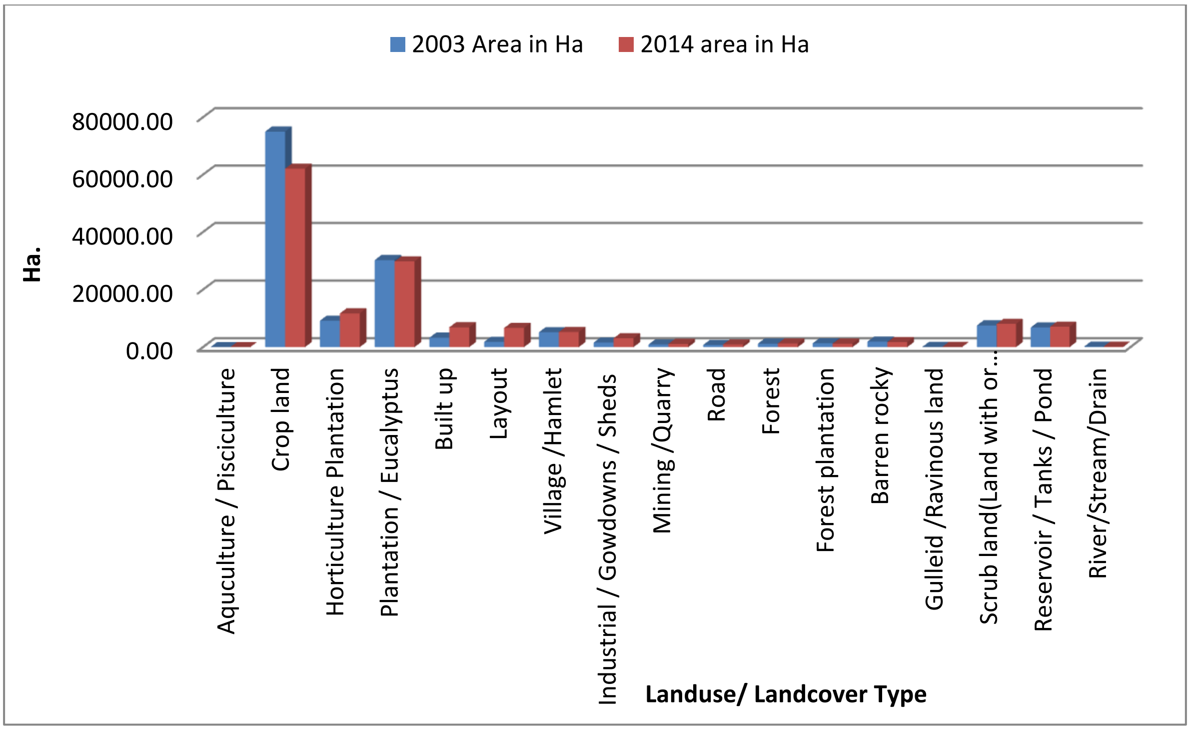


Figure-5.3. Graph showing LU/LC change in the entire catchment area

5.5.5. Village wise Information:

One of the Terms of Reference included in the study is to identify and denote the survey numbers in which the superstructures and other infrastructure have been put up. The KSRSAC has undertaken the change in landuse and landcover study for the years 2003 and 2014 and the digitalized village boundaries were superimposed on the landuse/ landcover maps of the Zones-2, 3 & 4. Following this process, village wise data which covers 200 villages in these zones under different landuse/ landcover classes has been extracted. The landuse/ landcover data of all the 200 villages are compiled as village wise tables and given in Annexure-5.1. This was also corroborated with field observations.

5.5.5a. Villages where the Landuse has Changed Substantially between 2003 and 2014:

An attempt has also been made to identify critical villages undergoing significant landuse changes in recent years. The village wise statistics indicate that increase in built up area is seen in 23 villages, which have under gone changes in landuse, particularly in development of layouts, roads, construction of storage structure/ godowns, mining/quarry etc. Among these 23 villages, 15 villages have significant landuse/landcover changes (Table-5.6 and Figure-5.10). The following table indicates the change in landuse/ landcover in the villages and also the survey numbers where developments have happened to a greater extent.

Table 5.3: Landuse/Landcover classification for the year 2003 and 2014 of Zone-2

				2003		2014	
Sl. No	**Level-1**	**Level-2**	**Level-3**	**Area in Ha**	**% of Total Area**	**Area in Ha**	**% of Total Area**
1	Agricultural land	Crop land	Crop land	2888.11	49.32	2775.45	47.40
		Plantation	Horticulture Plantation	174.88	2.99	286.79	4.90
			Plantation / Eucalyptus	175.48	3.00	156.42	2.67
Sub total				**3238.48**	**55.31**	**3218.66**	**54.97**
2	Built-up	Built up(Urban)	Layout	3.39	0.06	17.21	0.29
		Built up(Rural)	Village /Hamlet	104.68	1.79	136.88	2.34
		Mining /Industrial	Industrial / Gowdowns / Sheds	22.50	0.38	44.22	0.76
			Mining /Quarry	41.11	0.70	41.64	0.71
Sub total				**171.67**	**2.93**	**239.95**	**4.10**
3	Forest	Forest	Forest	186.45	3.18	241.41	4.12
			Forest plantation	58.64	1.00	4.61	0.08
Sub total				**245.09**	**4.19**	**246.02**	**4.20**
4	Wastelands	Barren rocky	Barren rocky	177.44	3.03	350.03	5.98
		Scrub land	Scrub land(Land with or without scrub)	1347.78	23.02	1131.01	19.31
Sub total				**1525.22**	**26.05**	**1481.04**	**25.29**
5	Water bodies	Reservoir / Tanks / Pond	Reservoir / Tanks / Pond	633.44	10.82	628.24	10.73
		River/Stream/ Drain	River/Stream/Drain	41.74	0.71	41.74	0.71
Sub total				**675.18**	**11.53**	**669.98**	**11.44**
Total area of Zone-2: 5855.64 Ha							

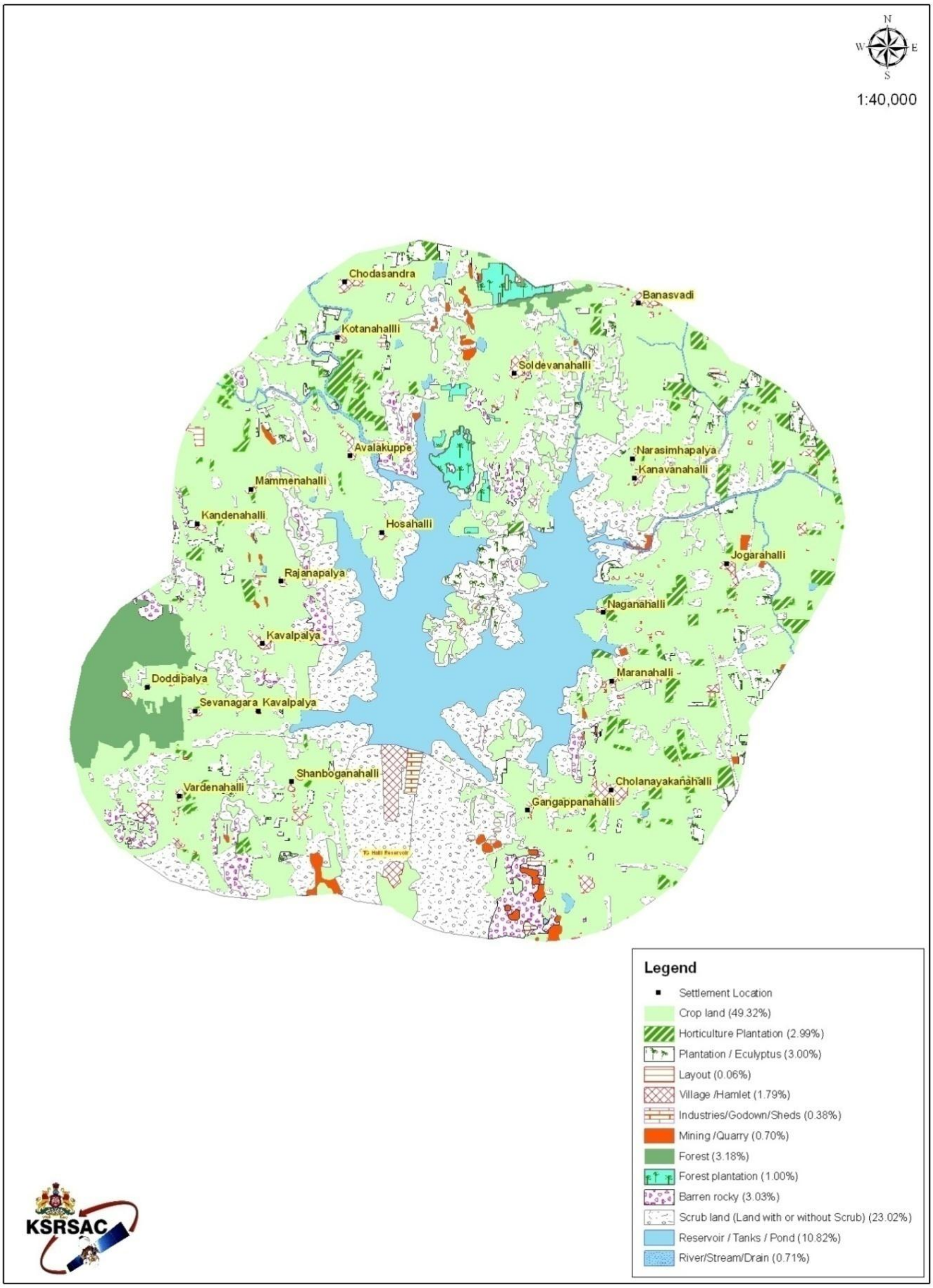


Figure-5.4a.Landuse/landcover map of zone-2 of TGR catchment area (2003)

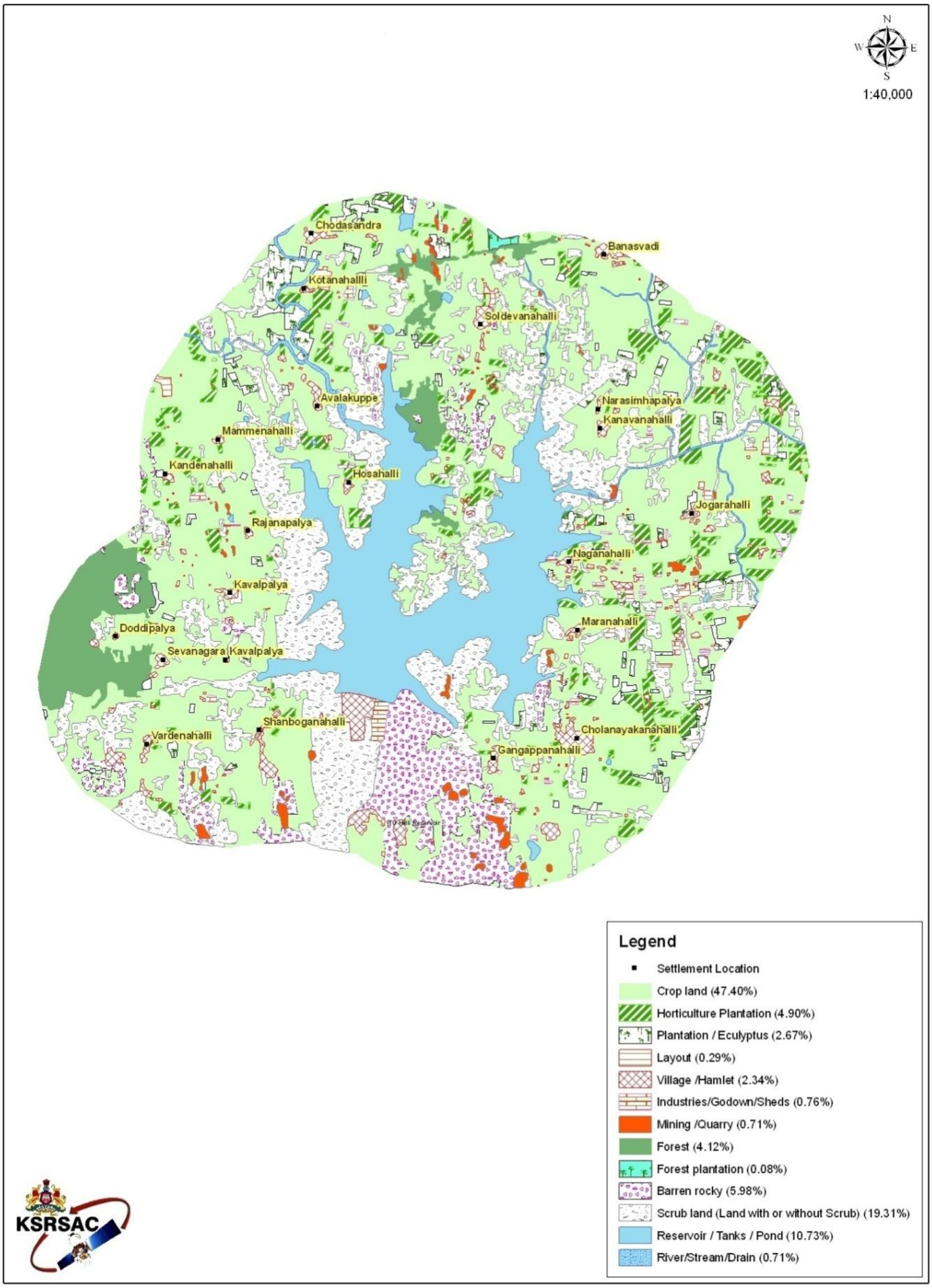


Figure-5.4b.Landuse/landcover map of zone-2 of TGR catchment (2014)

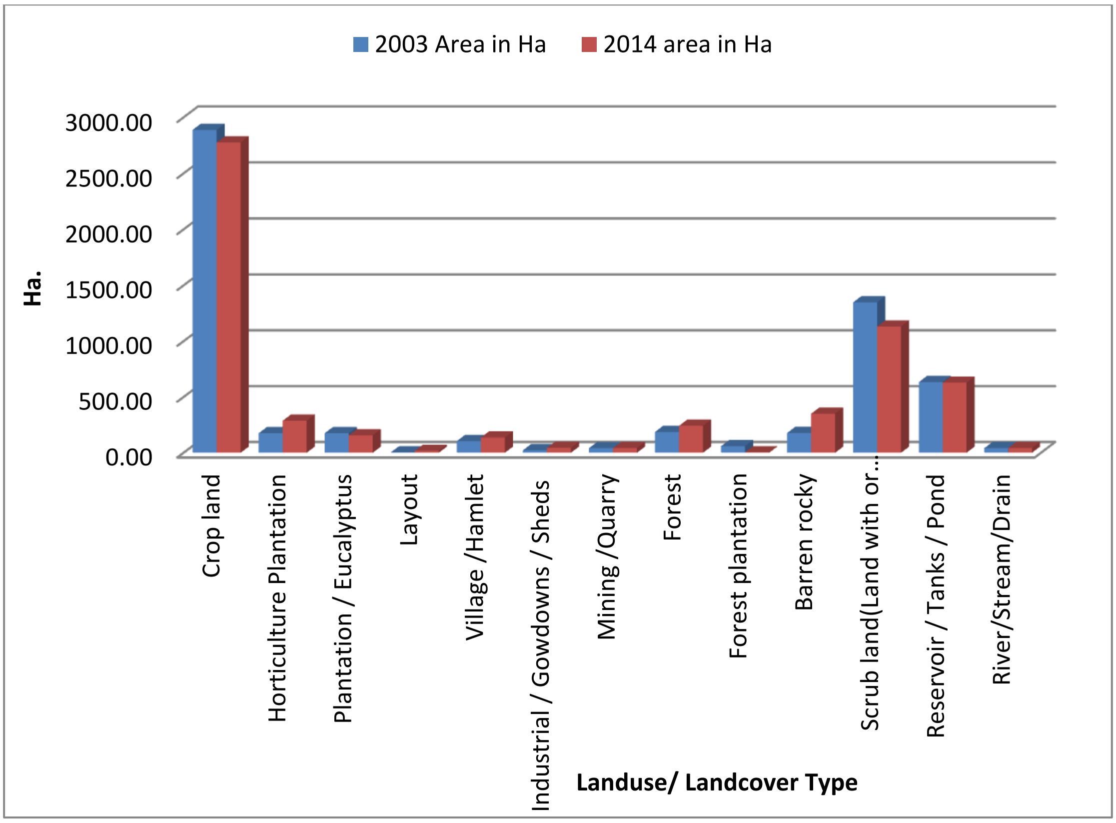


Figure-5.5: Graph showing LU/LC type zone-2

Table-5.4: Landuse/Landcover classification for 2003 and 2014 of Zone-3

Year				2003		2014	
Sl. No	Leve-1	Level-2	Level-3	Area in Ha	% of Total Area	Area in Ha	% of Total Area
1	Agricultural land	Aquaculture / Pisciculture	Aquaculture / Pisciculture	0.00	0.00	0.64	0.01
		Crop land	Crop land	6884.162	55.56	5382.11	43.44
		Plantation	Horticulture Plantation	1438.693	11.61	1639.67	13.23
			Plantation / Eucalyptus	1790.167	14.45	1970.70	15.90
Sub total				**10113.023**	**81.62**	**8993.12**	**72.58**
2	Built-up	Built up(Urban)	Built up	95.721	0.77	221.83	1.79
			Layout	109.791	0.89	817.67	6.60
		Built up(Rural)	Village /Hamlet	448.727	3.62	555.90	4.49
		Mining /Industrial	Industrial / Gowdowns / Sheds	127.789	1.03	232.34	1.88
			Mining /Quarry	126.797	1.02	150.64	1.22
		Transportation	Road	53.292	0.43	61.34	0.50
Sub total				**962.117**	**7.76**	**2039.73**	**16.46**
3	Forest	Forest	Forest plantation	53.526	0.43	51.93	0.42
Sub total				**53.526**	**0.43**	**51.93**	**0.42**
4	Wastelands	Barren rocky	Barren rocky	66.816	0.54	71.13	0.57
		Scrub land	Scrub land(Land with or without scrub)	675.734	5.45	716.33	5.78
Sub total				**742.550**	**5.99**	**787.46**	**6.36**
5	Water bodies	Reservoir / Tanks / Pond	Reservoir / Tanks / Pond	385.328	3.11	384.71	3.10
		River/Stream/Drain	River/Stream/Drain	134.502	1.09	134.09	1.08
Sub total				**519.83**	**4.20**	**518.80**	**4.19**
Total area of Zone-3: 12391.05 Ha							

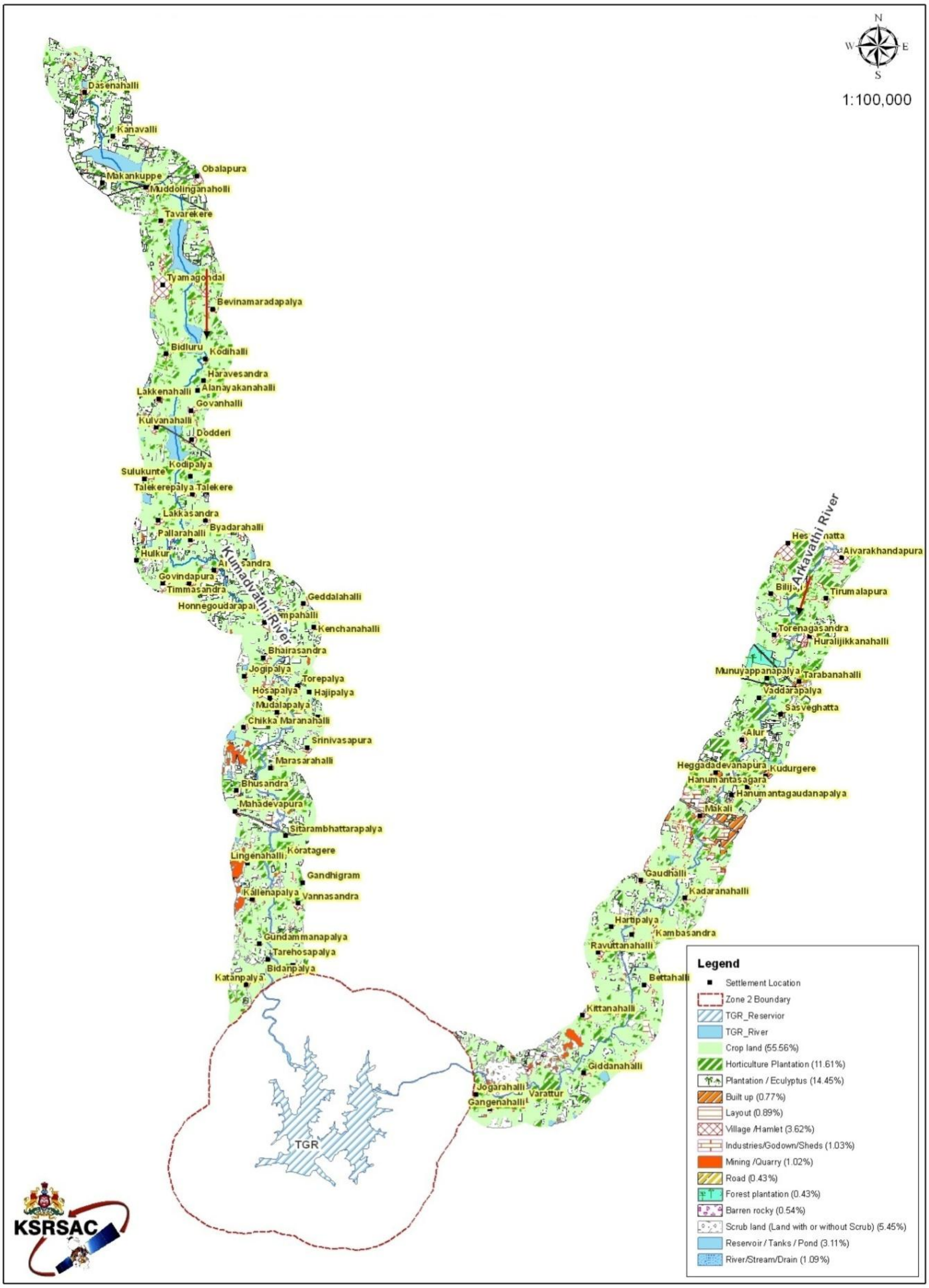


Figure-5.6a. Landuse/landcover map of Zone-3 of TGR catchment area (2003)

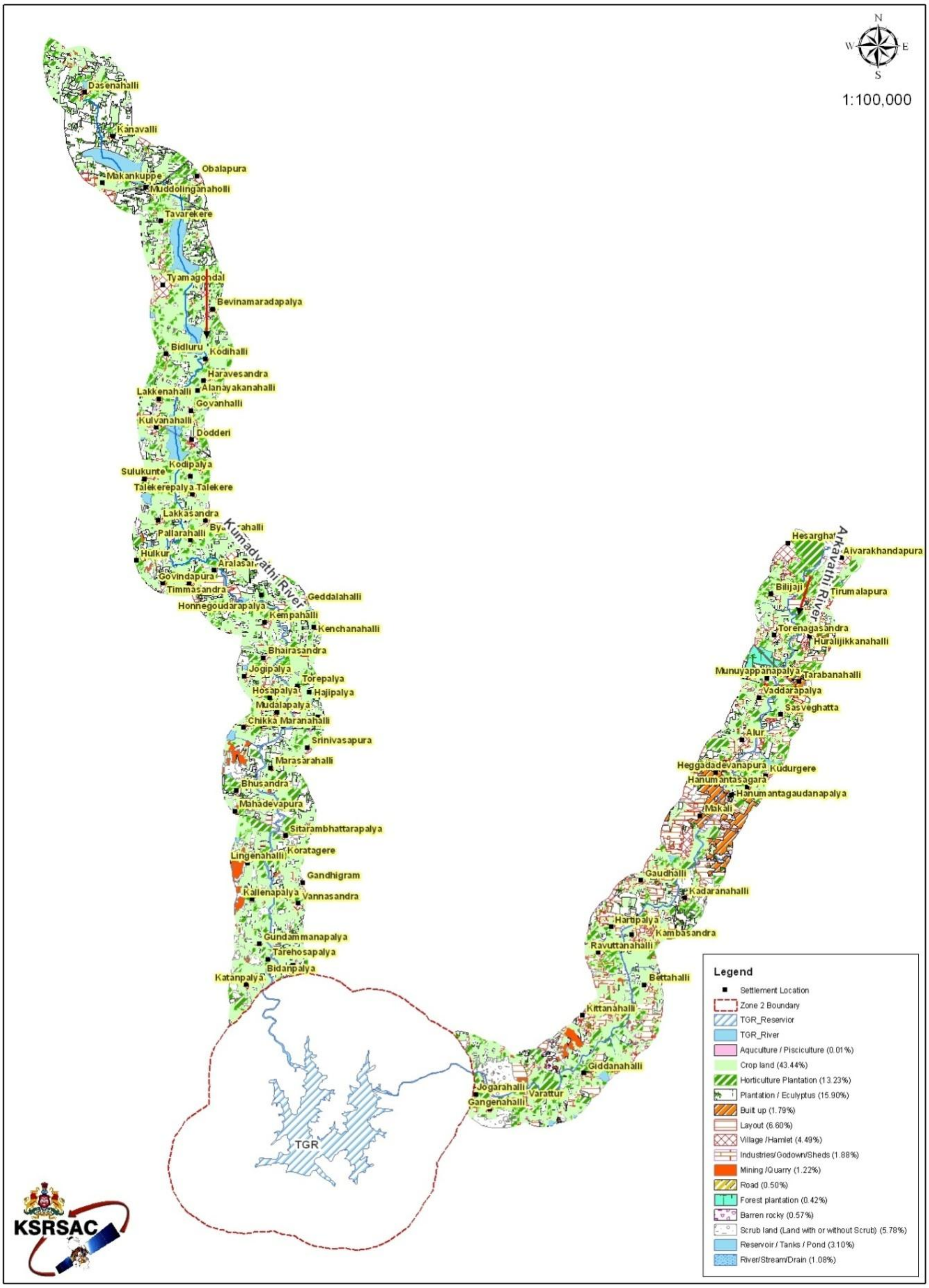


Figure-5.6b.Landuse/landcover map of Zone-3 of TGR catchment area (2014)

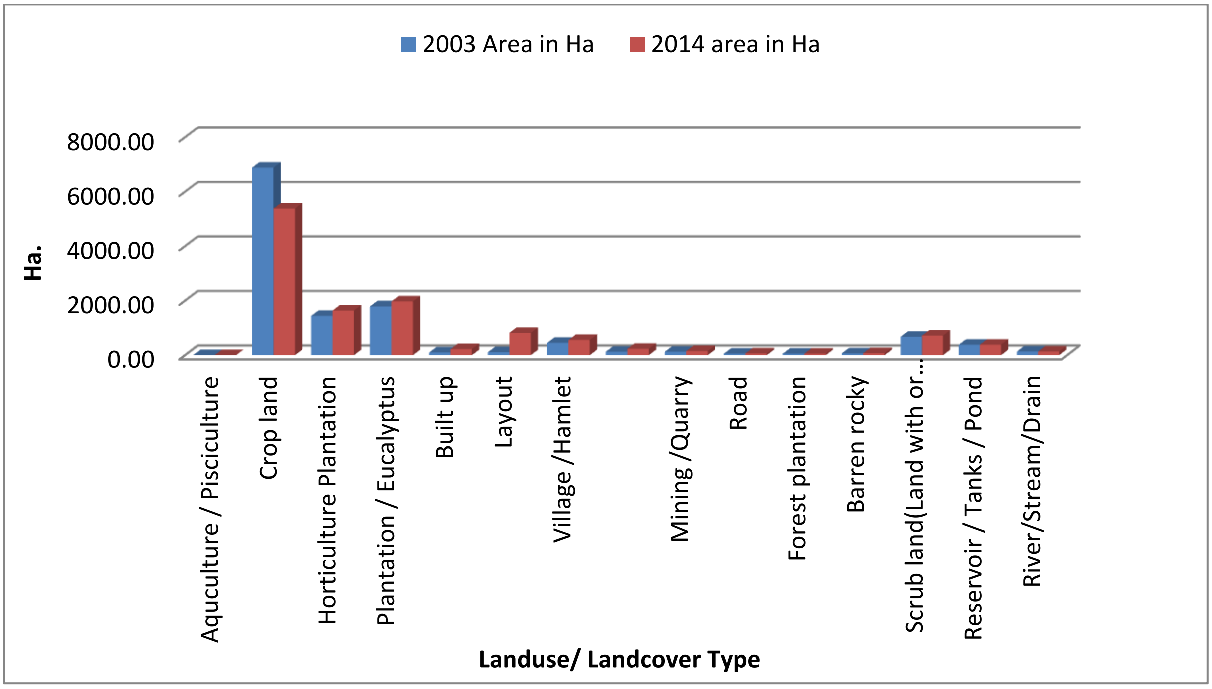


Figure-5.7. Graph showing LU/LC type Zone-3

Table-5.5.Landuse/Landcover classification for the year 2003 and 2014 of Zone-4

				2003		2014	
Sl. No	Level-1	Level-2	Level-3	Area in Ha	% of Total Area	Area in Ha	% of Total Area
1	Agricultural land	Aquaculture / Pisciculture	Aquaculture / Pisciculture	0.00	0.00	0.86	0.01
		Crop land	Crop land	6605.97	57.69	4901.43	42.80
		Plantation	Horticulture Plantation	1244.38	10.87	1468.87	12.83
			Plantation / Eucalyptus	1640.86	14.33	1774.33	15.49
Subtotal				**9491.21**	**82.88**	**8145.49**	**71.13**
2	Built-up	Built up(Urban)	Built up	88.47	0.77	180.48	1.58
			Layout	227.91	1.99	1082.91	9.46
		Built up(Rural)	Village /Hamlet	335.89	2.93	428.25	3.74
		Mining /Industrial	Industrial / Gowdowns / Sheds	95.90	0.84	313.77	2.74
			Mining /Quarry	138.05	1.21	165.48	1.45
		Transportation	Road	48.60	0.42	55.67	0.49
Subtotal				**934.81**	**8.16**	**2226.56**	**19.44**
3	Forest	Forest	Forest	11.69	0.10	6.54	0.06
			Forest plantation	18.23	0.16	27.50	0.24
Subtotal				**29.92**	**0.26**	**34.04**	**0.30**
4	Wastelands	Barren rocky	Barren rocky	150.54	1.31	165.16	1.44
		Scrub land	Scrub land (Land with or without scrub)	511.30	4.46	557.89	4.87
Subtotal				**661.84**	**5.78**	**723.05**	**6.31**
5	Water bodies	Reservoir / Tanks / Pond	Reservoir / Tanks / Pond	328.19	2.87	316.82	2.77
		River/Stream/ Drain	River/Stream/Drain	5.43	0.05	5.43	0.05
Subtotal				**333.62**	**2.91**	**322.24**	**2.81**
Total area of Zone-4: 11451.40 Ha							

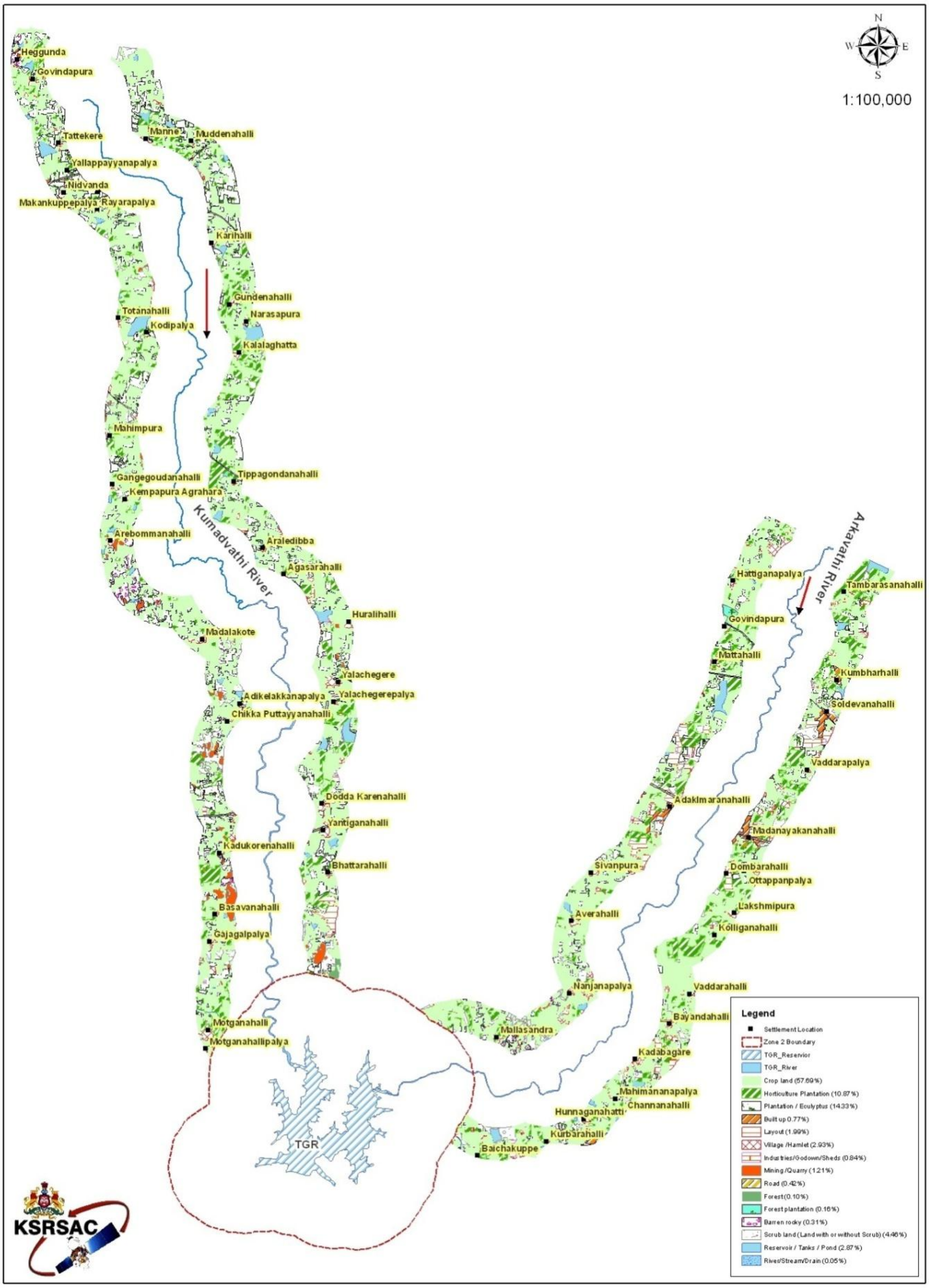


Figure-5.8a.Landuse/ landcover map of Zone-4 of TGR catchment area (2003)

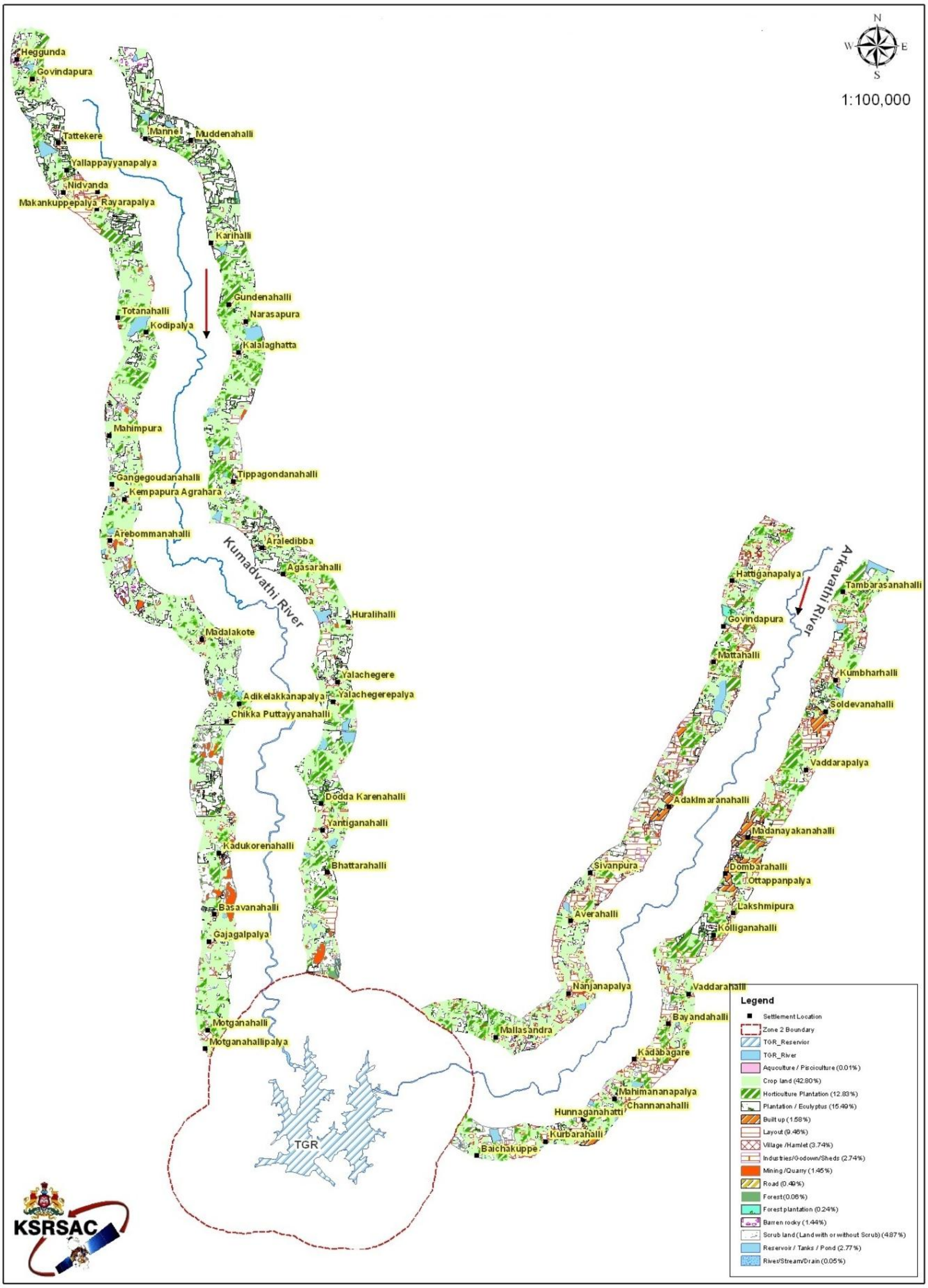


Figure-5.8b.Landuse/ landcover map of Zone-4 of TGR catchment area (2014)

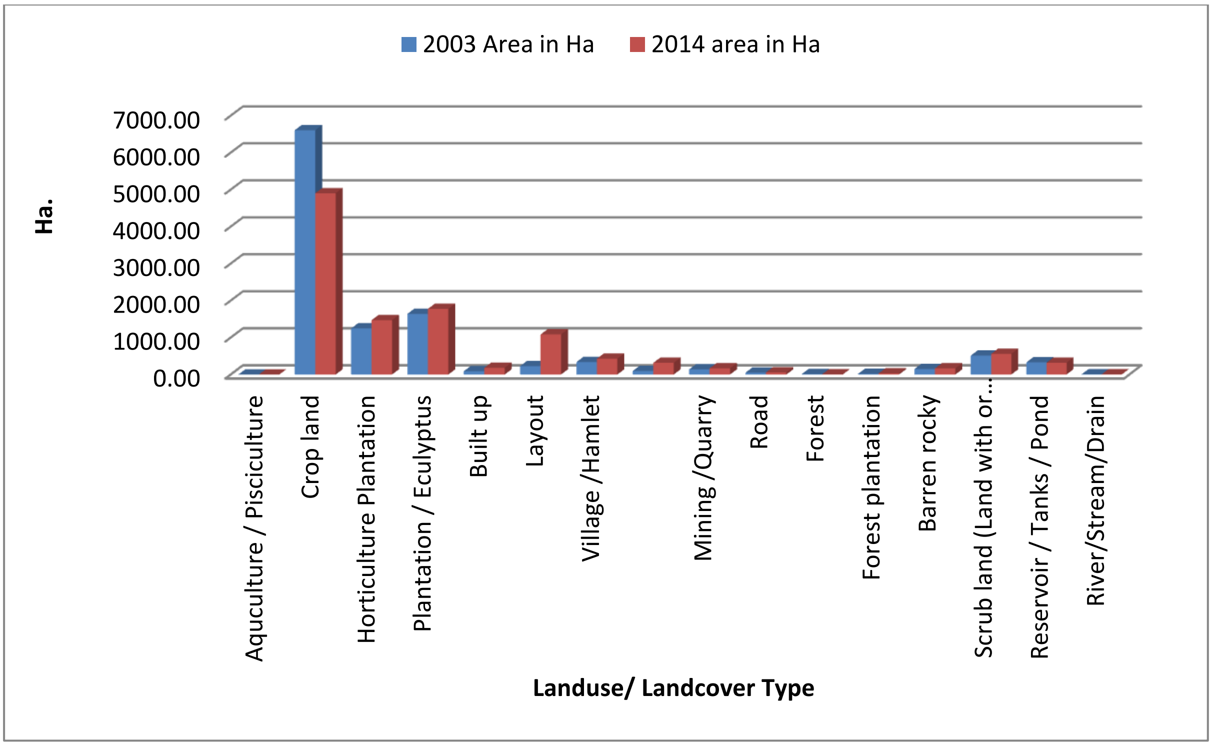


Figure-5.9: Graph showing LU/LC type Zone-4

Table-5.6. Village wise changes in more intensely affected villages in built up area indicating survey numbers where the development is more prominent

Sl. No.	Villages	Built up area (Ha)		Difference (Ha)	Survey No.
		2003	2014		
1	Kadabagere	49.17	178.68	129.51	171,166,165,152,136,173,172, 131,26,35,36,53, 54, 49,79,80,97,90
2	J.I.Heggadadevanapura	26.76	111.30	84.54	51,53,62,63,64,75,72,71,66,45, 67,4, 80,11,8
3	Huralichikkanahalli	22.76	94.17	71.41	117,118,68,57,52,73,71
4	Bylkonehalli	2.96	71.50	68.54	16,15,42,43,41,5,145,23,51,50, 16
5	Madhanayakanahalli	93.45	145.74	52.29	6,12,26,67,30,70,29,71,73,23, 22,34
6	Dasanapura	40.90	83.59	42.69	71,72,78,88,94,106,112,130, 139,100, 101,95
7	K.G.Kurubarahalli	3.44	44.41	40.97	26,52,51,49,48,29,40,47,45,44, 35,38, 37,23,43,42,39,40,61,9, 10,63
8	Dombarahalli	27.59	67.01	39.42	24,25,15,27,2,8,6
9	Madhavara	30.17	63.41	33.24	27,28,30,34,23,108,102,105,79, 80,74,81,83, 123,76
10	Makali	44.27	69.70	25.43	13,11,14,10,6,3,4,5
11	Tharabanahalli	19.19	44.18	24.99	54,56,55,32,2,3,58,59,15
12	Adikemaranahalli	47.59	66.51	18.92	4,6,5,8,14,15,16,3,30,27,16,37
13	Bilijaji	6.26	23.96	17.70	29,33,28,19,11,3,12,36,15
14	Honniganahatti	5.09	15.91	10.82	36,3,4,5,16,8,67,6,5
15	Naganahalli	5.17	15.91	10.74	26,55,45,54,29,35,33,32,49,48, 2,24,43
16	Shiddanahosahalli	35.42	42.95	7.53	32,5,29,16,33,19,4,6, 10
17	Tavarekere	7.67	13.53	5.86	167,15,178,182,97,98,76,75,68, 67,63,65,59,52,48,41,44,53,20, 184,108,123, 45
18	K.G.Hanumanthasagara	4.79	9.20	4.41	13,12,18
19	Channenahalli	3.19	6.84	3.66	51,41
20	Dasenahalli	10.96	13.08	2.12	4,5,36,10
21	J.I.Ivarakondapura	33.74	35.59	1.85	150,121,116,199,186,180,177, 176,74,73,68,2,1,23,22,20,13,2, 6, 7
22	Gejjagadahalli	21.92	23.29	1.37	-
23	Madhagirihalli	0.59	1.57	0.98	25,21,28,20,24,26

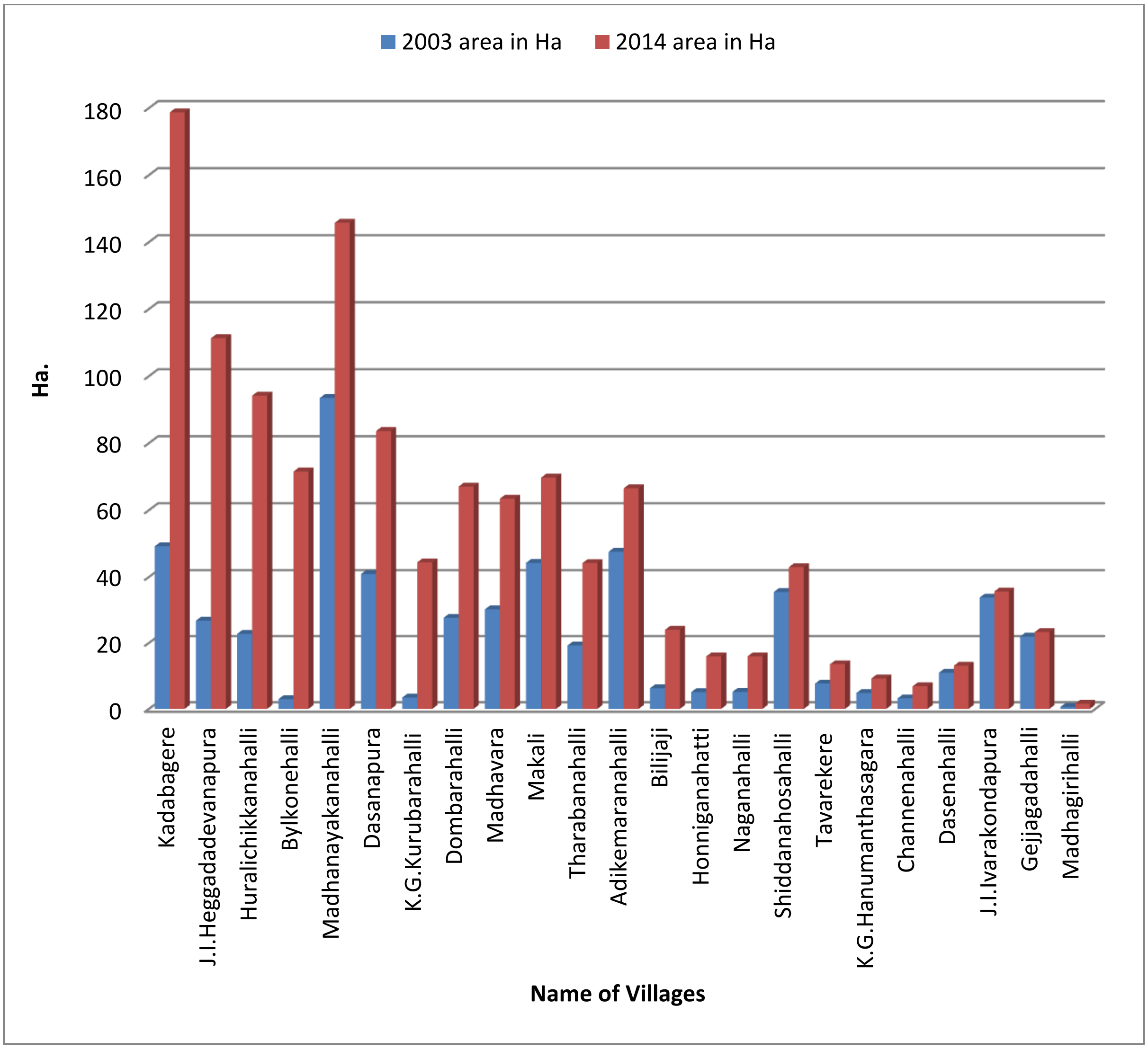


Figure-5.10: Graph showing village wise increase in built up area from 2003 to 2014

The above graph is showing the village wise increase in built up area from 2003 to 2014. It is observed and analysed that Kadabagere village is showing maximum development followed by J.I. Heggadadevanapura and Huralichikkanhalli. Further detailed information about the type of built up area (built up, layout, industrial area, mining/quarry, and village/hamlet) for all the 23 villages (tables and maps) are given in Annexure-5.2 and Annexure-5.3 (Village maps are given in A_3 size).

It is submitted that on the basis of remote sensing analysis with LISS IV imagery of resolution 5.8 m, it is only possible to indicate the survey numbers wherein more area has come under built-up or layout. However it is not possible to provide the exact nature of such superstructures and the purpose for which it is being currently used. However a detailed survey of the superstructures that are under litigation in various writ petitions has been carried out and covered in chapter 6. From the field observations of writ petitions, it is clear that most of the superstructures are being used for the residential purpose/ godown for storage/ commercial purpose or in few uses for industries.

To give a visual understanding of the developments, Google imageries of 2004 and 2014 were also used to identify major changes in landuse particularly increased activities in developing layouts, formation of new godowns, expansion of settlements etc. The maps are indicative and should be used only for visualization. Fifteen villages which have significant changes were selected from Arkavathi river stretch and four from Kumudvathi river stretch. Delineation of all the superstructures and changes in the area are done using Google map of 2004 and 2014 (detailed maps are attached as Annexure-5.4 for Arkavathi river stretch villages and Annexure-5.5 for Kumudvathi river stretch villages). From the analysis it is inferred that the maximum development has taken place in these areas in the form of new godowns, layout formation, expansion of road and expansion of settlements. Maximum development in superstructures and infrastructures are observed in the vicinity of NH-4, NH-48 (Figure-5.11). As compared to Kumudvathi river stretch, Arkavathi river surrounding is much more disturbed due to development of superstructures, layouts, etc. As it is near to Bangalore city and the Peenya Industrial area, more development has occurred along Arkavathi river area.

5.5.6. Encroachment of Tanks

The effect of urbanization has also taken a toll on the tanks in the TGR area. Developmental activities have caused conversion of water bodies to godowns, industries and layout formation. Some of these encroachments were observed during field visits and also compared with available satellite imageries. The details of the identified encroachments have been enclosed as Annexure-5.6. These encroachments should be verified by revenue Authorities and Tank Development Authority by conducting detailed survey.

5.5.7. Drainages affected in TGR catchment

An effort has also been made to identify the changes in drainage pattern in the last 11 years (2000 and 2011) from the available data. Change in drainage pattern analysis was done by using available data of 2000 and 2011 from KSRSAC and 2009 from Nelamangala Planning Authority (NPA). It is inferred that, around 80 primary drainages have disappeared, dried up and encroached due to several developmental activities and also for agricultural purposes. The drainages present in Bangalore North taluk are mostly affected. The change analysis is done purely based on the available data that needs to be further verified in field. The same is enclosed as Annexure-5.7.

5.5.8. Main roads and Rail network:

The map (Figure-5.11) shows the rail and main roads passing through the TGR catchment area. There are two main rails passing through the area. NH4 is also passing through Zone-1, Zone-3 and Zone-4. NH48 is passing through Zones-1, 3 and 4. NH207 is passing through Zones-1, 3 and 4. Apart from this many State Highways (SH) are passing through the area. Only few main SH are shown in the map (Figure-5.11).

5.5.9. Waterspread area of Thippagondanahalli and Hesaraghatta

The waterspread area is delineated by using visual interpretation technique and LISS-IV imageries of 2003 and 2014. The waterspread area covered in 2003 was 166.47 ha and in 2014 it is 183.89 ha (Figure-5.12 and 5.13). There is a slight difference of i.e.17.42 ha change in the waterspread area. The waterspread area is increased slightly in 2014 as compared to 2003.

The waterspread area for Hesaraghatta was 13.83 ha in 2003 and it is 66.14 ha in 2014 (Figure-5.14 and5.15). From the above observation it is inferred that the waterspread area for Hesaraghatta has increased significantly i.e. 52.37 ha.

The waterspread area calculation for TG Halli reservoir and Hesaraghatta given by KSRSAC is only one season data which needs to be confirmed if all the other season data are taken into consideration.

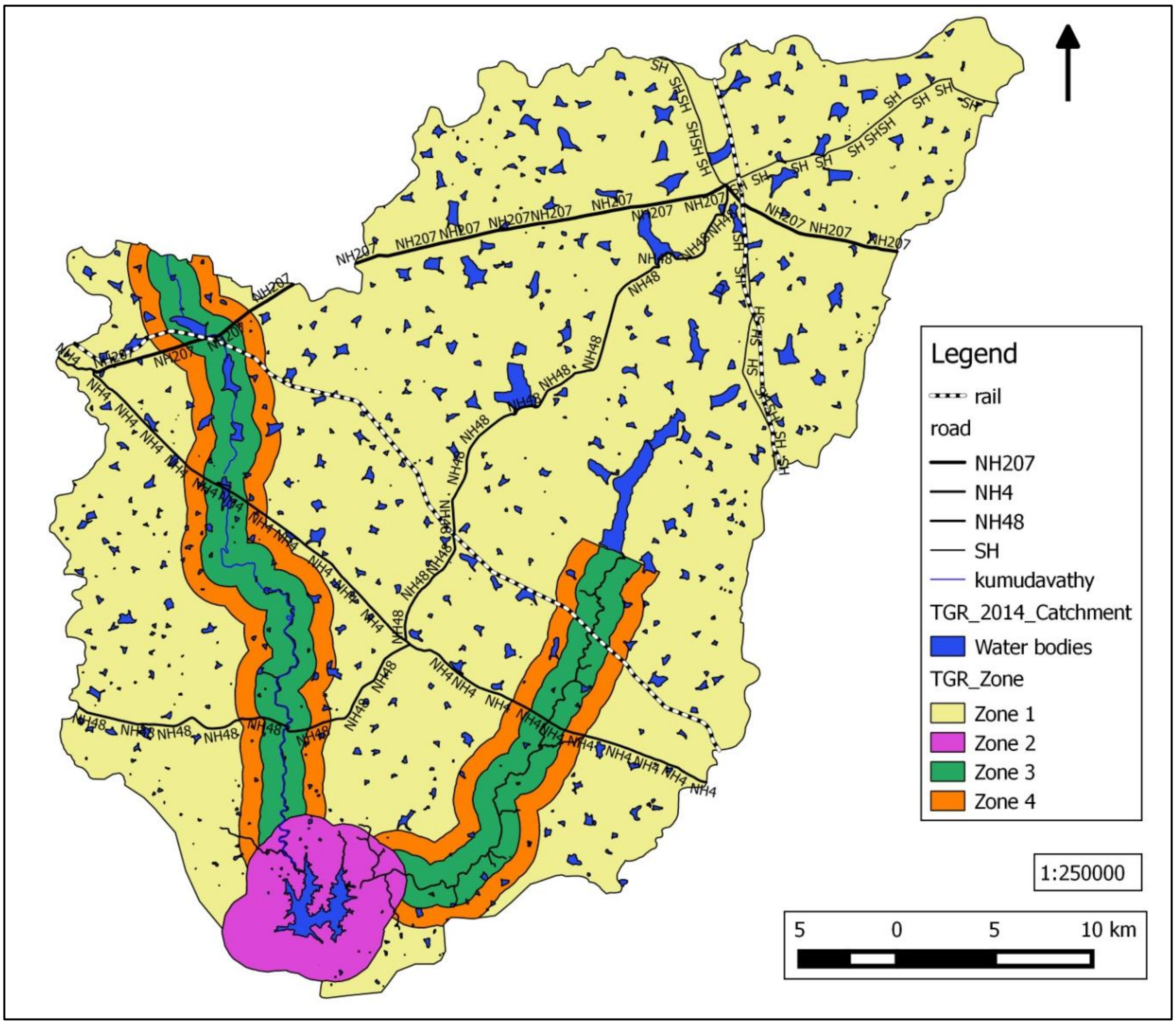


Figure-5.11. Rail and Main Road network of TGR catchment area

5.10. Conclusions:

The following are the general conclusions for the Remote Sensing analysis:

1. Some of the villages particularly in Zone-3 and Zone-4 have undergone remarkable developmental activities in the form of buildings, layouts, godowns etc.
2. Conversion of agricultural area to built-up (settlements/layouts/roads/quarries/storage structures etc.) is significant in zones 1, 3 and 4.
3. Remarkable urbanization has happened, particularly in zone-3 of Arkavathi river stretch in the form of layouts, godowns, houses, commercial buildings, industries etc.

4. A large number of godowns have come up in the area under the Gramin Bhandar Yojana Scheme, particularly in the villages surrounding NH-4 of Arkavathi and Kumudvathi river stretch and NH-48 of Kumudvathi river stretch.

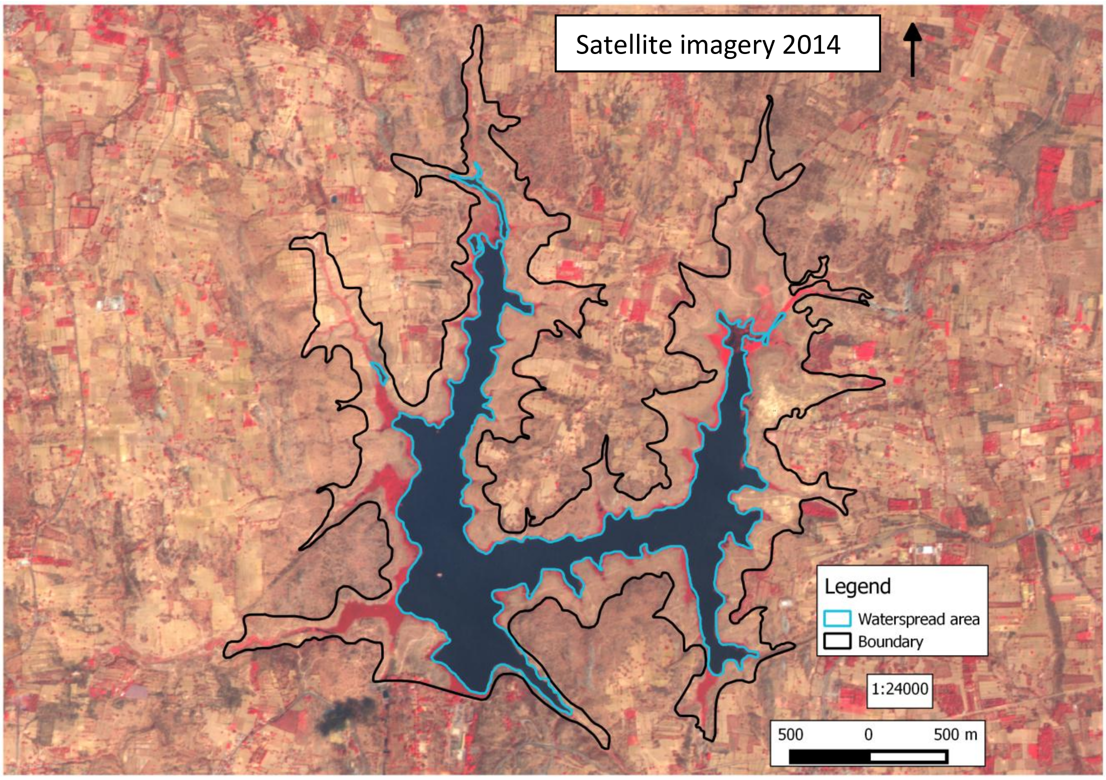


Figure-5.12. TGR waterspread area in 2014

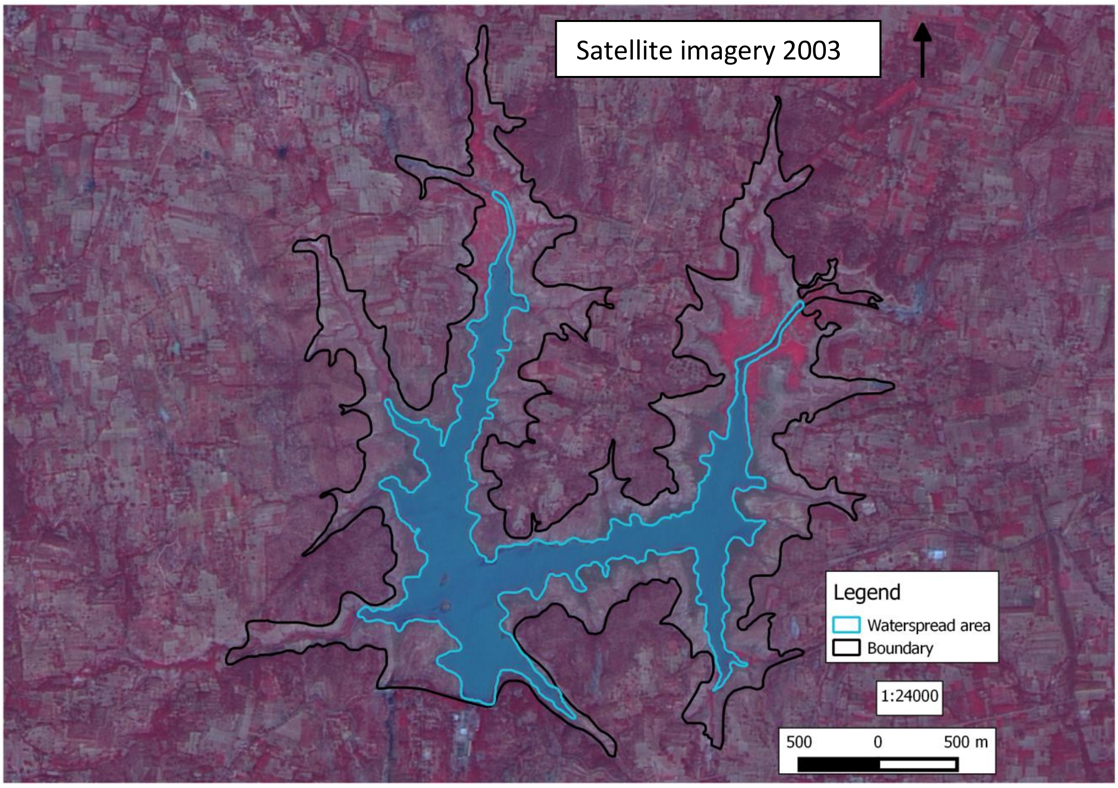


Figure-5.13: TGR waterspread area in 2003

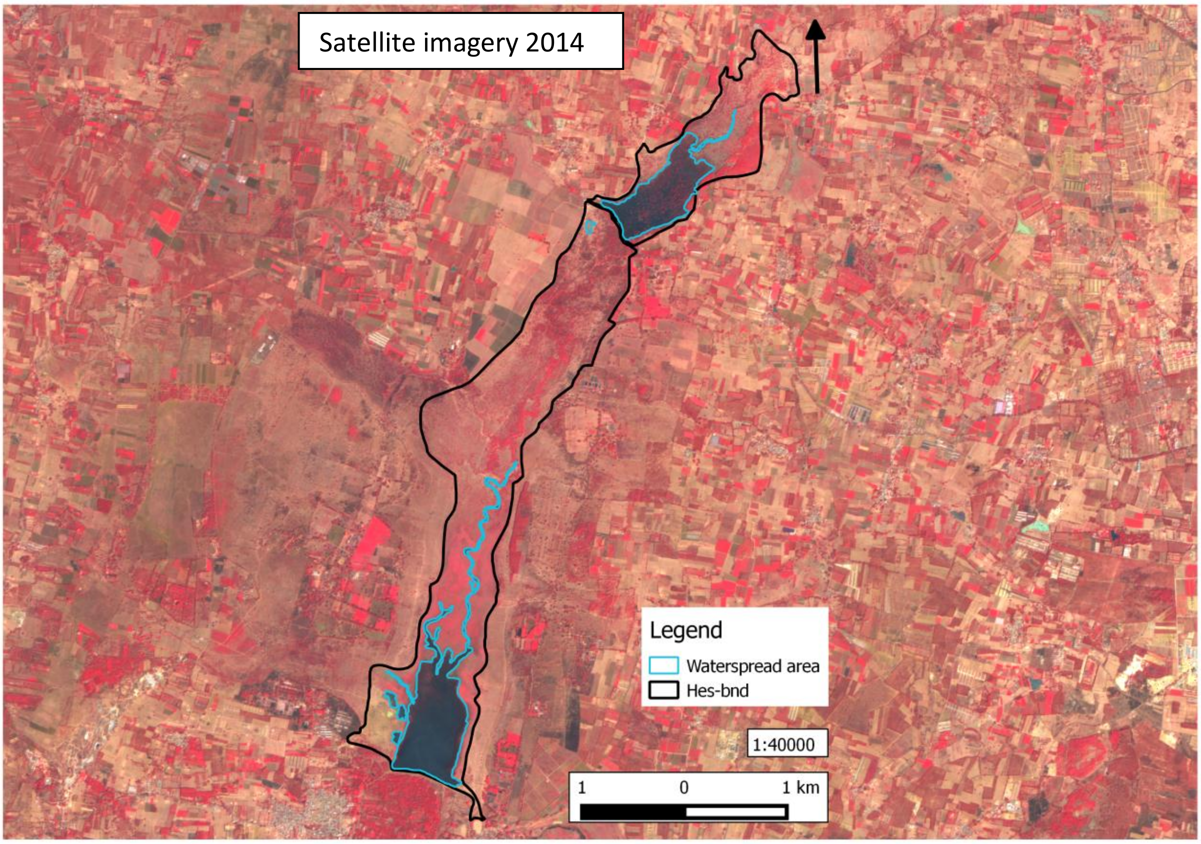


Figure-5.14. Hesaraghatta Reservoir waterspread area in 2014

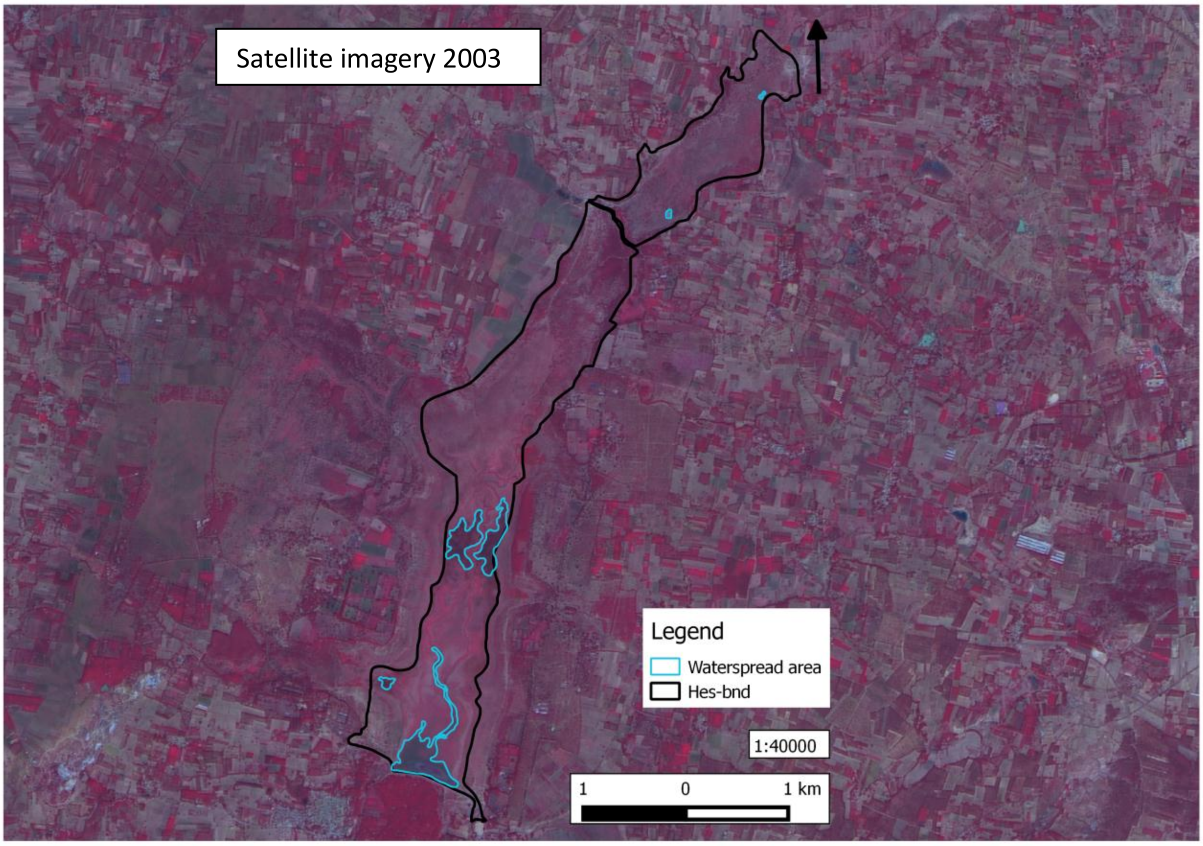


Figure-5.15. Hesaraghatta Reservoir waterspread area in 2003

Chapter-6: Water Yield and Availability

6.1. Introduction:

A river is a natural flowing watercourse, usually freshwater, flowing towards an ocean, a lake, a sea, or another river. In some rare cases a river could flow into the ground and dry up completely at the end of its course, without reaching another waterbody. A river begins at a source (or more often several sources) and ends at a mouth, following a path called a course. The water in a river is usually confined to a channel, made up of a stream bed between banks. Throughout the course of the river, the total volume of water transported downstream will often be a combination of the free water flow together with a substantial volume flowing through sub-surface rocks and gravels that underlie the river and its floodplain (hyporheic zone). Two major river systems in India are grouped according to the origin such as Himalayan and Peninsular rivers. The Peninsular rivers are draining its water into the Bay of Bengal and Arabian Sea. Peninsular rivers in India have relatively steep gradients and thus rarely rise to floods of the type, despite considerable variations in flow from the dry to wet seasons. The lower courses of these rivers are marked by rapids and gorges, because of their steep gradients, rocky underlying terrain, and variable flow regimes, the peninsular rivers are not navigable. The Arkavathi and Kumudvathi rivers drain into Cauvery river, which drain in to the Bay of Bengal.

Further based on the permanence of water flow, the rivers are classified as permanent river and intermittent river. Intermittent river (ephemeral river) flows occasionally and can be dry for several years at a time. These rivers are found in regions with limited or highly variable rainfall, or can occur because of geologic conditions such as a highly permeable river bed. Kumudvathi river is one of the ephemeral rivers, which flows during the monsoon season. Water supply to the irrigation area and to the residential houses depends primarily on the availability of the water at its source. Availability may vary a lot over the years, or even between one year and another. Supply depends on the capacity of the facility installed to withdraw the water from the water source. Thus it is important to know how much water can be tapped from a water source over the course of a season or a year. The flow of river fluctuates over time, some rivers fluctuate greatly over relatively short periods of time; these are mainly small local rivers which respond quickly to rainfall in their catchment area. Large rivers show little fluctuation or vary only over a long period of time, mainly rivers with a large catchment area, where the rains are spread over a greater area and for a longer period of time. River flows vary considerably, not only within a given year, but also from one year to the next. In a year with little rain during the rainy season, the river flow will be small; sometimes the river flow will cease altogether during the dry season. The river flow will be far more in years with heavy rainfall during the wet season.

Water availability in reservoir depends on the river discharge (depends on rainfall), height of the dam and the location area of the reservoir. A dam built in a valley will block the river or stream and water can then be stored behind it, which is also called as on-stream storage. Water is also stored off-stream by diverting the flow into a natural depression or dead river branch alongside the river, or by constructing a storage reservoir. Availability of groundwater is less irregular than that of small rivers. Aquifers at shallow depths are likely to be very thin with a limited storage capacity for groundwater. So the water pumping during the rainy season is easier, after the aquifer has been replenished. The aquifers dry up after a few months. The total water availability from shallow groundwater is determined by the number of wells and the capacity of these wells, or by the capacity of the pumps installed, whichever is smaller. To ensure a stable supply of groundwater, the rate of use should not exceed the rate of recharge.

6.2. Methodology:

In this study, the water yield in TGR was estimated based on the secondary data collected from the BWSSB and the yield is correlated with the rainfall data procured from the Karnataka State Natural Disaster Monitoring Centre (KSNDMC). Groundwater level data for the TGR catchment area were collected from the DMG groundwater monitoring cell. Water spread area in the TGR during the month of December'2014 is mapped with the help of GPS tracking system. Since the information about Arkavathi and Kumudvathi could not be obtained from any Government Agency, it is not possible to provide data on the yield or availability of water in these two rivers separately. For the purpose, Central Water Commission, State Water Resources Department, Cauvery Neeravari Nigam Limited were contacted. For visualization of the stretches in which water is presently available, the present water availability has been mapped and super-imposed on imagery.

6.3. TGR Water Yield:

Water yield by TGR is highly dependent on the water availability and water flow in the Arkavathi and Kumudvathi rivers. Since the flow and availability of river water has been steadily declining, the inflow to TGR has also reduced as per BWSSB data. Presently, the TGR is still receiving some inflow mainly from Arkavathi river (sewage water) and from Kumudvathi during monsoon season (Figure-6.1). TGR received the maximum inflow as 23059.89 MCFT in 1964 (Figure-6.2). The last 30 years (1984-2014) TGR inflow data showed that 1368.71 MCFT was on an average flowing to the TGR, whereas 4655.08 MCFT of maximum water was recorded as inflow during the year 1988 and 9.91 MCFT during the year 2012 as minimum water inflow to TGR (BWSSB data).

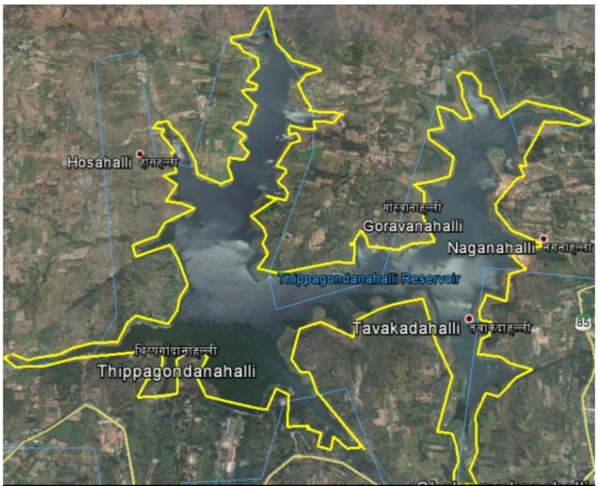


Figure-6.1: Water spread area in TGR in December'2014

Meanwhile the rainfall data in the TGR catchment area showed that there was heavy rainfall (1287.73 mm) during the year 1975. Previous 30 years (1984-2014) rainfall data showed that the average of 848.5mm rainfall was documented in the TGR catchment area, with the maximum of 1218.32 mm and minimum of 504.33 mm rainfall during the year 1991 and 1985 respectively. The correlation between the TGR catchment area rainfall and the inflow water in TGR showed that the water inflow to TGR was reduced even though there was no major change in the rainfall received in TGR catchment area. Thus the correlation between the rainfall and the water inflow revealed that the rainfall runoff generated in the TGR catchment area was not reaching the TGR, which may be due to the change of land use pattern, encroachment on the 2nd and 3rd order drains, diversion of drains by the unplanned developments, etc. As the sluice gate of TGR has failed to stop the flow of water to Manchanbele Dam, the water storage capacity of TGR was less even during the monsoon season also.

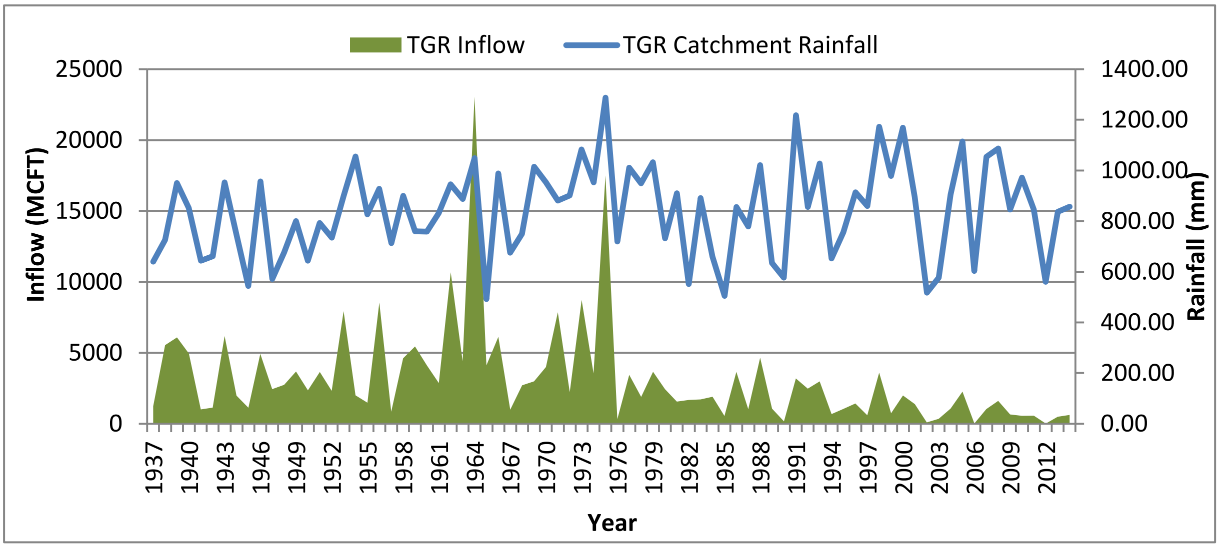


Figure-6.2: Water inflow in TGR and Rainfall in the TGR catchment area (Source: BWSSB)

6.4. Availability of water in rivers of TGR catchment area:

The flow and the availability of water for Arkavathi and Kumudvathi rivers have not been maintained by the concerned Authorities. Further, the Cauvery Neeravari Nigam Limited (CNNL) and Central Water Commission have also informed that there was no data on the availability of water in the Arkavathi and Kumudvathi rivers. But based on the ground verification by the EMPRI team, the present water availability in Arkavathi and Kumudvathi rivers have been recorded. However there is no exact record or estimation of the river flow.

6.4.1. Arkavathi River:

Irrigation is a major use of water in the Arkavathi sub-basin; particularly in rural areas. Agriculture remains the main stay of rural livelihoods in the Arkavathi sub-basin. Presently, the lands under the agriculture and plantations are dependent on groundwater as the primary source in most areas. Some areas of Doddaballapur taluk have a large number of minor irrigation tanks. There were no studies on peri-urban agriculture in Arkavathi sub-basin, so the water 'scarcity' in this sub-basin was not estimated. In the northern Arkavathi sub-basin, many irrigation tanks have dried up and the groundwater table has dropped below 500 ft. in places. People reported a shift towards urban land uses and plantation crops – driven partly by water scarcity and partly by industrialisation, urbanisation, poor labour availability, etc. In the southern portion of the sub-basin (Downstream of TGR), water is more plentiful but much of it is of poor quality, as it comes from the polluted Vrishabhavathy river. The land under agriculture is decreasing; cropping patterns are intensifying and shifting from cereals to cash crops through the drip irrigation.

Figure-6.3: Dry Arkavathi River shown within circle

Arkavathi river was the first river identified as the large water source for the Bangalore City, which flows to Hesaraghatta reservoir. After the Hesaraghatta reservoir, the Arkavathi river flows for about 33km in the southwest direction to the TGR located in the downstream of Hesaraghatta reservoir. During recent times, there has been no outflow downstream from the Hesaraghatta reservoir. Mostly the flow of Arkavathi river from downstream of Hesaraghatta reservoir is high only in monsoon season due to rainfall runoff and during summer, the river is mostly dry, but there is inflow of polluted water i.e. sewage from village settlements and layouts, greywater from warehouses and effluents from industries. Arkavathi river course is dry and stagnant in few places and receives flow of sewage in most places (Figure-6.3). In the following paragraphs, the condition of the Arkavathi river is explained in detail.

6.4.1a. Dry Stretches of the River:

Only excess rainfall flows from the Hesaraghatta reservoir sub-catchment area to the TGR, but due to uneven distribution of rainfall in the catchment, the flow of water has reduced drastically over the years. Arkavathi river is dry in the 5.6 km stretch, downstream of Hesaraghatta reservoir until the Tarabanahalli village and further down of South, about 2.65km until Alur village. Further down, about 2.12km till Heggadevanapura village, the river is dry with dense growth of weeds. About 10.37 km river stretch is dry in 2015 summer season. The conversion of agricultural lands for unplanned layouts has put impediments to the flow of rainfall runoff by diverting the drain or encroachment.

6.4.1b. Stagnant Stretches of the River:

Blotches of stagnant muddy water in the river course of Tarabanahalli and Heggadevanapura villages are documented. The inflows of sewage to river from Madanayakanahalli village godowns have increased the growth of water hyacinth and duck weed in the stagnant water. Fishing in one of the stream confluencing with the Arkavathi river in Byandahalli (Figure-6.4) and Kittanahalli villages are documented during the ground verification.

6.4.1c. Sewage flow in the River:

Figure-6.4: Fishing in stream of Arkavathi River off Byandahalli village

Sewage joins the Arkavathi river from the village settlements. As the catchment area is the mixture of urban, sub-urban and peri-urban region, the untreated sewerage is diverted to the Arkavathi river. Under Ground Drainage (UGD) manhole of Alur village that was broken to clear the blocks of UGD has resulted in the flow of sewage into Arkavathi river. Makli and Madanayakanahalli village settlements sewage are directly let into the river. Additionally, greywater from Madanayakanahalli village godowns such as wastewater generated from bathrooms and floor washing, etc. are entering the 2.6 km river stretch. Wastewater from slaughter houses and dying units, and sewage from the Madavara, Jinnamabanagar and Siddanahosahalli villages flow to the Arkavathi river through the 2nd order stream in Siddanahosahalli village. In Bettahalli village, the 2nd order stream flow to Arkavathi river is carrying the wastewater generated through the cloth washing and also algae. Granite and quarry slurry from Gattisiddanahalli village directly flow to the Arkavathi river. Untreated sewage flow starting from Alur village is further joined by sewage inflow from the subsequent villages such as Makli, Madanayakanahalli, Siddanahosahalli, Bettahalli, Gattisiddanahalli and completes its 19.3 km travel by entering the TGR at Kanuvanahalli village.

Streams and rivers provide habitat for aquatic organisms, and if they dry up or get polluted, this habitat gets adversely affected. From that perspective, the biodiversity in the Arkavathi river has declined sharply. The diluted sewage in TGR is leaked through the sluice gate and flows to the Manchanabele dam, where the water is used by Magadi town people. Sewage water in the Arkavathi river is pumped for the irrigation purposes in Gowdahalli (Figure-6.5) and Kammasandra villages of Zone-3 and 4 for growing of banana, maize, coconut, chilli plants etc.

Figure-6.5: Sewage of Arkavathi River was pumped for irrigation purpose in Gowdahalli village

There was no flow of water in the Arkavathi river course in the Zone-1 from the foothills of Nandi hills (Chikkarayappanahalli village) to Hesaraghatta reservoir located in the Hesaraghatta sub-catchment area. As the Arkavathi river course in the Zone-1 is linked with the major waterbodies, these waterbodies are not able to overflow for last 10 years to generate the flow in the Arkavathi river, which resulted in the dry river bed. Water is available only in the few major waterbodies located in the Arkavathi river course are tabulated in the Table-6.1. Further the water stored in the major waterbodies was also muddy and polluted due to open defecation and dumping of solid wastes.

Table-6.1: Major waterbodies located in the Arkavathi river course of Hesaraghatta sub-catchment area

Location	GPS Location		Observations
	Latitude	Longitude	
Chikkarayappanahalli kere	13°22′53.1″	77°38′48.4″	Muddy water with fishing activity located at foothill of Nandi hills
Doddarayappana kere	13°22′11.2″	77°38′21.4″	Less water located in Doddarayappanahalli village
Malekote kere	13°21′21.7″	77°37′29.1″	Water distributed in patches with weeds
Karehalli kere	13°19′04.2″	77°41′41.4″	Less muddy water
Doddaballapura kere	13°18′06.7″	77°32′37.3″	Water availability is less
Doddatumakur kere	13°13′35.2″	77°31′43.2″	Patches of muddy water
Haniyuru kere	13°12′56.2″	77°30′56.5″	Less water distributed in patches
Madhure kere	13°12′26.0″	77°26′27.3″	Muddy Water available
Kakolu kere	13°11′27.9″	77°30′18.7″	Less water available

6.4.1.1. Hesaraghatta Reservoir:

Figure-6.6: Hesaraghatta Reservoir water spread area during December'2014

The total area of Hesaraghatta reservoir is about 744 ha (1912 acres) and the water spread area in August 2009 was about 400 ha (980 acres) as per BWSSB data. Presently, the water availability in Hesaraghatta reservoir is relatively better with the 10.6Kms of shore length as per the GPS tracking (Figure-6.6), but the water is not used for any purpose. Due to the Hesaraghatta reservoir, the groundwater availability is good and the Hesaraghatta village people use the groundwater through bore-wells near the reservoir for their domestic purposes.

6.4.2. Kumudhavathi River:

It was observed that some stretches of Kumudvathi river has stagnant water (Figure-6.7). This has been recorded in the villages of Basavenahalli, Magadi taluk and Doddakarenahalli, Kodihalli, Tippadabegur, Dodderi and Chikkamaranahalli of Nelamangala taluk. Approximately, 108m river stretch in Chikkamaranahalli, 805m river stretch in Doddakarenahalli and 663m river stretch from Lingenahalli to Basavenahalli villages. Along the river stretch, Doddabegur Kere of Zone-1, Bidluru Kere and Chikkannane Kere near Dodderi village of zone-3 are moderately filled with water. Kumudvathi river was having only stagnant water for approximately 1.58Km river stretch out of 48Km. During the field verification, water scarcity was seen in the Kumudvathi surrounding villages and parts of Doddaballapur taluk were observed.

6.5. Groundwater Scenario:

Different public agencies supply water to different settlements in the Arkavathi sub-catchment area. BWSSB is the biggest supplier, but it is also the least dependent on local sources. The four big Class-II towns located in the Arkavathi sub-basin have water supply systems managed by the town municipality and/or the Karnataka Urban Water Supply and Drainage Board (KUWS&DB) depending on a range of sources for bulk water. Kanakapura town draws its bulk water from BWSSB's Cauvery pipeline and operates only the distribution system. Ramanagara, Doddaballapur and Nelamangala are the other three towns that treat and distribute their own water, sourced mostly from municipal bore-wells.

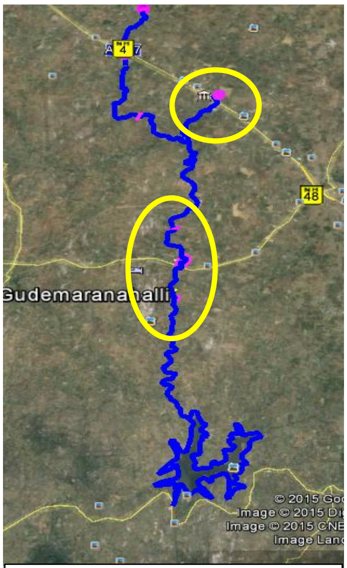


Figure-6.7: Water availability in Kumudvathi River

The municipal bore-wells have to depend on the availability of electricity in order to pump water to overhead storage tanks, chlorinate and delivere to users. Additionally, Ramanagara gets a portion of its supply by treating and using the backwash water from Torekadanahalli treatment plant, which treats Cauvery water for Bengaluru supply. Finally, a small quantity of water is exported out of the Arkavathi sub-basin by supplying from Manchanabele reservoir (further downstream of the Arkavathi river) to Magadi town (lies just outside the western boundary of the sub-basin). Further, the commercial and industrial water users in the Arkavathi sub-basin area are completely dependent on groundwater either by their own bore-wells or purchased from private groundwater supplier. There is no formal and systematic monitoring of ground water extraction in the sub-basin areas, so the density of wells and electricity consumption for pumping has increased over the year (Lele *et al.*, 2013). Further, the groundwater exploitation is occurring at unsustainable rates (DMG, 2011). The village community of Doddatumkuru village off Doddaballapur road (Zone-1) found that the groundwater levels were decreasing, so they voluntarily terminate the private water connections and instead set up common pipes in the village centre.

Groundwater level data collected from the DMG has been segregated under the Arkavathi and Kumudvathi sub-catchment area. Adikemaranahalli, Chikkabanavara, Sondekoppa, Thaverekere, Thotagere, Nelamangala and Rajankunte are the seven villages considered for the Arkavathi sub-catchment groundwater level study (Figure-6.8). Adikemaranahalli village is located in the Zone-3 and 4 of the Arkavathi river course and all other six villages are located in the Zone-1. The results showed that the depth of groundwater level is increasing year-by-year. As per the data, all the villages have average fluctuation in groundwater level from 21m to 49m, only Sondekoppa village has less fluctuation as 13.08m as on 2014.

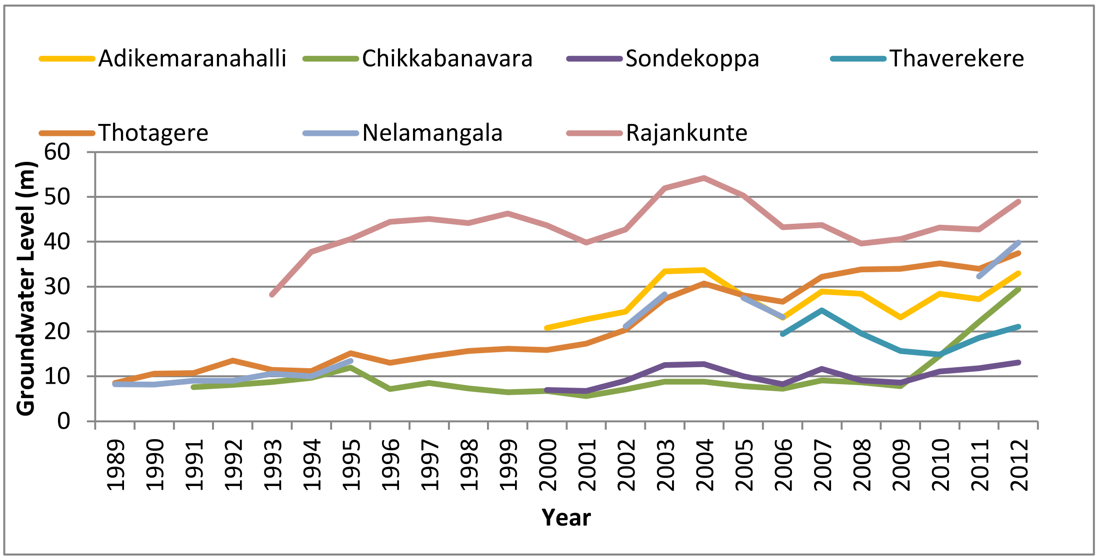


Figure-6.8: Groundwater level fluctuations in Arkavathi River Course (Source: DMG)

Thyamagondlu, Mahadevapura, Marenahalli and Thonachanakuppe are the four villages considered for the Kumudvathi sub-catchment groundwater level fluctuation study (Figure-6.9). Within the villages, only Thyamagondlu village is located in zone-3, whereas other three villages are located in the zone-4 of the Kumudvathi river course. The results showed that there was no data after 1995 for Thonachanakuppe village, Marenahalli village have data only from the year 2000. As the Thyamagondlu and Mahadevapura villages are located near the Kumudvathi river, the water level fluctuation were 9 and 12m respectively.

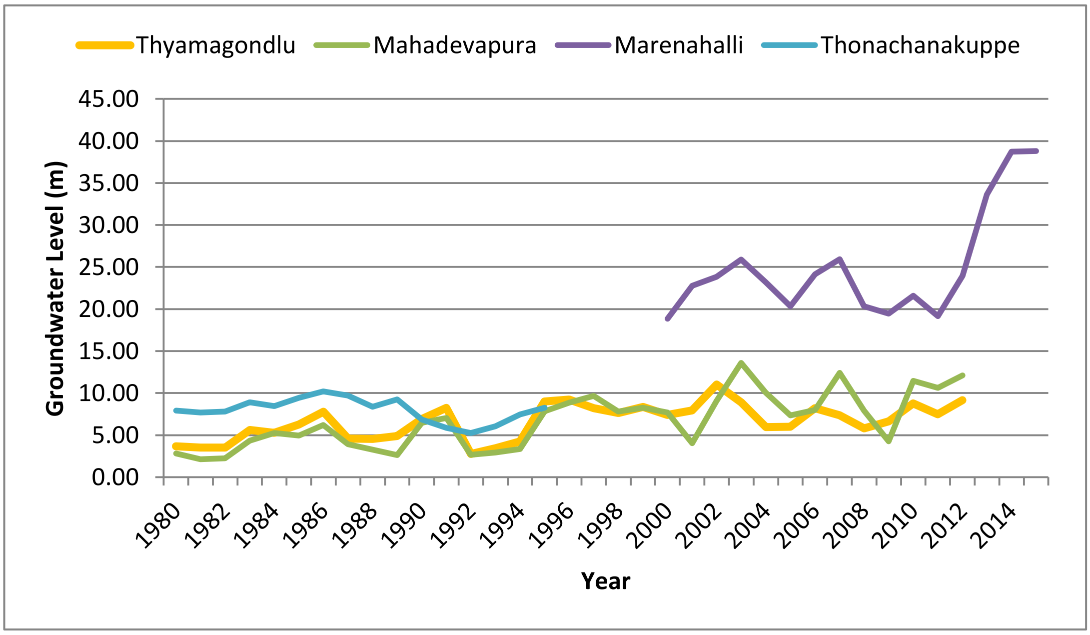


Figure-6.9: Groundwater level fluctuations in Kumudvathi River Course (Source: DMG)

6.6. Reasons for the Water Depletion:

Water yield and availability in the Arkavathi and Kumudvathi rivers is found to be depleting year-by-year for the following reasons, such as

1. Encroachment of waterbodies and their streams
2. The blockage of drains due to the land use pattern change, particularly the encroachment of 2nd and 3rd order drains of rivers. Encroachments due to extension of settlements and the emerging industries in the river catchment zone have resulted in increased anthropogenic activities which have caused decline in surface water as well as ground water in the region.
3. Traditional water intensive agriculture practice followed by the TGR catchment area village farmers.
4. Over-exploitation of groundwater for domestic and agricultural purpose.
5. Lack of maintenance of the tanks system has resulted in lack of water availability in the tanks.
6. Extensive sand mining and soil excavation in the river bed.
7. Eucalyptus cultivation was actively promoted among farmers by the state government under its farm forestry programme in the 1980s (Shiva *et al.*, 1981). This might have affected the groundwater level.

The water depletion and pollution of the Arkavathi and Kumudvathi rivers pose greater challenge to the Authorities. Both these issues have large social and health impacts on the people residing in the TGR catchment area as well as to the supply and potable water to Bangalore city and Magadi town. The water quality deterioration in the TGR catchment area is elaborately discussed in the following chapter.

Chapter-7: Water Quality Deterioration and Reasons for Pollution

7.1. Introduction:

As the demand for water increases in line with human population pressure and economic development activities, river ecosystems will continue to deteriorate unless they are managed in a sustainable way. The problem related to water quantity (occurrence of extremely low flows) is governed by both natural events (drought) and human-induced factors (large upstream freshwater withdrawals). High levels of water withdrawal or loss from upstream river sections or tributaries can considerably affect the water quality of downstream river reaches. In turn, reduced flows can cause accelerated sedimentation and increases Total Dissolved Solids (TDS) concentrations in downstream reaches of the river (Qader, 1998; Mokhlesur *et al.*, 2000).

Water quality can be defined by a range of variables which limit water use. Although many uses have some common requirements for certain variables, each use will have its own demands and influences on water quality. Quantity and quality demands of different users will not always be compatible, and the activities of one user may restrict the activities of another, either by demanding water of a quality outside the range required by the other user or by lowering quality during use of the water. Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource. The natural ecosystem is in harmony with natural water quality, any significant changes to water quality will usually be disruptive to the ecosystem. The effects of human activities on water quality are widespread and varied in the degree to which they disrupt the ecosystem and/or restrict water use. Faecal pollution may occur where there are no community facilities for waste disposal, collection and treatment facilities are inadequate or improperly operated, or when on-site sanitation facilities drain directly into aquifers. The effects of faecal pollution vary. Eutrophication results not only from point sources, such as wastewater discharges with high nutrient loads, but also from diffuse sources such as run-off from livestock feedlots or agricultural land fertilised with organic and inorganic fertilisers.

The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic materials present in the water, together with certain physical characteristics of the water. It is determined by *in situ* measurements and by examination of water samples on site or in the laboratory. The results of analyses performed on a single water sample are only valid for the particular location and time at which that sample was taken. One purpose of the monitoring programme is to gather sufficient data by means of regular or intensive sampling and analysis to assess spatial and/or temporal variations in water quality.

Water quality deterioration in reservoirs usually comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing practices. The effects of these "imports" into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring loss of structural biodiversity of the reservoir. The use of the physico-chemical properties of water to assess water quality gives a good impression of the status, productivity and sustainability of water body. The changes in physical characteristics like temperature, transparency and chemical elements of water such as dissolved oxygen, chemical oxygen demand, nitrate and phosphate provide valuable information on the quality of the water, the source(s) of the variations and their impacts on the functions and biodiversity of the reservoir. Kimmel and Groeger (1984) found that the water quality will change as per the longitudinal zonation in the reservoir due to the dilution of chemicals in vast water stored near the dam (Figure-7.1). Water quality is determined by the physical and chemical limnology of a reservoir (Sidnei *et al.*, 1992) and includes all physical, chemical and biological factors of water that influence the beneficial use of the water. Water quality is important in drinking water supply, irrigation, fish production, recreation and other purposes to which the water must have been impounded.

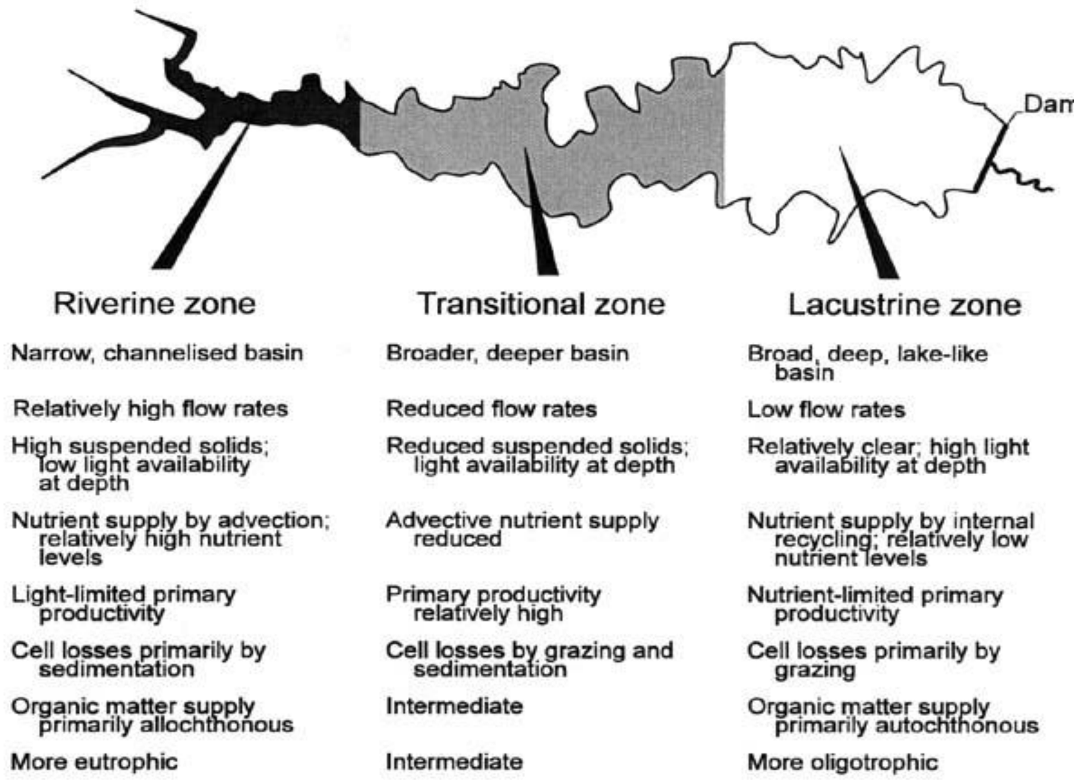


Figure-7.1. Longitudinal Zonation of water quality conditions in Reservoirs

Though the spiritual reverence for rivers remains intact, the physical well-being of the rivers show that community in general have failed in keeping the reverence for rivers. Rapid growth in industrialization to support the country's growing population and economy has polluted the rivers like never before. Earlier studies showed that the domestic and industrial sewage and agricultural wastes have polluted almost all of Indian rivers by turning them into sewage carrying drains. This poses a serious health problem as millions of people continue to depend on the polluted water from the rivers. Water-borne diseases are a common cause of illness in India today. The bad effects of river pollution are not limited to human population only. Pollution of river has affected animal, fish, and bird population, sometimes threatening their very existence. Polluted water seriously affects the reproductive ability of animal and fish species in rivers thus making them extinct in future.

River pollution is increasing day by day. There are several sources of water pollution, which work together to reduce overall river water quality. Industries discharge their liquid wastes into rivers. Agriculture practice that uses chemical fertilizers and pesticides also contribute to river pollution as rainwater drains these chemicals into the rivers. Domestic wastes thrown into rivers add to pollution levels. As population grows, the size of towns and cities also grows and the amount of domestic wastes thrown into river also increases. In most of the towns and cities, the municipal drains carry the wastes to rivers. Pollution of water has emerged as one of the most significant environmental problems of the recent times. Not only there is an increasing concern for rapidly deteriorating supply of water but the quantity of utilizable water is also fast diminishing. The causes of such a situation may be many, but gross pollution of water has its origin mainly in urbanization, industrialization, agriculture and increase in human population observed in past one and a half century.

For any water body to function adequately in satisfying the desired use, it must have corresponding degree of purity. Drinking water should be of highest purity. The concept of management of the quality of water is as important as its quantity. To set the standard for the desired quality of a water body, it is essential to identify the uses of water in that water body. The Central Pollution Control Board (CPCB) has developed a concept of designated best use. According to this, out of the several uses of water of a particular body, the use which demands highest quality is termed its designated best use. Five designated best uses categories have been identified depending on various uses of water based on the tolerance limit of IS: 2296-1992 (Table-8.1) as follow

i. Class-A: Drinking water source without conventional treatment but after disinfection
ii. Class-B: Outdoor bathing
iii. Class-C: Drinking water source with conventional treatment followed by disinfection
iv. Class-D: Fish culture and wild life propagation
v. Class-E: Irrigation, Industrial cooling or controlled waste disposal
vi. Below Class-E: Not meeting any of the A, B, C, D & E criteria

7.2. Methodology:

Water quality data of TGR, Arkavathi and Kumudvathi rivers for the past years were collected from the BWSSB and KSPCB, and the groundwater quality data were collected from the DMG. To identify the present water quality of the TGR, Arkavathi and Kumudvathi rivers, Twenty five sampling points were selected based on the water availability and samples were collected in the 1st week of April'2015. The water samples from Arkavathi river were collected only in the stretch between the Hesaraghatta reservoir and TGR located in Zone-3 (Figure-7.2). Water sampling locations along with the GPS co-ordinates are tabulated in Table-7.2. Water samples for quality analysis were collected from the inlet and outlet points of Hesaraghatta reservoir; three inlet and outlet points of TGR and Arkavathi and Kumudvathi rivers. At least

1km distance has been maintained between the sampling points to study the exact quality of drained water in Arkavathi river.

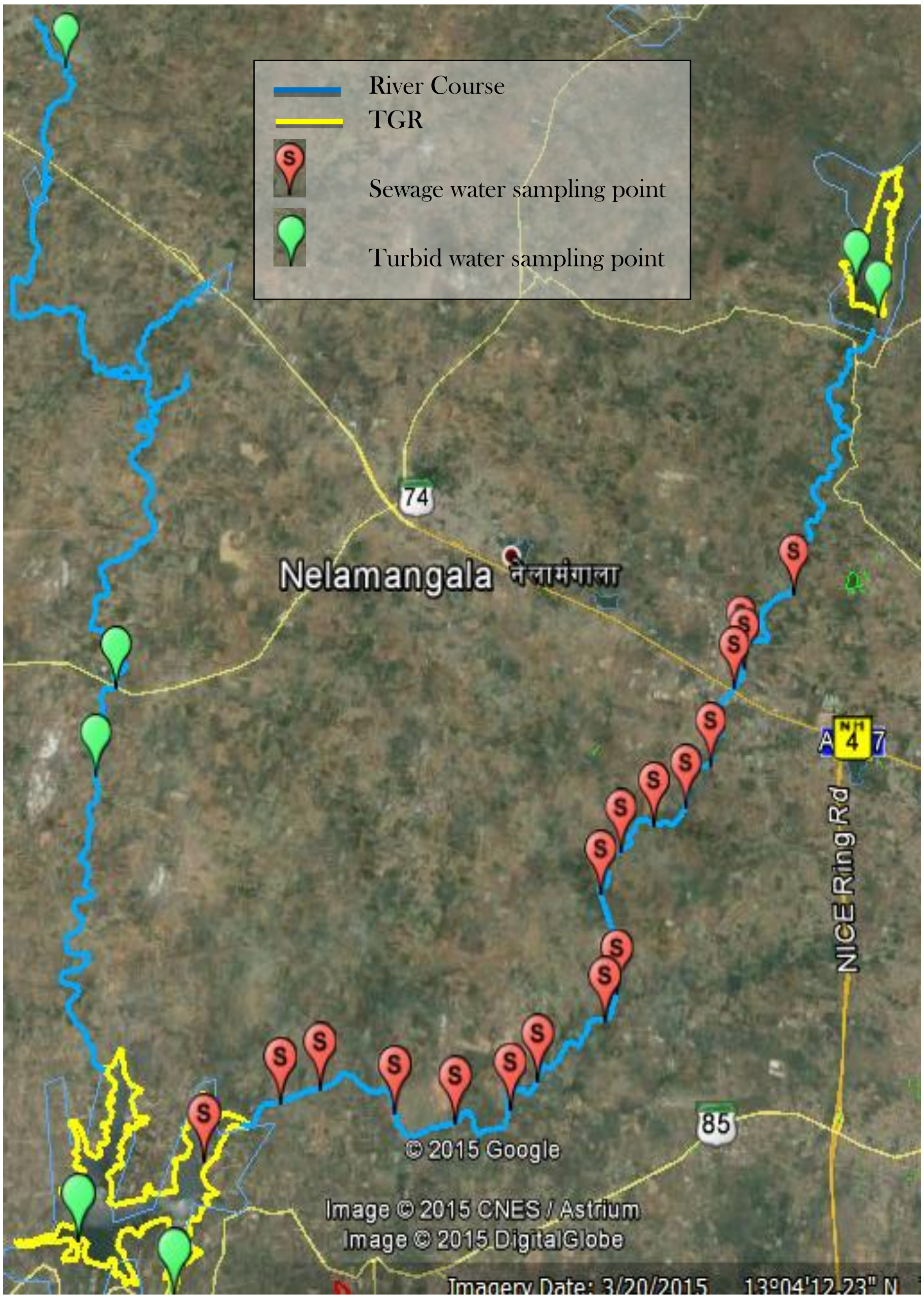


Figure-7.2: Sampling Location in the Reservoirs and River Course

Further, the groundwater sample from the 19 villages located in the Arkavathi river course from Hesaraghatta village to Dombarahalli village are analysed for the pH, EC and TDS with the handheld Testers (Aquasol Digital-Rakiro Biotech, Mumbai). The groundwater samples were collected from the bore-wells, Mini Water Supply Tanks and public taps maintained by Gram Panchayat, which provide the water for village communities. The sample collection points are illustrated in the Figure-7.3.

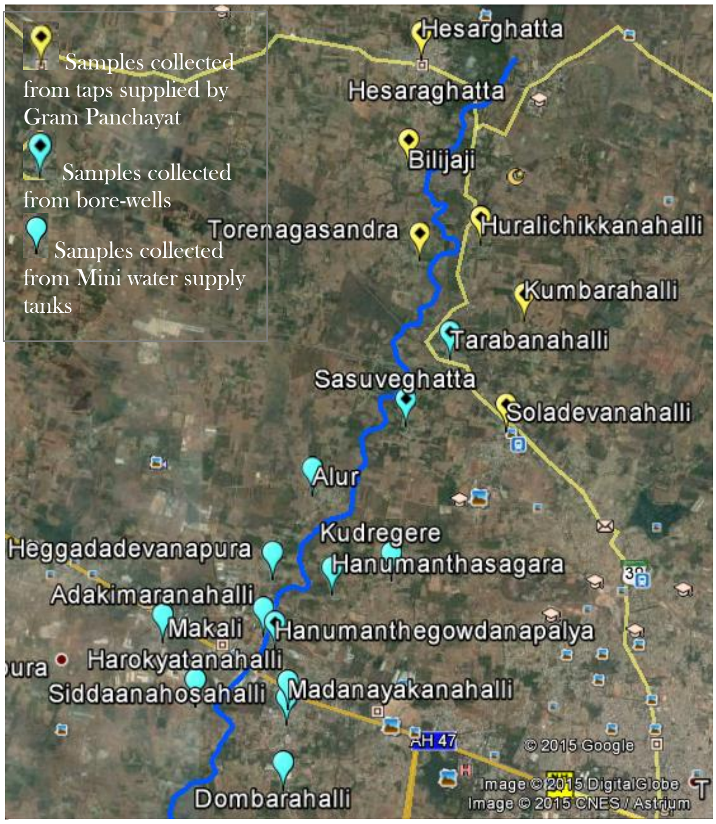


Figure-7.3: Groundwater sampling location villages in the Arkavathi river course

7.2.1. Water sample collection:

Water samples were collected in the early morning to analyse 41 parameters comprising of 22 physico-chemical parameters, two bacteriological test, eight heavy metals and nine pesticide residues. For physico-chemical parameters, the water samples were collected in cleaned 1L narrow mouth polythene cans, which were rinsed out 2-3 times with the water to be sampled before collecting water samples. The water samples were also collected in pre-sterilized bottles for bacteriological (coliform) analysis and wrapped with the aluminium foil to avoid sunlight. Water samples from the Hesaraghatta reservoir, TGR, Arkavathi and Kumudvathi Rivers were collected in the cans manually by plunging bottle's neck downward below the surface, bottle mouth being directed against the current. Apart from the physico-chemical parameters and coliform analysis, the 2L water samples from all the sampling locations were collected in 2.5L narrow mouth tinted brown amber bottles to analyse the presence of nine organochlorine pesticides. To avoid contamination during the collection of freshwater samples for coliform analysis, the pre-sterilized bottle was unwrapped only at the time of sample collection. To avoid the contact of hand, the bottle was closed with pre-sterilized lid after the water sample was collected. The collected water samples for coliform analysis were stored in closed icebox and transported to water quality analysis laboratory within three hours.

All the collected water samples were properly labelled and accompanied with complete descriptive data. Care was taken to obtain a sample that truly represents the existing conditions and was handled in such a way that it does not get contaminated before it reaches the laboratory. The parameters for the water quality analysis have been selected by following the uniform protocol on water quality monitoring order (MoEF Notification, 2005) based on the recommendation by Water Quality Assessment Authority (WQAA).

Temperature (Atmosphere and water), pH and EC of the water were analysed in the field itself during the collection of water samples with the help of mercury thermometer, pH and EC pen respectively. Dissolved Oxygen (DO) in the water samples were analysed with the help of hand-held DO meter in the field itself. The collected water samples were analysed in the Government approved laboratories such as Department of Mines and Geology (DMG) water testing laboratory for the analysis of physico-chemical and biological parameters in freshwater (23 parameters for seven fresh water samples), KSPCB central water laboratory (eight heavy metals for 25 water samples) for the analysis of heavy metals in the water samples and Sneha test laboratory (23 parameters for 18 sewage water samples collected from Arkavathi river), an MoEF approved lab for analysis of physico-chemical and biological parameters collected from Arkavathi river. Pesticides were analysed in Shiva Analytical (India) Pvt. Ltd. (nine organochlorine pesticides for 25 water samples), which is the KSPCB empanelled 'A' Grade lab. The methods used for the analysis of all parameters in the laboratories are tabulated in the Table-7.3.

The reason for the pollution of the Arkavathi and Kumudvathi rivers were documented by the visual encounter method and ground verification. During the inspection of rivers, interaction with the local community was also done to document the pollution sources and also to confirm the ground verification of river pollution.

7.3. Water Quality of Arkavathi River based on Secondary Data:

There was a huge gap and no uniformity of parameter analysis observed in the Arkavathi river water quality secondary data for the years 2010 to 2014 collected from the KSPCB. Arkavathi river samples were collected from the two stations i.e. one from the Varthur Metipalya village Bridge (VB), Thaverekere hobli and another one was TGR inlet. The compiled water quality data of the Arkavathi river is tabulated in the Table-7.4, which also shows that there was non-uniformity between the water quality data. As there was flow of sewage in the Arkavathi river, the total coliform and the heavy metal such as iron and lead have exceeded the BIS limit. Further the iron content was high in the TGR inlet rather than the Varthur village bridge, which also revealed that the sewage influx is happening to the Arkavathi river between the Varthur village bridge and the TGR inlet.

7.3.1. Present Scenario:

To know the status of water quality in Hesaraghatta reservoir, the samples were collected from the inlet and the outlet. Based on the water availability, 17 water samples are collected from the Arkavathi river course until the TGR from the Hesaraghatta reservoir. Arkavathi river water inflow at point into reservoir falls in class-E and outlet from Hesaraghatta reservoir falls in the class-D (Table-7.5) due to the high iron concentration (1.3mg/l). Class-E becomes class-D water in the Hesaraghatta reservoir because of the settlement of particles in the water by gravity. The iron concentration (1.3mg/l) has exceeded the limit of BIS: 10500-2012, which is 0.3mg/l. The comparative water quality results of inlet and outflow water of Hesaraghatta reservoir shows that the Electric conductivity, total dissolved solids, total hardness, calcium, chloride, sulphate, nitrate, potassium concentrations are in the increasing trend. But, the coliform counts are found drastically decreased in the Hesaraghatta reservoir outlet water may be due to settling of nutrient particles and there is no outflow of water.

The Arkavathi river water (Hesaraghatta to TGR) reaching the TGR becomes class-E, which can be used for irrigation or industrial cooling or controlled waste disposal. But except the Alur village river course, the water quality is below class-E (Table-7.7). The water is classified particularly based upon the pH and electric conductivity values, which is above 8.5 and 2250 µmhos/cm. Water quality results showed that the odour of the water is pungent and the dissolved oxygen in water is below 1mg/l, whereas the BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) are above 30 and 7.5mg/l respectively. BOD is a measure of the quantity of dissolved oxygen necessary for the decomposition of organic matter by microorganisms such as bacteria, whereas the COD is used not only to measure the amount of biologically active substances such as bacteria but also biologically inactive organic matter in water. It is the oxygen equivalent of the total organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant such as dichromate. Presence of coliform and pH above the 8.5 has confirmed that the water is raw sewage from the settlement.

In Kadaranahalli village, the river water turbidity is drastically increased from 72 to 340NTU and drastically decreased to below 9, when it reaches the TGR. But TDS (Total Dissolved Solids) in the water is constantly maintained between 1500 and 1650mg/l throughout the Arkavathi river course. There was no Dissolved Oxygen (DO) in the water until Giddenahalli village, but when the water reaches the TGR, DO is 1.06mg/l.

The heavy metals are not removed by the conventional water treatment method, which was in TGR by BWSSB for the supply of potable water to Bangalore city. The impacts of heavy metal concentration on the health of users are high. Heavy metal analysis result showed that the Manganese is high in Alur, Heggadadevanapura, Makali and Madanayakanahalli villages river course and reach maximum to 10mg/l in Kadaranahalli village river course. Nickel concentration is 0.047mg/l in Kadaranahalli village river course, whereas the BIS limit is only 0.02mg/l. As per the BIS: 10500-2012, the heavy metals such as iron concentration is 1.38 to 4.87mg/l in the villages of Alur, Heggadadevanapura, Makali and Madanayakanahalli and it is reduced to 0.88 in Harokyathanahalli and 0.4 in Gangenahalli villages river course. The heavy metals such as lead, chromium and cadmium are Below Detectable Limit (BDL) and copper and zinc metals are below the limit of BIS: 10500-2012 standard. The nine organochlorine pesticides in the Hesaraghatta reservoir and in Arkavathi river course water is BDL, which indirectly proves that the agriculture practise is less in the banks of Arkavathi river.

The high concentration of Turbidity (340NTU), Nickel (0.047mg/l) and Manganese (10mg/l) in the Kadaranahalli village river course show that industrial effluents are existing between the villages of Harokyathanahalli and Kadaranahalli. Further, the heavy metals such as iron and manganese concentration have exceeded the limit of BIS: 10500-2012 in the river course of Alur, Heggadadevanapura, Makali and Madanayakanahalli villages, which are the villages highly packed with the godowns and also in the ribbon of NH-4.

7.4. Water Quality of Kumudvathi River based on the Secondary Data:

The water quality data collected from the KSPCB for the year 2013 and 2014 in the month of July (Figure-7.4) had revealed that the heavy metal iron content has drastically increased to 10.78mg/l during the year 2014. The iron content was not analysed for the year 2013. The reason may be that the iron-enriched river sediment was disturbed by the mining activities. Further, Class-C water quality in 2013 has become Class-D during the year 2014.

8.4.1. Present Scenario:

Kumudvathi river water quality falls in class-D in Basavanahalli village due to the presence of 0.77mg/l of iron concentration. At other two stations, the water quality is class-C (Table-7.5), which is considered as drinking water source with conventional treatments followed by disinfection as per the IS:2296-1992 tolerance limits for inland surface waters. The comparative water quality results between the sampling villages shows that the colour is 10 Hazen units in Basavenahalli village, but it drastically falls to 1 Hazen units. Calcium, magnesium and sulphate concentrations are in the increasing trend. The drastic increase of colour (10 Hazen units) and marginally exceeded (BIS: 10500-2012) manganese concentration as 0.34mg/l in Basavanahalli village may be due to the operation of stone crusher in this village. Heavy metal analysis result showed that the lead, chromium, nickel and cadmium are Below Detectable Limit (BDL) and copper and zinc metals are below the limit of BIS: 10500-2012 standard. The nine organochlorine pesticides in the river course water is BDL, which indirectly show that the agriculture practise is less in the banks of Kumudvathi river also.

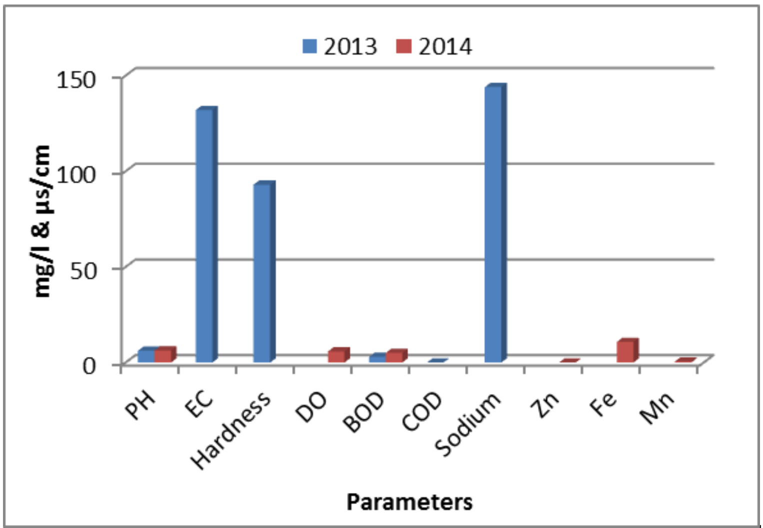


Figure-7.4. Water quality of Kumudvathi River (Source-KSPCB)

7.5. Water Quality of TGR based on the Secondary Data:

Water quality data for the physico-chemical parameters collected from the BWSSB between the years 2000 and 2014 for TGR water showed that the colour of the water, oil content and calcium hardness have exceeded the BIS: 10500-2012 limit during the year 2004, 2010-2014 and 2014 respectively. Light brown colour of the water may be due to the high turbidity caused by the high rainfall runoff. Calcium hardness has increased due to the brick kilns, surrounding TGR which was evident through the study conducted by Rizwana Khan and Harish Vyas (2008) that shows the impact of brick industries on Kshipra river, Ujjain. There was a data gap and no uniformity of water quality parameter analysis (Figure-7.5), but the data represents clearly that the Total Dissolved Solids (TDS) and Electric conductivity of TGR water were in increasing trend in 2014.

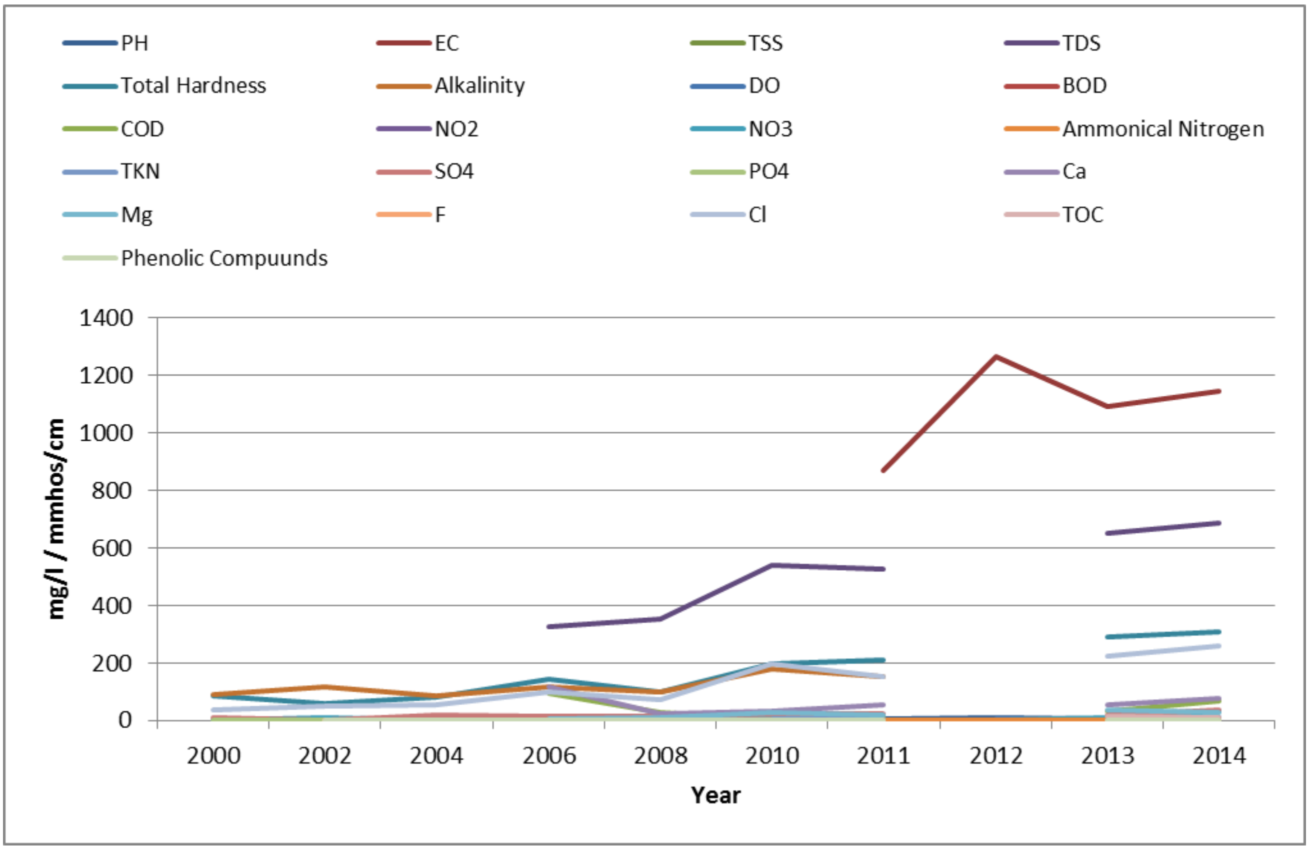


Figure-7.5: TGR water quality between the year 2000 and 2014 (Source-BWSSB)

Biological parameters for the TGR water between the years of 2008 and 2014 showed that the faecal coliform was very high in the year 2013 with the presence of *Escherichia coli* (Figure-7.6). Inflow of sewerage through the Arkavathi river is one of the main source for the presence of *E.coli* and faecal coliform in the TGR water. While the chlorophyll has shown decreasing trend during the year 2010-2011, the chlorophyll-a has shown increasing trend during the year 2013-2014, and vice-versa for chlorophyll-b.

Heavy metal analysis results of TGR water between the year 2002 and 2011 revealed that the cadmium (2002-2011), iron (2006-2010), chromium during 2004, Lead and selenium during the year 2008 had exceeded the limit prescribed by the BIS: 10500-2012 for the drinking water. The iron content in the water was very high during the year 2006 and 2008 (Figure-7.7), probably due to inflow of industrial effluents.

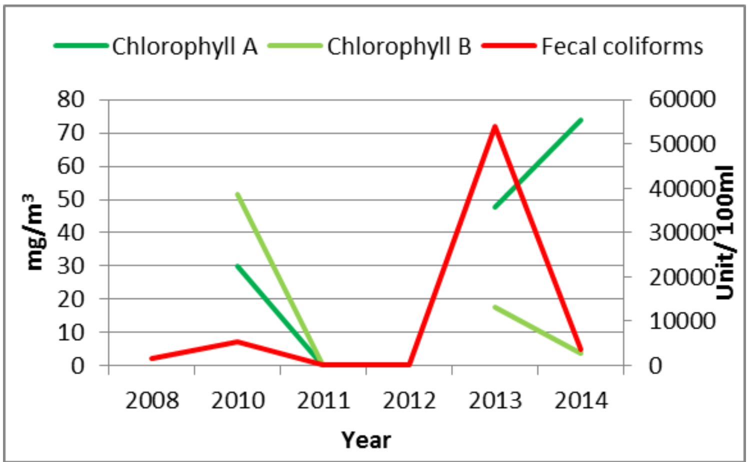


Figure-7.6. Biological parameters of TGR (Source-BWSSB)

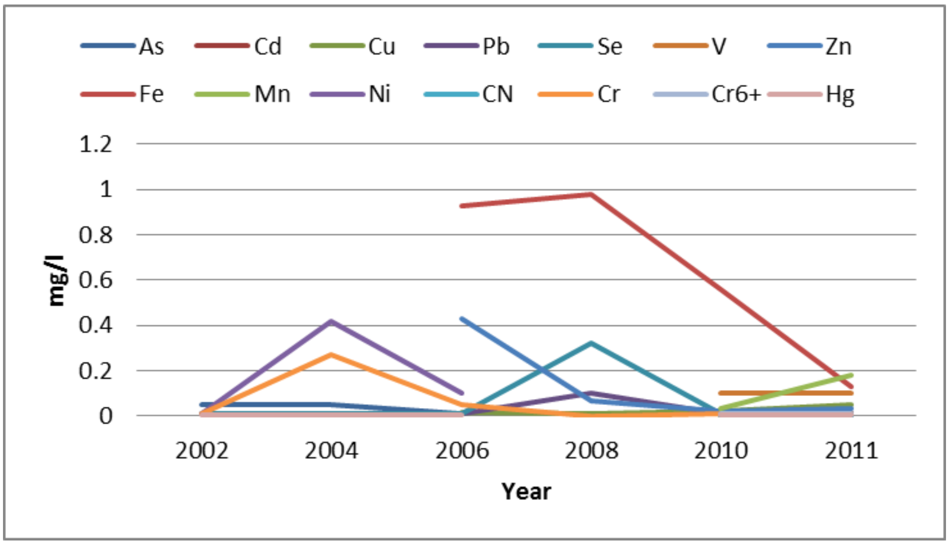


Figure-7.7: Heavy metal results of TGR between the year 2002 and 2011 (Source-BWSSB)

7.5.1. Present Scenario:

Water samples were collected from the three inlets such as Arkavathi river, rainfall runoff inlet in Gangappanahalli village and Kumudvathi river, and an outlet from the TGR. Water quality results showed that the inlet water from the Arkavathi river and Gangappanahalli village inlet to TGR fall in the class-E and class-C (Table-7.5) respectively. As the concentration of water pollutants are diluted in the TGR, the outlet water from the TGR belonged to the class-D. There could be gross differences in the test results of some samples at different laboratories such as BWSSB, KSPCB, DMG and also other private laboratories. Heavy metal analysis result showed that the lead, chromium, nickel and cadmium are Below Detectable Limit (BDL) and copper and zinc metals are below the limit of BIS: 10500-2012 standard. The nine organochlorine pesticides in the river course water is BDL, which indirectly shows that the agriculture practise is less in the TGR catchment area.

7.6. Groundwater Scenario:

Groundwater quality data was collected from the DMG, who is the Nodal monitoring Agency for the State. Within the TGR catchment area, water quality data was available only for one well, which is located in the Zone-4 of the Kumudvathi river course (downstream) of Marenahalli village,

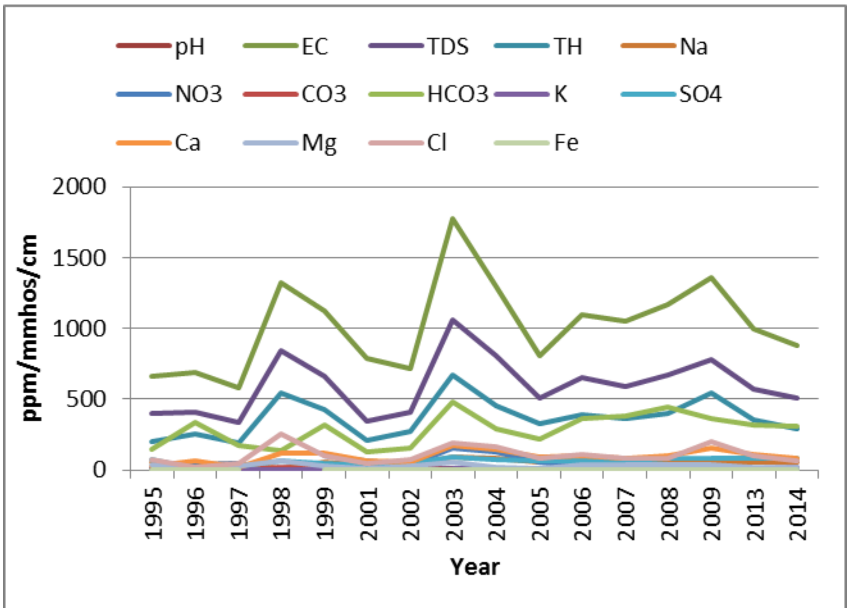


Figure-7.8. Groundwater quality of Kumudvathi sub-catchment area (Source-DMG)

Bangalore Rural district. Water quality data had the gaps between the years as there was no data for the year 2000, 2010, 2011 and 2012. The water quality between the year 1995 and 2014 revealed that the total hardness during the year 2003 and nitrate during the year 1997-2001 and 2003-2005 had exceeded the BIS portable quality limit. Excess of nitrate in the groundwater may be due to the percolation of sewage in to groundwater channel, but the Kumudvathi river was free from the sewerage. The line chart (Figure-7.8) illustrated that all the parameters were increasing year by year. The chart also revealed that all the parameters become high after a period of 5-6 years (1998, 2003 and 2009). Concentration level of nitrate, chromium, aluminium and faecal coliform in the groundwater of Bangalore North, Bangalore South, Doddaballapur, Nelamangala and Ramanagara exceeded the BIS limit as per the study (Lele, 2013).

7.6.1. Present Scenario:

EC, TDS and pH are analysed in the groundwater from the Hesaraghatta village to downstream of Dombarahalli village. Groundwater quality of Arkavathi river course has revealed that the TDS of 16 villages groundwater are above (500mg/l) the requirement limit of BIS: 10500-2012. EC and TDS are negatively correlated with the pH has showed that the groundwater may be polluted through the wastewater flow in the Arkavathi river in Soladevanahalli, Heggadadevanapura and from Makali to Siddanahosahalli villages (Figure-7.9).

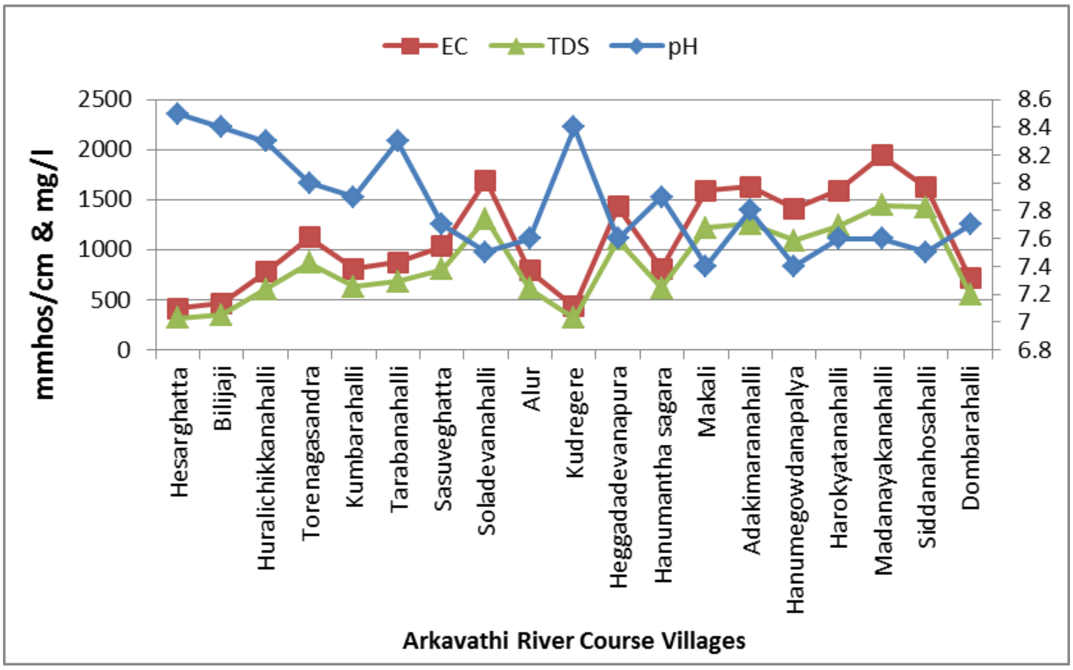


Figure-7.9: Groundwater quality in Arkavathi river course villages

7.7. Arkavathi River Pollution:

Arkavathi river is highly polluted due to unplanned urbanization and rapid development in the Arkavathy sub-catchment area. Further, the pollution points of the Arkavathi river course in zone-3 are tracked during the study to trace the pollution sources. Arkavathi river is polluted by the connecting streams from the seven villages (Table-7.6 and Figure-7.10), which are deliberately discussed below

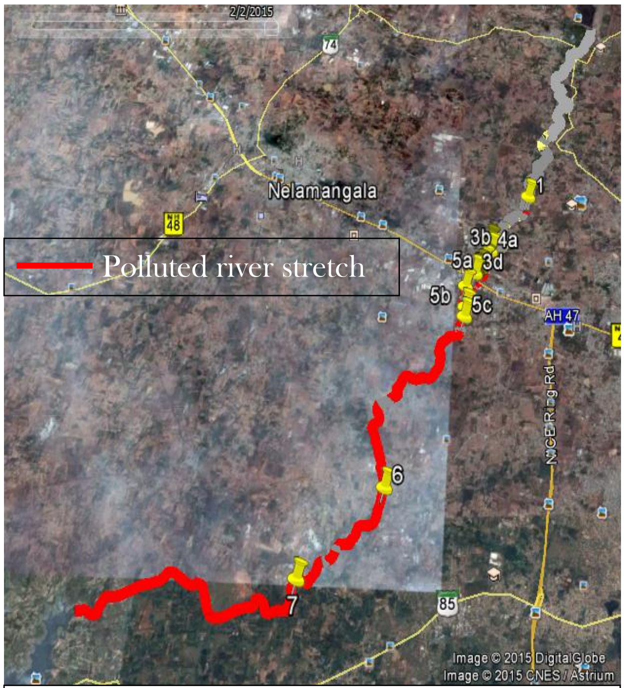


Figure-7.10: Polluted Arkavathi river stretch

Sewage generated by the village settlements from the Alur (Plate-7.1a), Heggadevanapura (Plate-7.1 b and c), Makali (Plate-7.1 d and e), Madhanayakanahalli (Plate-7.1f) and Harokyathanahalli villages (Plate-7.1g) are entering into the Arkavathi river through the 2nd order drains. Further the wastewaters generated from the godowns located in the Makali (Plate-7.1h) and Madhanayakanahalli villages (Plate-7.1i) are also let into the Arkavathi river. River is highly polluted by the slurry from the granite factories in Kadabagere village (Plate-7.1j) and due to the illegal extensive quarrying activities in the Giddenahalli village (Plate-7.1 k and l). Further the 2nd order stream connected to the river in Harokyathanahalli village (Plate-7.1 m and n) brought enormous solid wastes and sewage from the BBMP area (located out of TGR catchment area) and from the settlements of Madavara (Plate-7.1 o-q) and Dommarahalli villages (Plate-7.1 r and s). This stream also carry the dye waste from the illegal operation of the garment dyeing units located in the Thirumalapura village (Plate-7.1t) of Zone-1 behind the Madavara lake.

7.8. Reasons for Pollution of Arkavathi and Kumudvathi River Courses:

Two types of pollutants are documented for the Arkavathi river i.e. point and non-point source of pollution.

7.7.1. Point Source Pollution:

1. Sewerage drainages of residential units such as houses, unplanned layouts are connected directly to the nallah of Arkavathi river.
2. As there was no UGD system in most of the surrounding villages, the surface flow sewage reaches the Arkavathi river through the storm water drain.
3. Wastewaters from godowns are let into the Arkavathi river.
4. Dumping of solid wastes such as the domestic garbage on the banks of Arkavathi river.
5. Letting out of industrial wastes such as granite slurry and garment dye and also effluent from unregulated small scale industries, particularly the dyeing and electroplating industry.
6. Illegal stone quarry and stone crushing units in the catchment area (Zone-3 & 4) have also polluted the Arkavathi river through the rainfall runoff.
7. Sand washing in the bank of Arkavathi river has increased the siltation and TDS level in the water quality.

7.7.2. Non-Point Source Pollution:

1. Sewage/ wastewater/ sullage water from the village settlement/ layouts/ apartments in nearby Arkavathi river are discharged in to the river. Further, the untreated sewage

water from the BBMP area also flows to the Arkavathi river through the nallah. Phosphorus from household waste water and sewage is another powerful pollutant. It comes from detergents and stays in rivers for a long time where it takes up valuable oxygen. Only few sewage systems are equipped to remove phosphates.

2. In most of the TGR catchment area villages, household sewage is let into the nearby vacant/ waste land, but due to the unsaturation level of groundwater, the sewage water may be reaching the Arkavathi river through the sub-surface percolation.
3. As there was no proper solid waste management in the entire catchment area; solid waste, plastic bags and flower garlands are disposed into rivers.
4. There is no proper disposal of slaughter and poultry wastes in the nearby villages. These are dumped in the nallah of Arkavathi river and washed to river during rainy season.
5. Rapid sand mining in the waterbodies also add the TDS in water, which get transported to the river during rainy season. Further, the waterbodies are not maintained properly, and hence the aquatic weeds, *Eichhornia sp.* grown in the waterbody join the Arkavathi river during the heavy rainfall.
6. People defecating in open and near rivers contribute to river pollution

7.8. Consequence of Pollution:

The main factors influencing human-induced pollution in the watershed zone include:

1. **Non-point source nutrient** inputs originating from soil erosion in the catchment contribute to algal outbreaks and growth of aquatic weeds, which causes fish death through the reduced oxygen levels.
2. **Agro-chemical pollution** such as pesticides, metal-complexed inorganic fertilizers, volatile organic substances (VOS), poly-aromatic hydrocarbons (PAH) can persist in lake sediments for a long time. The bio-accumulation and bio-magnification will enhance the pollution as poison to the man-kind.
3. **Sewage pollution** caused by untreated direct discharge of domestic waste water from surrounding households exacerbates BOD, reduction of DO, and increase in bacterial contamination.
4. Loss of wetlands and littoral habitats across the entire stretch of the Arkavathi basin from Hesaraghatta to TGR region.
5. Weed infestations (Water Hyacinth, Amaranthus family, *Ipomoea* sp.), which affects lake's water quality, interfering in navigation and water flows.

Once a trend in pollution sets in, it will generally accelerate the cause for greater water quality deterioration; which also seen in the Arkavathi river course. When there was water in the river, the concentration of pollution is diluted, but when the water availability in the river gets reduced, then the reverse occurs. Hence the pollution concentration increased due to pollutants (sewage) flow in the river course. So there is a need to stop the inflow of sewage and other contaminants in the river course through the initiation of river revival process, which are discussed in the conclusion and recommendation chapter.

Table-7.1. Class of water based on the tolerance limit of water quality parameter as per IS: 2296-1992

S.No.	Parameters	Unit	Maximum Tolerance limits				
			Class-A	Class-B	Class-C	Class-D	Class-E
1	pH	---	6.5 to 8.5	6.5 to 8.5	6.0 to 9.0	6.5 to 8.5	6.0 to 8.5
2	Dissolved Oxygen	mg/l	6.0	5.0	4.0	4.0	---
3	BOD_5 below	mg/l	2.0	3.0	3.0	---	---
4	Total Coliform	MPN/100ml	50	500	5000	---	---
5	Colour	Hazen units	10	300	300	---	---
6	Odour	---	Unobjectionable	---	---	---	---
7	Taste	---	Tasteless	---	---	---	---
8	Total Dissolved Solids	mg/l	500	---	1500		2100
9	Electrical Conductivity	µS	---	---	---	---	2250
10	Free Carbon-dioxide (as $C0_2$)	mg/l	---	---	---	6.0	---
11	Total Hardness (as $CaCO_3$)	mg/l	200	---	---	---	---
12	Calcium Hardness (as $CaCO_3$)	mg/l	200	---	---	---	---
13	Magnesium Hardness (as $CaCO_3$)	mg/l	200	---	---	---	---
14	Copper (as Cu)	mg/l	1.5	---	1.5	---	---
15	Iron (as Fe)	mg/l	0.3	---	0.5	---	---
16	Manganese (as Mn),	mg/l	0.5	---	---	---	---
17	Chlorides (as Cl)	mg/l	250	---	600	---	600
18	Sulphate (as SO_4)	mg/l	400	---	400	---	1000
19	Nitrates (as NO_2)	mg/l	20	---	50	---	---
20	Free Ammonia (as N)	mg/l	---	---	---	1.2	---
21	Fluorides (as F)	mg/l	1.5	1.5	1.5	---	---
22	Sodium %	---	---	---	---	---	60
23	Sodium Adsorption Ratio	---	---	---	---	---	26
24	Phenolic compounds (as C_6H_5OH)	mg/l	0.002	0.005	0.005	---	---

S.No.	Parameters	Unit	Maximum Tolerance limits				
			Class-A	Class-B	Class-C	Class-D	Class-E
25	Mercury (as Hg)	mg/l	0.001	---	---	---	---
26	Cadmium (as Cd)	mg/l	0.01	---	0.01	---	---
27	Selenium (as Se)	mg/l	0.01	---	0.05	---	---
28	Arsenic (as As)	mg/l	0.05	0.2	0.2	---	---
29	Cyanides (as CN),	mg/l	0.05	0.05	0.05	---	---
30	Lead (as Pb)	mg/l	0.1	---	0.1	---	---
31	Zinc (as Zn)	mg/l	15	---	15	---	---
32	Chromium (asCr^{6+})	mg/l	0.05	---	0.05	---	---
33	Anionic detergents (as MBAS)	mg/l	0.2	1.0	1.0	---	---
34	Mineral oil	mg/l	0.01	---	---	---	---
35	Oils and Grease	mg/l		---	0.1	0.1	---
36	Barium (as Ba)	mg/l	1.0	---	---	---	---
37	Boron	mg/l	---	---	---	---	2.0
38	Silver (as Ag)	mg/l	0.05	---	---	---	---
39	Pesticides	---	Absent	---	Absent	---	---
40	α emitters	μc/ml	10^{-9}	10^{-8}	10^{-9}	10^{-9}	10^{-9}
41	β emitters	μc/ml	10^{-8}	---	10^{-8}	10^{-8}	10^{-8}

Table-7.2. Details of water sample collection locations

Area	Sampling Location	GPS location		Sampling Point Description
		Lat. (N)	Long. (E)	
Hesaraghatta Reservoir	Inlet	13°08′30.8″	77°29′23.9″	Near the rusted pipeline were water is turbid and fishing is there
	Outlet	13°08′54.2″	77°29′05.1″	Near the surrounding of soil excavation, where water is turbid
Arkavathi River Course	Alur	13°05′02.5″	77°28′06.2″	Sewage inflow to river from settlement area and weeds are present
	Heggadadevanapura	13°04′06.5″	77°27′29.2″	Sewage inflow to river and weeds (*Ipomoea fistulosa*) surrounded area with beside temple
	Makali	13°04′14.3″	77°27′27.5″	Sewage inflow from village settlement with odour and weeds are present
	Madanayakanahalli	13°03′52.6″	77°27′21.3″	Sewage inflow and weeds *Typha* and *Colacassia* are present. The place also have the solid wastes such as poultry wastes, dumped waste clothes
	Harokyathanahalli	13°03′02.6″	77°27′03.3″	Sewage inflow with foam and dyes. Weeds such as *Alternanthera, Typha, Eichhornia* are present
	Kadaranahalli	13°02′33.6″	77°26′45.0″	Sewage inflow to river from settlement area and weeds (*Eichhornia*) are present
	Gaudahalli	13°02′21.4″	77°26′21.9″	Sewage inflow with weeds on sides of stream and also grazing animals are noted
	Kammasandra	13°02′03.8″	77°25′58.9″	Sewage inflow with weeds *Eichhornia* are present
	Ravothanahalli	13°01′37.0″	77°25′44.8″	Sewage inflow with foam and common defecation along the stream. Religious activity wastes also present
	Bettahalli	13°00′36.7″	77°25′55.4″	Sewage inflow with weed *Eichhronia*
	Kittanahalli	13°00′21.4″	77°25′47.4″	Sewage inflow with ashes in the places of *Alternaria*, *Colacassia* weeds
	Gattisiddanahalli	12°59′44.5″	77°25′02.7″	Sewage inflow with weeds are present
	Giddenahalli	12°59′28.2″	77°24′44.8″	Sewage inflow with weeds such as *Alternanthera* sp., *Ipomoea fistulosa*
	Varthur	12°59′20.0″	77°24′08.9″	Location is nearer to the Tavarekere and Sondekoppa villages main road. Sewage inflow with solid wastes and poultry wastes
	Gangenahalli	12°59′25.1″	77°23′28.5″	Sewage inflow with foam and *Eichhornia* weed
	Nagasandra	12°59′37.4″	77°22′38.5″	Nearer to stream agricultural activity with sewage inflow
	Jogerahalli	12°59′27.6″	77°22′12.1″	Sewage inflow, encroached land with horticultural crops, agricultural wastes beside the river

Area	Sampling Location	GPS location		Sampling Point Description
		Lat. (N)	Long. (E)	
Kumudhavathi River Course	Basavenahalli	13°02′45.8″	77°19′48.0″	Turbid stagnant water as patches in the surrounding area of agricultural activity and the presence of grazing animals.
	Doddakarenahalli	13°03′44.0″	77°19′56.8″	Turbid stagnant water in the presence of solid wastes, medical wastes (Cotton, injection bottles, syringes and its packing materials) and also near to Cadbury factory
	Kodihalli	13°11′45.6″	77°18′26.3″	Turbid stagnant water as patches with huge quantity of religious wastes
TGR	Arkavathi river Inlet (Varthur)	12°58′55.2″	77°21′24.6″	Sewage inflow
	Inlet (Kutlu)	12°57′41.4″	77°21′11.0″	Inflow of muddy water, where water is from the leaking Cauvery pipeline with the weeds
	Outlet (Gangappanahalli)	12°58′09.3″	77°20′07.0″	Major area of this water spread area is covered with *Eichhornia* and water flowing is appeared to be light brown in colour

Table-7.3. Methodology adopted for analysis of water samples

S.No.	Parameters	Unit	Protocol
Physico-chemical			
1	Water Temperature	Degree C	IS:3025
2	Colour	Pt-Co	IS:3025 (P- 4)
3	Odour	-----	IS:3025 (P- 5)
4	Turbidity	NTU	IS:3025 (P-10)
5	pH value	-----	IS:3025 (P-11)
6	Electrical Conductivity	µmhos/cm	IS:3025 (P-14)
7	Total Dissolved Solids	mg/L	IS:3025 (P-16)
8	Calcium (as Ca)	mg/L	IS:3025 (P-40)
9	Magnesium (as Mg)	mg/L	IS:3025 (P-46)
10	Bicarbonates (as $CaCO_3$)	mg/L	IS:3025 (P-23)
11	Carbonates (as $CaCO_3$)	mg/L	IS:3025 (P-23)
12	Chloride (as Cl)	mg/L	IS:3025 (P-32)
13	Sulphate (as SO_4)	mg/L	IS:3025 (P-24)
14	Nitrate (as NO_3)	mg/L	IS:3025 (P-34)
15	Nitrite (as NO_2)	mg/L	APHA
16	Ammonical Nitrogen	mg/L	IS:3025 (P-34)
17	Sodium (as Na)	mg/L	IS:3025 (P-45)
18	Potassium(as K)	mg/L	IS:3025 (P-45)
19	Total Phosphorus (as P)	mg/L	IS: 3025 (P-31)
20	Dissolved Oxygen	mg/L	IS:3025 (P-38)
21	COD	mg/L	IS:3025 (P-58)
22	BOD for 3 days @ 27°c	mg/L	IS:3025(P-44)
Bacteriological Analysis			
23	Total Coliform	MPN/100ml	APHA
24	Faecal Coliform	MPN/100ml	
Heavy Metals			
24	Copper	mg/L	AAS
25	Lead	mg/L	
26	Zinc	mg/L	
27	Nickel	mg/L	
28	Total Chromium	mg/L	
29	Cadmium	mg/L	
30	Iron	mg/L	
31	Manganese	mg/L	
Organochlorine Pesticides			
32	α-HCH	µg/l	USEPA 508
33	β-HCH	µg/l	
34	Gamma HCH	µg/l	
35	Delta HCH	µg/l	
36	Aldrin	µg/l	
37	o,p-DDT	µg/l	
38	p,p-DDT	µg/l	
39	Endosulfan-I	µg/l	
40	Endosulfan-II	µg/l	

Table-7.4. Water quality data of Arkavathi river between years of 2010 and 2014 (Source-KSPCB)

Parameters	2010	2011		2012		2013		2014	
	VB	VB	TGR Inlet	VB	TGR Inlet	VB	TGR Inlet	VB	TGR Inlet
Physico-Chemical parameters									
pH	8.0	7.4	7.7	7.5	8.2	7.3	7.1	7.2	7.1
Elect. Conductivity (mmhos/cm)	710	2090	ND	2480	ND	2080	2510	1491	1476
TDS (mg/l)	ND	ND	1320	ND	ND	ND	ND	ND	ND
Total Hardness as CaCO3 (mg/l)	ND	ND	ND	ND	ND	708	ND	ND	ND
DO (mg/l)	11	1.84	ND	2.78	6.86	5	5.2	5.1	5
BOD_3 (mg/l)	1	4	3	7	8	4	4	4	10
COD (mg/l)	ND	ND	31	ND	ND	ND	ND	ND	ND
Nitrates (mg/l)	ND	18.8	30.06	22.39	20.17	9.95	ND	ND	ND
Kjeldhal Nitrogen (mg/l)	ND	ND	28	ND	ND	ND	ND	ND	ND
Ammonical Nitrogen (mg/l)	ND	ND	17	0.29	0.36	ND	ND	ND	ND
Sulphates (mg/l)	ND	ND	32	48	142	137	ND	ND	ND
Phosphate (mg/l)	ND	ND	0.07	ND	ND	ND	ND	ND	ND
Fluoride (mg/l)	ND	ND	0.41	0.52	0.47	0.36	ND	ND	ND
Chloride (mg/l)	ND	ND	380	ND	ND	ND	ND	ND	ND
Biological Parameters									
Total Coliform/ 100ml	21	7600	11600	ND	ND	>1200	ND	990	690
Heavy Metals									
Lead (mg/l)	ND	ND	0.53	ND	0.017	ND	ND	ND	ND
Zinc (mg/l)	ND	ND	0.05	0.101	0.216	ND	ND	ND	ND
Iron (mg/l)	ND	ND	1.38	0.036	0.406	ND	ND	ND	ND
Class IS:2296-1982	**A**	**D**	**D**	**D**	**C**	**D**	**D**	**D**	**D**

Note: ND- No Data

Table-7.5. Water quality data of Hesaraghatta reservoir, TGR and Kumudvathi river for the year-2015

Parameters	Unit	Sampling Station							
		Hesaraghatta Reservoir		TGR			Kumudvathi River		
		Inlet	Outlet	Arkavathi Inlet	GPH Inlet	Outlet	Basavenahalli	Doddakarenahalli	Kodihalli
Physico-chemical Parameters									
Colour	Hazen units	5.0	5.0	4	1.0	1.0	10	1.0	1.0
Odour	---	Nil	Nil	Slight Odour	Nil	Nil	Nil	Nil	Nil
WT	°C	27.3	26.8	34	28.1	29.1	32.8	28.2	30.6
pH	6.0-8.5	8.27	7.9	8.52	7.67	7.91	8.01	7.72	7.68
EC	µmhos/cm	145	265	962	530	1085	625	355	695
Turbidity	NTU	0.1	1.0	10.2	0.1	0.1	0.1	0.1	0.1
TDS	mg/l	90	150	580	295	615	345	195	390
DO	mg/l	4.67	3.13	1.8	4.04	4.21	4.15	4.14	4.13
BOD	mg/l	0	0	31.15	0	0	0	0	0
COD	mg/l	0	0	7	0	0	0	0	0
Calcium (Ca)	mg/l	10	14	43.12	40	59	30	30	62
Magnesium (Mg)	mg/l	8.0	7.0	28.51	24	31	11	9.0	23
Total Hardness (CaCo3)	mg/l	48	91	104	228	201	290	141	257
Chloride (Cl)	mg/l	17	22	178.42	45	230	48	36	42
Sulphate (So4)	mg/l	10.5	25	10.34	15.2	52.8	6.9	1.0	74.6
Nitrate (No3)	mg/l	0.84	2.54	6.48	0.38	0.76	1.02	0.36	0.62
Sodium	mg/l	3.0	3.0	110	30	113	83	26	40
Potassium (K)	mg/l	8.8	10.6	9	2.36	14.54	9.34	6.71	8.35
Phosphate (P)	mg/l	0.09	0.07	0.048	0.11	0.12	0.09	0.13	0.08
Bacteriological Analysis									
Faecal Coliform	MPN/100ml	1600	110	2	300	0	≥1600	300	≥1600
Total Coliform	MPN/100ml	1600	170	4	500	50	≥1600	500	≥1600

Parameters	Unit	Sampling Station							
		Hesaraghatta Reservoir		TGR			Kumudvathi River		
		Inlet	Outlet	Arkavathi Inlet	GPH Inlet	Outlet	Basavenahalli	Doddakarenahalli	Kodihalli
Heavy Metals									
Copper	mg/l	0.027	0.021	0.002	BDL	0.035	0.016	0.001	0.024
Lead	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	mg/l	0.026	0.005	0.063	0.027	0.084	0.013	0.026	0.022
Nickel	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Chromium	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron	mg/l	1.303	1.308	0.495	0.684	0.087	0.770	0.392	0.097
Manganese	mg/l	0.052	0.090	0.068	0.166	0.034	0.341	0.184	0.030
Organochlorine Pesticides									
α-HCH	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-HCH	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Gamma HCH	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Delta HCH	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Aldrin	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
o,p-DDT	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p-DDT	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endosulfan-I	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endosulfan-II	μg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
IS 2296:1992 Class		**E**	**D**	**E**	**D**	**D**	**D**	**C**	**C**

Note: GPH- Gangappanahalli village

Table-7.6. Pollution points of Arkavathi river in Zone-3

Sl. No.		Village	GPS Location of Streams		Issues
			Lat. (E)	Long. (N)	
1		Alur	13°05'10.45"	77°28'06.88"	Sewage influx to the river from a Alur village UGD manhole
2		Heggadevanapura	13°04'14.42"	77°27'27.79"	Sewage from this village is influx into river through the storm water drain
4	a	Makli	13°03'56.01"	77°27'23.40"	Sewage from the settlements influx into river through three small drains
	b		13°03'54.96"	77°27'22.32"	
	c		13°03'53.27"	77°27'21.23"	
	d		13°03'44.52"	77°27'13.76"	Godown wastewater flow to river through the drain
3	a	Madhanayakanahalli	13°04'06.33"	77°27'28.71"	Village wastewater flow to river through the drain
	b		13°03'49.42"	77°27'19.11"	Reliance fresh godown wastewater flow to river
	c		13°03'45.84"	77°27'15.51"	Godowns wastewater flow to river through the underground drain
	d		13°03'45.03"	77°27'14.73"	
5	a	Harokyathanahalli	13°03'32.30"	77°27'04.38"	Settlements wastewater flow to river through the drains (adjacent to Himalayan drugs company)
	b		13°03'12.44"	77°27'04.72"	Growth of water hyacinth with the foul smell, but the source couldn't be traced
	c		13°03'03.81"	77°27'04.16"	Slaughter waste, sewage and effluent (dye) are influx into river from the Madavara, Dommarahalli and Harokyathanahalli villages through the Madavara (Jindal) lake stream
6		Bettahalli	13°00'37.65"	77°25'56.21"	Water from lake stream flow to the river
7		Giddenahalli	12°59'27.52"	77°24'44.40"	Water in the river is polluted by the surrounding granite factories and quarrying

Table-7.7. Water quality data of Arkavathi river for the year-2015

Parameters	Unit	Sampling Stations in Arkavathi River																
		AL	HP	MI	MH	HH	KH	GH	KS	RH	BH	KT	GD	GN	VR	GA	NS	JH
Physico-chemical Parameters																		
Colour	Hazen units	3.5	4	5.5	3	4.5	4.5	4	4.5	5	5	5	5.5	5	5	4.5	3.5	3.5
Odour	---	Pungent	Pungent	Pungent	Pungent	Pungent	Pungent	Pungent	Pungent	Slight	Slight	Slight	Slight	Slight	Slight	Slight	Slight	Slight
WT	°C	30.5	30.4	28.3	24.2	25.5	24.7	26.1	28.8	28.6	28	27.7	27.5	26.2	26.3	25.1	27.8	27.9
pH	6.0-8.5	8.36	8.52	8.43	8.65	8.58	8.96	8.63	8.59	8.59	8.62	8.69	8.73	8.72	8.62	8.62	8.54	8.59
EC	µmhos/cm	1465	2015	2015	2620	2710	2730	2530	2740	2740	2450	2430	2650	2580	2310	2530	2670	2600
Turbidity	NTU	92.5	18.5	69	39.6	72.5	340	29.5	31.1	28.3	21	24.5	26	26.2	16.4	14.6	8.8	8.4
TDS	mg/l	900	1300	1300	1650	1650	1620	1650	1650	1600	1500	1550	1550	1550	1500	1550	1600	1580
DO	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.46	0.89	1.01	1.06
BOD	mg/l	194.04	89.26	174.09	208	215	299.47	67.54	63.4	78.8	66.98	82.74	80.24	82.74	86.68	39.67	33.88	29.94
COD	mg/l	75	31	64	85.5	87.5	118.8	26	23	30	26.5	33	29.5	28.5	29	13	10	7.5
Calcium (Ca)	mg/l	94.08	152.88	102.96	188.16	117.6	137.2	152.88	133.28	152.88	129.36	137.2	152.88	137.2	180.32	188.32	156.8	148.96
Magnesium (Mg)	mg/l	47.04	85.53	118	108.19	89.37	89.37	65.85	84.67	65.85	72.91	70.56	65.85	84.67	44.68	37.63	72.91	87.02
Total Hardness ($CaCo_3$)	mg/l	114	133	246	285	95	190	133	171	190	114	114	152	133	133	133	123.5	152
Bicarbonate	mg/l	513.12	570.12	362	475	465.5	440	549	494.5	408	503.5	473.5	418	446	456	389	447	420
Chloride (Cl)	mg/l	144.63	309.2	337.21	349.78	380.2	400.47	354.85	364.99	354.85	324.43	334.57	400.47	370.66	344.71	390.34	415.68	405.54
Sulphate (So_4)	mg/l	25.41	24.07	32.26	29.73	107.21	94.95	86.77	100.73	86.77	93.75	90.16	75	82.18	94.59	90.96	106.98	101.73
Nitrate (No_3)	mg/l	10.78	13.63	15.23	17.82	20.35	29.36	19.36	25.15	24.86	20.2	26.29	21.13	23.54	19.26	15.14	16.23	19.45
No_2	mg/l	0.05	0.04	0.05	0.04	0.022	0.06	0.025	0.04	0.05	ND	0.05	0.02	0.03	ND	ND	ND	ND
Ammo-Nitrogen	mg/l	14.89	9.98	4.25	8.11	4.62	4.84	7.76	6.76	7.03	3.85	6.87	5.23	4.14	2.12	1.24	0.53	0.3
Sodium	mg/l	160	130	190	205	240	280	260	270	240	240	230	260	210	240	250	270	260
Potassium (K)	mg/l	15	17	15	18.0	18.0	22.0	16.0	18.0	20.0	17.0	19.0	17	18	19	19	21	20
Phosphate (P)	mg/l	2.14	1.21	2.89	2.89	2.18	4.12	1.80	0.92	1.12	0.86	0.72	0.86	0.68	0.54	0.86	0.86	0.54
Bacteriological Analysis																		
Faecal Coliform	MPN/100ml	79	33	27	94	84	84	17	39	32	21	76	76	22	26	33	21	26
Total Coliform	MPN/100ml	221	94	141	542	>542	>542	120	175	141	172	130	130	102	141	212	130	109

Parameters	Unit	Sampling Stations in Arkavathi River																
		AL	HP	MI	MH	HH	KH	GH	KS	RH	BH	KT	GD	GN	VR	GA	NS	JH
Heavy Metals																		
Copper	mg/l	0.127	0.072	0.052	0.056	0.048	0.212	0.018	0.011	0.006	0.009	0.006	0.009	0.004	0.006	0.002	0.007	0.026
Lead	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	mg/l	0.550	0.230	0.242	0.290	0.217	1.081	0.103	0.120	0.149	0.106	0.127	0.080	0.069	0.027	0.101	0.083	0.027
Nickel	mg/l	BDL	BDL	BDL	BDL	BDL	0.047	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Chromium	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron	mg/l	1.450	1.381	3.189	4.867	0.878	0.047	0.072	0.053	0.132	0.066	0.076	0.082	0.245	0.110	0.400	0.065	0.043
Manganese	mg/l	0.281	0.340	0.354	0.430	0.220	10.006	0.263	0.159	0.195	0.103	0.117	0.121	0.143	0.122	0.116	0.050	0.102
Organochlorine Pesticides																		
α-HCH	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-HCH	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Gamma HCH	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Delta HCH	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Aldrin	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
o,p-DDT	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p-DDT	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endosulfan-I	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endosulfan-II	µg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
IS 2296:1992 Class		E	↓E	E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E	↓E

Note: **AL-**Alur; **HP-**Heggadadevanapura; **MI-**Makali; **MH-**Madanayakanahalli; **HH-** Harokyathanahalli; **KH-** Kadaranahalli; **GH-**Gaudahalli; **KS-**Kammasandra; **RH-**Ravothanahalli; **BH-**Bettahalli; **KT-**Kittanahalli; **GD-**Gattisiddanahalli; **GN-**Giddenahalli; **VR-**Varthur; **GA-**Gangenahalli; **NS-**Nagasandra and **JH-**Jogerahalli village; ↓E- Below class-E

Plate-7.1: Pollution of Arkavathi River

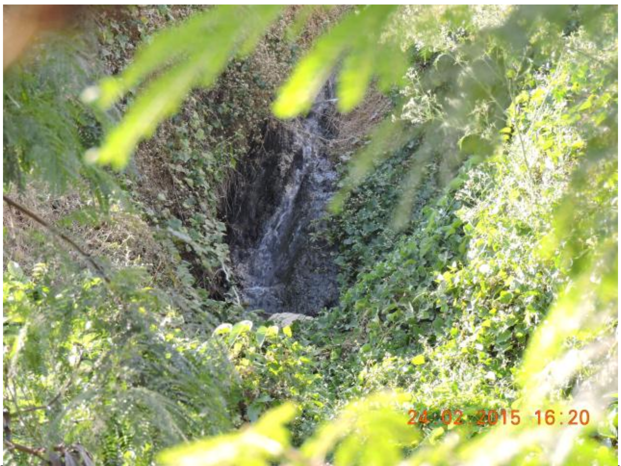
a: Broken UGD manhole of Alur village near the Arkavathi River

b: Wastewater from godowns let into the drain in Heggadevanapura village

c: Wastewater inflow into river in Heggadevanapura village

d: Wastewater from Makali village settlement inflow into river

e: Wastewater from Makali village settlement inflow into river



f: Wastewater flow to river through the storm water drain in Madanayakanahalli village

g: Sewage carrying drain connected to river in Harokyathanahalli village

h: Outlet of godown connected to river in Makali village

i: Reliance godown floor washing water flow to river in Madanayakanahalli village

j: Granite slurry dumped near the river in Kadabagere village

k: Active quarry in Giddenahalli village

l: Granite slurry dumped near the river bridge of Giddenahalli village


m: Construction & Demolition waste dumped near the drain in Harokyathanahalli village


n: Solid wastes burned near the drain in Harokyathanahalli village


o: Drain carrying sewage from BBMP area near BIEC in Madhavara village


p: Sewage flow in the Madhavara village drain


q: Solid waste dumped near the drain in Madhavara village


r: Construction & Demolition waste dumped near the drain in Dombarahalli village

s: Sewage flow in drain of Dombarahalli village

t: Effluents flow in drain connected to the Arkavathi river in Thirumalapura village of Zone-1

Chapter-8: An Analysis of Various Stakeholder Meetings

8.1. Introduction:

In order to understand the entire issue of the TGR catchment including the socio-economic aspects of the villagers residing in and around the declared zones, four stakeholders meetings were conducted in each zone of the TGR by inviting the Elected Members, Executive officers, Taluk Panchayat Officers, Assistant Directors, Panchayat Development Officers, Gram Panchayat Secretaries and General Public. In this Chapter, the opinion expressed by the local people has been explained as well as the roles and functions of the concerned Government Authorities has been analysed.

8.2. Stakeholder Meetings:

8.2.1. First stakeholder Meeting: The first stakeholders meeting was conducted for the Zone-2 (Area covered within 2 kilometres from the Tippagondanahalli reservoir boundary). In the total extent of the catchment area the Zone -2 covers a part of Magadi Taluk, Nelamangala Taluk and Bangalore South Taluk. There are 15 villages coming under the jurisdiction of the Bachenahatti Gram Panchayat of Magadi Taluk (Figure-8.1) with 17 hamlets. The meeting was conducted on 17th December, 2014 under the Chairmanship of the President of the Bachenahatti Gram Panchayat (Annexure-8.1).

Figure-8.1. Stakeholders Meeting Chaired by the President of the Bachenahalli Gram Panchayat

8.2.2. Second Stakeholder Meeting: The second stakeholders meeting was conducted in connection with the Zone-2 as the part of the reservoir that falls in the Bangalore South Taluk. There are 23 villages coming under the jurisdiction of the Chaudanayakanahalli Gram Panchayat of Bangalore South Taluk. The meeting was conducted in the Chaudanayakanahalli Gram Panchayat office (Figure-8.2) of Bangalore South Taluk by inviting the elected members, Panchayat Development Officer and Senior Citizens from 23 villages of the Chaudanayakanahalli Gram Panchayat, Bangalore South Taluk on 19th December, 2014 under the Chairmanship of the President of the Chaudanayakanahalli Gram Panchayat (Annexure-8.2).

Figure-8.2. Stakeholders Meeting Chaired by the President of the Chaudnayakanahalli Gram Panchayat

Figure-8.3. Stakeholders Meeting Chaired by the Executive Officer of the Nelamangala Taluk Panchayat

8.2.3. Third Stakeholder Meeting: The third stakeholders meeting was conducted for the Zone-1, 3 & 4 of the Kumudvathi Stream (Entire Thippagondanahalli reservoir catchment, Area that falls within 1 kilometre distance from the river banks of Arkavathi and Kumudvathi and Area that falls within 1 to 2 kilometres distance from the above mentioned rivers upto Hesaraghatta tank) and in the total extent of the catchment area the Kumudvathi river covers a part of Nelamangala and Magadi Taluk. There are 14 Gram panchayats coming under the Nelamangala taluk (Figure-8.3). The meeting was conducted in the Nelamangala Taluk Panchayat, on 02th January, 2015 under the Chairmanship of the Executive Officer of the Nelamangala Taluk Panchayat (Annexure-8.3).

Figure-8.4. Stakeholders Meeting Chaired by the Executive Officer of the Bangalore North Taluk Panchayat

8.2.4. Fourth Stakeholder Meeting: The fourth stakeholders meeting was conducted for the Zone-1, 3 & 4 of the Arkavathi Stream (Entire Thippagondanahalli reservoir catchment, Area that falls within 1 kilometres distance from the river banks of Arkavathi and Kumudvathi and Area that falls within 1 to 2 kilometres distance from the above mentioned rivers upto Hesaraghatta tank) and in the total extent of the catchment area the Arkavathi river covering a part of Bangalore North, Devanahalli, Chikkabalapura and Doddabalapura Taluk. There are 30 Gram panchayats coming under the Bangalore North taluk out of which 10 Gram panchayats fall in the catchment area. The meeting was conducted in the Bangalore North Taluk Panchayat, on 17th January, 2015 (Figure-8.4) under the Chairmanship of the Executive Officer of the Bangalore North Taluk Panchayat (Annexure-8.4).

8.2.5. Suggestions from Stakeholder:

The issues raised by the participant in the meetings and the suggestions received from them are summarised below;

i. Local people expressed lack of awareness of the 2003 notification. The people have come to know about the 2003 Notification only after receiving the demolition notice by the authorities like BDA, BMICAPA etc. in the month of Aug, 2013.

ii. The local people requested to reconsider the zones for restricted activities (Zones-2, 3 & 4) from 2 Km to 100 mtr in the declared zones of the catchment area and further to allow construction of houses, dairy & poultry farms and brick factories, which are the livelihood of the farmers.

iii. The local people expressed their difficulties in carrying out agriculture due to insufficient availability of surface or ground water for irrigating agriculture and also expressed problems of contamination of groundwater.

iv. They also expressed the impacts on their livelihood because of notification since people are not coming forward to buy/purchase their lands nor they are able to take up any developmental activities in their own land due to this notification.

v. **They suggested that any development activities coming up along the river beds and around the reservoir should be prohibited and also government should take stringent action for conservation of river and catchment area.**

vi. **They suggested that to rejuvenate the reservoir, eviction of all the illegal/unauthorized activities along the river should be taken up by the authorities.**

vii. **It is necessary to survey and demarcate the boundaries with fencing the TGR reservoir and also all along the Arkavathi and Kumudvathi river banks to maintain buffer zones and for avoiding dumping of solid waste, garbage, industrial wastes etc., and also to avoid the unauthorized activities.**

viii. **Government should take action for restricting the polluting activities in the surrounding area of TGR catchment area for conservation.**

ix. **All natural drains of Arkavathi and Kumudvathi rivers should be rejuvenated by clearing the encroachment for free inflow of water to TG Halli catchment area.**

x. Discharge of effluent/sewerage from the upstream of the rivers should be diverted since it not only pollutes the T.G.Halli reservoir and also the seepage water flows into Manchanabale Dam where this is further supplied for drinking purpose to Magadi town.

xi. **Illegal sand mining, quarrying and crushers which are operating till today be monitored and serious action taken.**

xii. **The Deputy Commissioners should not sanction any conversion for agriculture land to Commercial purpose, to control unauthorized layouts that are mushrooming in the whole catchment area.**

xiii. **The usage of pesticides/insecticides for vegetable crops should be stopped to avoid polluted water entering reservoir.**

xiv. The old village settlements should be reconsidered for relaxation of the buffer zone for natural expansion.

xv. **The buffer zone should be demarcated and it should be published through newspapers, display board, publicity through electronic media etc.**

xvi. **Setting up of a separate TG Halli catchment area conservation authority to avoid involvement of multiple agencies.**

xvii. Lack of co-ordination among the line Departments and Authorities of the Government has resulted in all the illegal activities.

xviii. Relaxing the buffer zone of 1 Km to 100 - 300 m. Those who are within the 300 mts should be compensated after acquisition of land.

xix. Even today the Arkavathi river is considered as a divine river: where though there is a conflict between environment and the development most of the people along the river bed still worship ganga puja in this catchment area example Thugalamma temple in Hessaraghatta reservoir and Bidluru Gangamma in Kodihalli, and hence there is a need to revive the river.

8.3. The Role and Efforts made by the Government Departments:

In accordance with the 10 Terms of Reference given by the Hon'ble High Court, EMPRI conducted an Advisory Committee Meeting inviting with all the concerned line departments, Authorities, Boards, Deputy Commissioners in order to collect information and action taken relating to the TGR catchment area. The meeting proceedings are placed in Annexure-1.9 and 1.10.

Further from information provided by the Departments, it is found that that the Departments have already made following efforts during the 7th meeting of TGR monitoring committee.

8.3.1. Department of Urban Development:

Department of Urban Development has informed in the 7th meeting of TGR monitoring committee (Annexure-8.5), that Dept. has proposed to create a separate authority called the Arkavathi and Kumudvathi River Basin Conservation and Development Authority for the TGR area by framing **"The Karnataka Arkavathi and Kumudvathi River Basin Conservation and Development Bill, 2013"** (Annexure-8.6) and informed that this act would pave way for effective implementation of the Notification dated 18.11.2003.

8.3.2. Department of Mines and Geology:

Department of Mines and Geology have taken stringent action based on the Govt. Notification No.FEE.25 ENV 2000 dated 18.11.2003. 05 cases in the Bangalore North Taluk, 20 cases in Magadi Taluk, 20 cases in Nelamangala Taluk for grant of new leases have been rejected. 06 jelly crushers licenses have been cancelled which existed in the catchment area (Annexure-8.5). One quarry activity has been identified in the Kadukarenahalli village of Nelamangala taluk and FIR has been filed. Both the Nelamangala Rural Police Station in coordination with Revenue Department has taken action.

8.3.3. Bangalore Water Supply and Sewerage Board (BWSSB):

BWSSB has informed in the 7th meeting of TGR monitoring committee that they identified an unauthorized layout in TGR zone-3 in the Kadabagere village boundary near to Kittanahalli bridge of Nelamangala Taluk (Annexure-8.5). Further they have consulted experts of national and international repute to take their suggestion and build up suitable proposal for revival of TG Halli reservoir.

8.3.4. Nelamangala Planning Authority (NPA):

Nelamangala Planning Authority has informed in the 7th meeting of TGR monitoring committee that out of 95 unauthorized non-residential developments, 16 have come up before 2003 and 79 after notification, out of which 25 are in Bangalore North Taluk and 70 in Nelamangala Taluk (Annexure-8.5). Notices have been issued to the building owners under section 15 and 17 of KTCP Act 1961 and public notification through newspaper has been published on 06.05.2014 for demolition of unauthorized developments coming under TGR Zone-3.

8.3.5. Bangalore Development Authority (BDA):

Bangalore Development Authority has informed in the 7th meeting of TGR monitoring committee that 167 unauthorized layouts and 238 unauthorized non-residential buildings have been identified and notices to the 1132 owners under Section 17(4) and 15(4) of KTCP Act, 1961 and under rules 37 of Planning authorities rules 1965 and under Section 32(7) & (9) of BDA Act, 1976 have been issued. 358 notices have been returned, 95 layout owners and 45 building owners have replied to the notice (Annexure-8.5). BDA has formed a sub-committee to review the objections received for the notice. BDA has formed a sub-committee to review the objections received from the aggrieved owners on 12.02.2014 and 13.02.2014. The sub-committee has taken the following decision.

- Demolition order issued in 48 cases (22 un-authorized layouts, 26 non-residential buildings)
- In respect of owners of 799 un-authorized layouts, 185 non-residential building who have not replied to the notices and 358 notices which have been returned, action is being taken to serve the notices directly and also through Gram Panchayats.

8.3.6. Karnataka State Pollution Control Board (KSPCB):

Karnataka State Pollution Control Board is issuing the consents with a condition to provide rain water harvesting facility for only green category industries only in Zone-4.

8.3.7. Magadi Planning Authority (MPA):

Magadi Planning Authority has informed in the 7th meeting of TGR monitoring committee that it has published public notification through newspaper dt.14.03.2014 with owner name, village, Sy.no. and extent for demolition of unauthorized developments coming under TGR zone-3 and the authority has requested DC Bangalore to convene a meeting for the demolition of unauthorized developments. MPA also has written a letter to the Additional Director of Urban and Rural Planning and Member Secretary, TGR Monitoring Committee to direct BESCOM (Annexure-8.5) for disconnecting the electricity supply for the unauthorized buildings coming in TGR Zone-3 dated 03.04.2014.

8.3.8. Bangalore International Airport Area Planning Authority (BIAAPA):

Bangalore International Airport Area Planning Authority has informed that they are taking action for the removal of unauthorized developments (Annexure-8.5) with co-operation from the Zilla Panchayat and the Revenue Department.

8.3.9. Cauvery Neeravari Nigam Limited (CNNL):

A project for the rejuvenation of Arkavathi and Kumudvathi rivers and its tributaries has been taken up in three packages. Administrative approval has been obtained for the DPRs for a total area of 1448 sq.km and 1319 km nala length. The rejuvenation works include (a) the removal of jungle clearance and desilting of nala from the Nandi hills to Hesaraghatta reservoir of Arkavathi river stretch (b) Hesaraghatta reservoir to TGR and (c) birth place of Kumudvathi river to TGR. Panchayat and Revenue Department are directed to fix the boundary stone and to evict encroachment on Arkavathi and Kumudvathi rivers and its tributaries respectively to co-operate with CNNL.

EMPRI also wrote letters to all the Departments to furnish information (Table-8.1) relating to permission given by them in the TGR catchment area. Pertaining to the letter Nelamangala Planning Authority (Annexure-8.7), Magadi Planning Authority (Annexure-8.8), Department of Mines and Geology (Annexure-8.9), Karnataka State Pollution Control Board (Annexure-8.10) and BIAAPA (Annexure-8.11) have furnished the details.

Table-8.1. Secondary data furnished by the line Departments with respond to the EMPRI letter

Sl. No.	Name of the Departments/Authorities	Details Furnished
1.	Department of Mines and Geology	Furnished the groundwater fluctuation and quality from the observatory wells (Annexure-8.9)
2.	Bangalore Water Supply and Sewerage Board (BWSSB)	• Furnished salient features of TGR; Inflow data of CRS reservoir from 1937-38 to 2014-15; TGR water sample analysis results from 2000 to November, 2014; Annual Rainfall data in the catchment area of CRS reservoir TG Halli from 1901 to 2010. • Information with regard to the no. of existing Wastewater Treatment Plant, its capacity and treatment facility and also the details of the new wastewater treatment plants coming up were collected. Rain fall data for 30 years, inflow data and water quality data
3.	Nelamangala Planning Authority (NPA)	• Furnished the list of authorized and un-authorized residential layouts in TGR Zone-3 and notice issued for eviction to the concerned (Copies of the notices are enclosed). Information regarding the formation of the committee is also furnished (Annexure-8.7). • Out of 95 unauthorized non-residential developments, 16 have come up before 2003 and 79 after notification, out of which 25 are in Bangalore North Taluk and 70 in Nelamangala Taluk. Notices have been issued to the building owners under section 15 and 17 of KTCP Act 1961 and public notification through newspaper have been published on 06.05.2014 for demolition of unauthorized developments coming under TGR Zone-3.
4.	Bangalore Development Authority (BDA)	Furnished the information regarding the unauthorized developments in Zone-3 of TGR catchment area. Newspaper notifications and a presentation on 'Rejuvenation Program of Arkavathi River'.
5.	Dept. of Agricultural / Horticultural	No information is available from both the Departments
6.	Bangalore Metropolitan Region Development Authority (BMRDA)	Furnished the Status Report of the Monitoring Committee constituted for TGR. Apart from this, no information is provided by the Authority and they have requested to collect the information from the concerned Planning Authorities in its reply.
7.	Magadi Planning Authority (MPA)	• Furnished the list of approved layouts, list of land conversion for technical opinion in Zone-4. • Details on agriculture land such as area under cultivable and non-cultivable land, rainfall data (2008 –2014), crop pattern, usage of surface and ground water, quantity of fertilizers and pesticides used, and usage of bio-pesticides, bio-fertilizers and water conservation activities in the catchment area.

Sl. No.	Name of the Departments/Authorities	Details Furnished
8.	Karnataka State Pollution Control Board (KSPCB)	Furnished the Water Quality report on TGR, Arkavathi and Kumudvathi rivers and also the list of existing industries in the entire TGR catchment area including mining, quarrying and stone crushers. Further it is submitted that KSPCB has taken action by issuing closure directions to the industries which are established and operating in zone-3 of TGR area. List of the industries that have been issued closure order is enclosed. Water quality and working efficiency report of ETP or CETP in TGR catchment area and also STP located in Jindal lake is submitted (Annexure-8.10)
9.	Dept. of Agriculture (Joint Director of Agriculture)	Furnished the details of the village no., Geographical area, rainfed area, irrigated area and total cultivable land of the Bangalore south, Devanahalli, Doddaballapur and Nelamangala taluks. General information such as crop pattern, water level, quantity of fertilizers & pesticides is given
10.	Bangalore International Airport Area Planning Authority (BIAAPA)	BIAAPA has furnished the list of approved layouts, residential and commercial superstructures (Annexure-8.11). List of Conversion Opinion files.
11.	Directorate of Census operations, Karnataka	District census booklets of Census of India 2011 were collected for the Bangalore Urban, Bangalore Rural, Ramanagara, and Chikkaballapura districts. Softcopy of Census 1991 and 2001 were also collected to gather information on Population, Households and the extent of the village
12.	Bangalore Urban District (DC office)	Not responded
13.	Bangalore Rural District (DC office)	Furnished the groundwater quality and the groundwater level from the observatory bore-well. The land conversion orders from 01.04.2012 to 31.05.2014 were collected
14.	Bangalore Mysore Infrastructure Corridor Area Planning Authority (BMICAPA)	Not responded
15.	Lake Development Authority (LDA)	There is no data regarding TGR
16.	Central Water Commission	As they are not monitoring the minor rivers in the state, there was no data regarding the Arkavathi and Kumudvathi rivers

Sl. No.	Name of the Departments/Authorities	Details Furnished
17.	Cauvery Neeravari Nigam Limited (CNNL)	• Furnished the information on 2nd Advisory Committee Meeting on TGR catchment area held on 12.02.2015 informed that the work "Rejuvenation of Rivers Arkavathi and Kumudvathi and its tributaries" in three packages after the approval of Govt. vide Order no. JSE 23 MMK 2009, dated 19.10.2011. (i) Birth place of Arkavathi river to Hesaraghatta Reservoir (Total length of the streams is 382.78kms and catchment area is 381.85 sq.kms). (ii) Birth place of Kumudvathi River to Thippagondanahalli Reservoir (Total length of the streams is 459.77 kms and catchment area is 464.56 sq.kms). (iii) Hesaraghatta Reservoir to Thippagondanahalli Reservoir (Total length of the streams is 476.51 kms and catchment area is 602.22 sq. kms). The major components of the project are clearing jungle, removal of silt in bed and excavation in soil for side slopes • It is submitted that the 394 tanks in the catchment have started getting filled with water, Hesaraghatta reservoir has received the water of 10–12ft. after 20 years due to rejuvenation, Thippagondanahalli reservoir has received about 40–45ft. of water in the current year; further obstructions/encroachment along the streams and tributaries are identified and about 124 acres of encroachment has been cleared and original valley course has been restored. It is reported that there is increase in the annual runoff from the last 2 years and the aquifers of the borewells which were dried up earlier are now got considerably replenished • The tanks in the catchment have getting filled with water and out of 394 tanks in the catchment, the status of tank filling is detailed as under; upto 100%-80 tanks: 80-90% - 135 tanks; 70-80% - 120 tanks and 60% - 59 tanks. Hesaraghatta reservoir which was completely dry since the past 20 years has received about 10-12ft. of water (0.35TMC). TGR has received about 40–45ft. (1.5 TMC) of water in the current year. Encroachment/ obstructions along the streams and tributaries are identified and about 124 acres of encroachment have got cleared and original valley course is restored. There is increase in the annual runoff from the last two years. The aquifers of the bore-wells which dried up earlier are now got considerably replenished

Chapter-9: Methodologies Adopted in other States in India and other Countries for Rejuvenation, Conservation and Preservation of Rivers and River Courses in Urban Agglomerations

9.1. Introduction:

Rivers, tributaries, lakes and other water bodies form an interconnected web of circulatory system pumping life into all the living organisms, animals and plants on this planet. River with its own natural flows, ecology and aquatic biodiversity is an ecosystem in itself and needs to flow if it has to perform its ecological functions and provide services to nature and human kind. Unsustainable development pathways and rapid urbanization leading to tremendous pressure on natural resources have affected the quality and availability of river water resources, thereby affecting their capacity to generate social and economic benefits, especially in urban set ups. Management and restoration of river ecosystems require holistic, interdisciplinary approaches based on an understanding of the relations between physical, chemical and biological processes at varying time scales. Rejuvenation, conservation and preservation of rivers are very important national priorities and national and state level initiatives have been in vogue since many years. The methodologies used by different states vary from state to state and there is a dire necessity to make a holistic view to decide on the future course of action to bring in equitable, sustainable, participatory, decentralized, democratic and transparent approach to river water management.

9.2. Legal and policy framework:

The history of river water management in India goes back a long way, even before some civilizations had begun settling down as organised societies. In the independent India, the constitutional provisions under Articles 51A(g), 48A and Article 21 make it abundantly clear that in order to uphold the most important fundamental right of every individual, the very source of all water, the rivers, must be protected by the people and state must take all necessary action to ensure this protection. The first attempt at river basin management was through an act of parliament when the Damodar Valley Corporation Act was passed in 1948. In 1956, the parliament passed the River Boards Act. In 1976, Betwa River Board was set up through an act of the parliament. In 1980, Brahmaputra Board was set up under an act of the parliament, under the Ministry of Water Resources, covering the Brahmaputra and the Barak Valleys for planning, investigation and implementation of water resources projects in these valleys (Himanshu Thakkar, 2012).

Some of the important Acts that directly or indirectly affect conservation or management of rivers and protection of lakes, inland water bodies and other water resources include : Interstate River Water Disputes Act, 1956; River Boards Act, 1956; The Wildlife (Protection) Act, 1972; The Water (Prevention and Control of Pollution) Act, 1974; The Forest (Conservation) Act, 1980; The Environment (Protection) Act, 1986; The Electricity Act, 2003; Interstate Water Dispute Tribunal awards and The EIA Notification, 2006.

9.3. Water Policy and Rivers:

The earlier National Water Policy was adopted in September, 1987 and it was redrafted as 2002 Draft National Water Policy (NWP). The section under Water Quality in the NWP 2002 had some relevant provisions for rivers: Effluents should be treated to acceptable levels and standards before discharging them into natural streams; minimum flow should be ensured in the perennial streams for maintaining ecology and social considerations; Necessary legislation is to be made for preservation of existing water bodies by preventing encroachment and deterioration of water quality.

9.3.1. National Water Policy, 2012:

The National Water Policy, 2012 has considered water as a scarce natural resource. The objective of the National Water Policy is to take cognizance of the existing situation, to propose a framework for creation of a new system of laws and institutions and a plan of action with a unified national perspective. Such a framework law must recognize water not only as a scarce resource but also as a sustainer of life and ecology. Therefore, water, particularly ground water, needs to be managed as a community resource, held by the state, under public trust doctrine to achieve food security, livelihood etc.

The policy has emphasized on strengthening and institutionalization of community based water management. The policy has also talked about adaptation to climate change through better demand management, particularly through adoption of compatible agricultural strategies and cropping patterns and improved water application methods such as drip/ sprinkler irrigation etc. As a strategy for enhancing water available for use to address the issues of rapid urbanization, population growth etc., direct use of rainfall, desalination and avoidance of inadvertent evapotranspiration should be adopted. It has also emphasized on introduction of improved technologies of water use, incentivizing efficient water use and community based management of aquifers to address the issue of declining ground water levels in over-exploited areas. The Policy has also emphasized on pricing of water to ensure efficient use and equitable access to water. The policy has talked about fair pricing for drinking and other uses such as sanitation, agricultural and industrial through independent Statutory Water Regulatory Authority, set up by each State.

As regards to conservation of river corridors, water bodies and infrastructure, the policy has emphasized that they should be undertaken in scientifically planned manner through community participation and restore the encroached rivers, lakes, tanks, ponds, etc. to the possible extent. The storage capacities of water bodies and water courses and/ or associated wetlands, the floodplains, ecological buffer and areas required for specific aesthetic, recreational and/or social needs may be managed to the extent possible in an integrated manner to balance flooding, environmental and social issues as per prevalent laws through planned development of urban areas. The Policy has also emphasized on the need to remove the large disparity between stipulations for water supply in urban areas and in rural areas. Efforts should be made to provide improved water supply in rural areas with proper sewerage facilities. Least water intensive sanitation and sewerage systems with decentralized sewage treatment plants should be incentivized.

The Policy says that water resources projects and services should be managed with community participation. Integrated Water Resources Management (IWRM) taking river basin/ sub-basin as a unit should be the main principle for planning, development and management of water resources. The Departments/ organizations at Centre/ State Governments levels should be restructured and made multi-disciplinary accordingly. Appropriate institutional arrangements for each river basin should be developed to collect and collate all data on regular basis with regard to rainfall, river flows, area irrigated by crops and by source, utilizations for various uses by both surface and ground water and related aspects. Appropriate water accounts for each river basin with budgets and accounts should be published. The State Water Policies may need to be drafted/ revised in accordance with policy.

The **National Water Mission,** one of the eight missions in the National Action Plan on Climate Change (EMPRI and TERI, 2013), aims for conservation of water, minimizing wastage and ensuring equitable distribution across and within states through integrated water resources development and management. The main objective of this Mission is to achieve **integrated management of water resources by conserving water, minimizing wastage and ensuring its more equitable distribution both across and within various States of our Union.** With this objective, five goals have been identified and strategies for achieving these have been identified. The five goals are:

- Establishment of a comprehensive water resource database in the public domain;
- Promotion of citizen and state actions for sustainable water consumption;
- Conservation and augmentation;
- Focused attention on over-exploited areas;
- Increasing the efficiency of water uses by 20%;
- Basin-wise designs for integrated water resources management.

9.4. River Conservation Initiatives at the National Level:

9.4.1. National River Conservation Directorate (NRCD):

The National River Conservation Directorate (NRCD) in the Ministry of Environment, Forests and Climate Change is implementing the Centrally Sponsored Schemes of National River Conservation Plan (NRCP) and National Plan for Conservation of Aquatic Eco-systems (NPCA) for conservation of rivers, lakes and wetlands in the country. The objective of the River Action Plans is to improve water quality of rivers through implementation of pollution abatement schemes in identified polluted stretches of rivers. NPCA aims at conserving aquatic ecosystems (lakes and wetlands) through implementation of sustainable conservation plans, and governed with application of uniform policy and guidelines.

9.4.2. National River Conservation Plan (NRCP):

The river conservation programme in the country was initiated with the launching of the Ganga Action Plan (GAP) in 1985. The Ganga Action Plan was expanded to cover other rivers under National River Conservation Plan (NRCP) in the year 1995. NRCP, excluding the GAP-I, GAP-II and National Ganga River Basin Authority (NGRBA) programme presently covers polluted stretches of 40 rivers in 121 towns spread over 19 States. The pollution abatement works are implemented on a cost sharing basis between the Centre and State Governments. Prevention and control of industrial pollution is being addressed by the Central and State Pollution Control Boards / Pollution Control Committees. In their last report of 2015, 302 polluted river stretches have been identified, out of which pollution abatement works in some of the stretches have been taken up under NRCP.

9.4.3. National Lake Conservation Plan (NLCP)

National Lake Conservation Plan (NLCP) was initiated by MoEF in June, 2001. The objective of NLCP is to restore and conserve the urban and semi-urban lakes of the country degraded due to waste water discharge into the lake and other unique freshwater ecosystems, through an integrated ecosystem approach. NLCP has supported the conservation and restoration of over 60 lakes in 14 states including Karnataka with the help of relevant departments and agencies of the state governments, with cost sharing between the Central Government and the States (70%:30%). In Karnataka a Lake Development Authority (LDA) was created and many States such as Madhya Pradesh, Manipur, Odisha etc. have constituted Lake Conservation Authorities either at the State level or for specific lakes/ water bodies. The MoEF has also been promoting wetland conservation through the National Wetlands Conservation Programme. To avoid overlap and promote better synergies, both the schemes NLCP and NWCP have been merged in February, 2013 into a new scheme called 'National Plan for Conservation of Aquatic Eco-systems' (NPCA).

MoEF has asked all states to constitute City Level Monitoring Committees (CLMCs) for all river and lake conservation projects for improving implementation and enhancing coordination between the Centre, the States and the Urban Local Bodies. CLMCs besides ensuring timely implementation, monitoring flow of funds and better coordination between concerned agencies, are also expected to secure public cooperation and facilitate community mobilization for the conservation of lakes and rivers in the region. MoEF has recognised the need of adequate trained manpower in various scientific and technical, social, economic, administrative aspects of conservation of lakes and rivers and has sponsored a multidisciplinary course "Conservation of Rivers and Lakes" with Alternate Hydro Energy Centre at the IIT, Roorkee. Activities aimed at creating public awareness and public participation are built into individual projects and are carried out by the implementing agencies in the respective states.

9.4.4. Proposed River Regulation Zonation (RRZ) for Regulation of Human Activities along Rivers and Lakes

During the National workshop on conservation of rivers and floodplains in Jawaharlal Nehru University (Delhi) held on 23-24 Nov 2001, it emerged that MoEF should take immediate necessary action to formulate the requirements for issuing notification for River Regulation Zone (RRZ) under the Environment Protection Act on lines similar to those of Coastal Regulation Zone (CRZ) notification. Consequently, the report – 'Regulation of Human Activities Along Rivers and Lakes', 2002 was prepared for National River conservation Directorate (NRCD), MoEF, GOI by the National Institute of Ecology (Brij Gopal *et al.*, 2002). Meetings were called by NRCD on January 8, 2002 and September 26, 2002 to discuss this further. However no further progress could be made. The meeting discussed the need to regulate the various activities affecting the rivers and floodplains. In January, 2011 the Union Environment Minister spoke about a RRZ notification to protect riverbeds from encroachments in the future. Though some of the states have adapted RRZs for their own activities, a national RRZ policy on the lines of CRZ is yet to get formulated. The Ministry has set up an Expert Group to formulate RRZ, which is now in the process of drafting a notification for RRZ on the lines of CRZ notification.

The report discusses and provides information on rivers of India, reasons for conservation of rivers, discusses river as ecosystem, lists various activities affecting the river such as human activities, urbanization, industrialization, extensive agricultural activities, encroachment on the flood plains, state of degradation etc. Zoning of rivers on the basis of climatic and geomorphic features is proposed (Table-9.1). The legal framework and suggestions for institutional mechanism and inter-ministerial coordination are discussed.

Construction of rail/road bridges, activities associated with power stations, irrigation, water supply and multipurpose reservoirs, specifically approved projects for the restoration of rivers/floodplains and for scientific purposes (research monitoring) are to be exempted from regulation. Further, it is also proposed to consider all the lakes and reservoirs apart from those covered by RRZ to bring into the purview of this notification as the human activities are similar in nature and have similar impacts on water resources and the ecosystem integrity of the lakes. A minimum belt of 500m to 1 km around the lakes (natural or manmade) from their highest shoreline (bank full level) has been proposed to be designated as buffer zone for regulating certain activities. The buffer zone may be extended to 10 km for specific industrial activity whenever it is necessary. Variety of other activities is also proposed to be regulated in and around the lakes.

Table-9.1. Suggested regulations within a distance of 500 m from the boundary of the floodplain in the proposed zones

Zones	Major Features	Totally Prohibited Activities	Regulated Activities
RRZ-I	Ecologically sensitive & fragile watershed areas, areas mostly in foothills (medium elevations), areas of pristine, heritage sites, areas rich in genetic diversity or important for biodiversity	All polluting activities including permanent or temporary construction (Residential, commercial, religious, recreational), agrochemical based cultivation, disposal of all kinds of solid wastes including religious offerings & idol immersion	Nil
RRZ-II	River channels & their flood plains in the hills (>300 m altitude), generally low human population density, high flow velocity, river regulation relatively low	Permanent or temporary construction on floodplains and on hill slopes facing the river, mining or quarrying on hills, use of fertilizers and pesticides for agriculture, solid waste disposal	Forage removal/grazing on hill slopes, gravel or sand mining
RRZ-III	River channels & their floodplains at lower elevation (<300 m), within municipal limits (high population densities) where floodplain has already been heavily reduced & infrastructure facilities are well developed. River stretches generally heavily regulated or channelised, water quality much degraded & restoration most difficult	No further extension of any infrastructure that may necessitate reduce the remaining floodplain or affect the course of the river channel, disposal of all kinds of solid wastes, ground water extraction	Limited extraction beyond 500 m of the river channel
RRZ-IV	Lower elevation (<300m) in suburban and rural areas where infrastructure development has not occurred or is only moderate, land is primarily under agriculture & grazing, areas with low degradation but high potential for restoration	All polluting activities including permanent or temporary construction (Residential, commercial, religious, recreational), agrochemical based cultivation, disposal of all kinds of solid wastes, ban on drainage and reclamation of existing wetlands	Gravel and sand mining, grazing and forage removal

9.5. Status of River Conservation in Different States:

The steps taken by different states are reviewed to get an idea of the status of conservation and rejuvenation of rivers and other water bodies in different states of India. Various states have adopted their own policies or following national regulations in vogue to conserve the rivers, lakes and other water bodies in the state. State wise analysis of various policies and activities which enable the conservation and rejuvenation of rivers is provided with details.

9.5a. Water Resources Regulatory Authority Constituted by Various States:

The water sector in India had changed after post-liberalisation era and the development of new institutional frame work has led to the formation of independent water regulatory authorities. The regulatory authority exercises rule making power, implementing these rules, and settle disputes (Koonan and Bhullar, 2012). Andhra Pradesh set up a separate authority for water regulation at the state level, adopted through Andhra Pradesh Water Resources Development Corporation Act, 1997. But this regulatory authority was only technically separate from the government and continued to be controlled by the government. Maharashtra is considered the first state in the country to set up a state level independent Maharashtra Water Resources Regulatory Authority (MWRRA) constituted by The Maharashtra Water Resources Regulatory Authority Act, 2005. Maharashtra is a model for many other states to establish regulatory authorities. Regulatory authorities established in other states are Arunachal Pradesh Water Resources Regulatory Authority (Arunachal Pradesh Water Resources Regulatory Authority Act, 2006), Uttar Pradesh Water Management and Regulatory Commission (Uttar Pradesh Water Management and Regulatory Commission Act, 2008), Jammu and Kashmir State Water Resources Regulatory Authority (Jammu and Kashmir State Water Resources (Regulation and Management) Act, 2010), Gujarat Water Regulatory Authority (Gujarat Water Regulatory Authority Notification, 2012), and Kerala State Water Resources Regulatory Authority (Kerala State Water Resources Regulatory Authority Bill, 2012). But, the Authority has been operationalized only in the State of Maharashtra.

9.5.1. Karnataka:

9.5.1a. State Water Policy 2002:

The State Water Policy of Karnataka aims at

- Providing drinking water at the rate of 55 LPCD (litres per capita per day) in rural areas, 70 LPCD in towns, and 100 LPCD in city municipal council areas and 135 LPCD in city corporation areas;
- Stepping up irrigation to reach an accumulated 45 lakh hectares under major, medium and
- Minor irrigation projects;
- Improved productivity of irrigated agriculture by involving users in irrigation management;
- Harness the hydropower potential in the state;
- Provide a legislative, administrative and infrastructural environment, which will ensure fair, just and equitable distribution and utilisation of water resources.

The State Water Policy has not been revised after the National Water Policy has come into vogue in 2012. In principle the National Water Policy 2012 is in effect as far as the State of Karnataka is concerned

9.5.1b. Regulations regarding Rainwater Harvesting:

The establishment of Rainwater harvesting (RWH) structure has been made mandatory for certain categories of buildings within the area of Bangalore Water Supply & Sewerage Board (BWSSB) and enforced by BWSSB itself through the Bangalore Water Supply and Sewerage (Amendment) Act, 2009. According to press articles, some 25,000 RWH systems have been established in the 58,000 buildings coming under the purview of the Act. Though it is a noteworthy achievement, a lot more needs to be done.

9.5.1c. Water Resources Management:

In order to address knowledge deficits in water management and for providing a platform for the inclusion of stakeholders in decision processes, GoK established the Karnataka Water Resources Authority under chairmanship of the Minister for Water Resources in 2008. There is however an impression that the authority failed to live up to expectations. In addition a Groundwater Authority is now established under the Karnataka Groundwater Act, 2011. There is a rapidly growing understanding that water is a precious resource that requires protection and professional management. This led to the transformation of the former Irrigation Department into the Water Resources Department. Besides planning, constructing and monitoring irrigation projects, the department develops command areas, collects and analyses hydrological data and, by mandate, is required to conduct research. Subsidiary bodies include the Water Resources Development Organisation (WRDO) and a number of Command Area Development Authorities. However the primary role of Water Resources Department has been implementation of Irrigation Projects and much less on river basin management or integrated water management.

9.5.1d. Municipal Water Supply:

The second priority of BWSSB is addressing the water supply deficit. Bangalore is receiving only around 800 MLD of its required 1,200 MLD from surface water and the difference is chiefly met by groundwater drawings. The board has been criticised for focussing on augmentation of further water resources (500 MLD from the Cauvery River) while not succeeding in reducing unaccounted-for water (UFW), which stands at 48%. This amount would suffice meeting water requirements altogether and may last for another 5-10 years if one assumes continued rapid growth of Bangalore. It is noted with appreciation that BWSSB has commenced tendering of work addressing unaccounted-for water for around 1 lakh households, a scale greater than that of a pilot project. This leaves hope that UFW will be addressed and utilised systematically and thus effectively contribute to reducing water requirements.

9.5.1e. Activities under National River/lake Conservation Plan:

The National River Conservation Programme (NRCP), initiated 1992-93, identified eight towns of Karnataka for initiation of actions on preventing further pollution. Under this scheme, sewage has been diverted from flowing into rivers and sewage treatment plants are established in eight towns, six of which have already been completed. The Karnataka State Pollution Control Board is the nodal agency for implementation schemes under NRCP while work is undertaken by BWSSB and Karnataka Urban Water Supply and Drainage Board respectively.

Government of India provides financial assistance to the state governments to conserve lakes under the National Lake Conservation Programme (NLCP). Activities carried out under this scheme include de-silting, de-weeding, strengthening of bunds, interception and diversion of sewage entering the tanks, fencing and similar work. Conservation plans for 16 lakes in the state have been approved for the year 2002-03 and development of four lakes has been completed by November 2009.

9.5.1f. Department/ Organisations in Karnataka:

i. **The Water Resources Department** is one of the major departments in the Government of Karnataka harnessing the surface water for Irrigation and drinking purposes. The Water Resources Department consists of three major corporations-**Krishna Bhagya Jala Nigam Limited (**KBJNL), **Karnataka Neeravari Nigam Limited (**KNNL) and **Cauvery Neeravari Nigam Limited (**CNNL). These are unique establishments, envisaged as Special Purpose Vehicles for speedy implementation of irrigation projects and to enable the Government to borrow funds from external sources. Some projects are handled by Water Resources Department directly (www.waterresources.kar.nic.in).

   a. **Karnataka Neeravari Nigam Limited (KNNL)** studies the planning and design aspects and monitors the progress of the work and through tracking field periodically, clears bottle necks and ensures time bound progress of work. KNNL also intends to thrust to new areas of development such as participatory irrigation management, encouragement to modern irrigation practices with more duty on water, exploration of new possibility of conjunctive use of water, advocating a holistic approach towards agricultural farming practices for economic security to the farmer and using modern technologies in survey and design of canal systems.

   b. **Krishna Bhagya Jala Nigam Limited (KBJNL)** deals with implementation of the Upper Krishna Project (UKP) in the State of Karnataka. The Company is responsible for planning, investigation, estimation, execution, operation and maintenance of all irrigation projects coming under the UKP. The Company is also entrusted with the responsibility of Rehabilitation and Resettlement of the people affected by the Project.

   c. **Cauvery Neeravari Nigam Limited (CNN)** came to existence on 4-6-2003.The Nigam is proposed to raise funds in the period of 3 years for completion of all ongoing works and modernisation of completed projects in Cauvery basin.

   d. **Jala Samvardhane Yojana Sangha (JSYS)** is a society, established by Government of Karnataka to serve as the nodal Agency in the State for community based tank management (www.jsys.nic.in). JSYS carries out the project for existing Minor

Irrigation and Zilla Panchayath in Tumakuru District, Karnataka state. The project aims to demonstrate the viability of a community-based approach to tank improvement and the management by entrusting the main responsibility to people on a selected basis. After restoring the tanks, they are handed over to the communities who are registered as society. Each of such associations are named as Tank Management Institutions (TMI).

ii. **Karnataka Groundwater Authority:**

Groundwater quality is monitored by the Department of Mines and Geology through network laboratories in all districts of Karnataka. While surface water is not monitored routinely, its quality is assessed in cases of complaints. With financial assistance from World Bank a state-of-the-art Hydrological Information System (HIS) has been established. The department also played a key role in the formulation of the long-anticipated Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011, which received the Governor's assent in April 2011. Through the constitution of an empowered Groundwater Authority, the Act is a key instrument for curbing indiscriminate exploitation of groundwater. **Karnataka Groundwater Authority is constituted to control and prevent over exploitation of ground water in the whole state. Every person, household or firm is required to register with the authority indicating the purpose of use of borewell water and further to get permission of the Authority to dig an open well or drill a borewell in the** notified areas (35 taluks including Bangalore Urban, Bangalore Rural, Ramanagara, Kolar, Chikaballapur and parts of Tumakuru, the over exploited areas). In notified areas, well owners will be obliged to obtain registration certificates for continued use of groundwater which can be refused by the Groundwater Authority if certain conditions are not met. **Further the drilling agency has to register with the authority. Any person found to be violating is susceptible for fine or imprisonment.**

iii. **Lake Development Authority:**

Lake Development Authority (LDA) was constituted vide Government Order No.FEE/12/ENG/02-Bangalore, dated 10th July 2002, registered as a Society under the Karnataka Societies Registration Act, 1959. LDA has its jurisdiction over the metropolitan area of Bangalore, Bangalore Metropolitan Region Development Authority (BMRDA) areas, over the lakes in other City Municipal Corporation and Town Municipal Councils in the State. LDA is a regulating, planning and policy making body like giving clearances to detailed project reports of lake development projects to different authorities and also is the nodal agency for National Plan for Conservation of Aquatic Eco-systems (NPCA) and took up 16 lakes in Karnataka under NLCP, with 5 of them in Bangalore City and 6 projects in Karnataka under National Wetlands Conservation Programme.

Recently in February 2015 the Karnataka Government passed 'The Karnataka Lake Conservation and Development Authority Act, 2014' for constitution of Karnataka Lake Conservation and Development Authority with necessary powers and functions to protect, conserve and rejuvenate the water bodies like tanks, lakes, wet lands and their catchment areas, inlets and outlets for ensuring their long term sustenance. The jurisdiction of the authority extends to all water bodies within the limits of all the city corporations and BDA in the state and any other water body of the state identified by the government. The authority can control and remove encroachments, impose fines and imprison the violator's found discharging untreated sewage into the lake and dumping construction debris.

iv. **Tank Development Authority:**

Karnataka Tank Development Authority Act, 2014 passed in July 2014, provides for the establishment of a Tank Development Authority with the power to protect, conserve and rejuvenate water bodies in the rural areas of the State and to improve groundwater. The Bill empowers the authority to exercise regulatory control over all tanks, ponds and lakes including prevention and removal of encroachments of tank and evict any person found occupying any tank land or part of it with in 30 m from the outer boundary of the tank. Further the Authority has powers to impose penalty or can imprison the violators.

9.5.2. Maharashtra:

Maharashtra had one of the unique River Policy (Table-9.2) which came into effect on 15th July 2000 (G.R. No MMV/2000/326/22/TB-3). The River Catchment Area of 20 rivers were classified in 4 categories based on the designated use of river water, namely A-I, A-II, A-III and A-IV. Water quality for these categories was prescribed, for example, A-I (from origin upto 1st dam) class of river water to be supplied for public water supply after approved disinfection, A-II (from 1st dam to the area designated) class of river water to be supplied after approved treatment equal to coagulation, sedimentation & disinfection and A-III & A-IV both unfit for human consumption, hence A-III class of river water is recommended to be used for fish & wildlife propagation while A-IV class of river water is recommended to be used for agricultural, industrial cooling and process water. Further from High Flood Level (HFL) on either side of the river, the category of industries to be established are specified. But recently the Government of Maharashtra has scrapped the 15 years old policy while the Central Government is still planning to come up with similar policy (Times of India, Feb 2, 2015).

Maharashtra Water Resources Regulatory Authority (MWRRA) was constituted by 'The Maharashtra Water Resources Regulatory Authority Act, 2005'. MWRRA regulates water resource within the State of Maharashtra, facilitate and ensure judicious, equitable and sustainable management, allocation and utilization of water resources, and fix the rates for use of water for agriculture, industrial, drinking and other purposes, and matters connected. As per Section-11 of the MWRRA Act, 2005 read MWRRA (Amendment and Continuance) Act, 2011 the Authority is bestowed with certain powers and functions such as determining the criteria for the distribution of entitlements by the River Basin Agencies, enforcing the decisions or orders issued under the Act, to determine the priority of equitable distribution of water available at the water resources project, sub-basin and river basin levels during periods of scarcity, to establish a water tariff system, and to fix the criteria for water charges at sub-basin, river basin and State level after ascertaining the views of the beneficiary, public etc.

Environment Department, Government of Maharashtra, vide Govt. Resolution dated 15th July'2009 had notified the industrial location policy (Table-9.2) in the river catchments. The restrictions are applicable to industrial areas to be developed by Maharashtra Industrial Development Corporation (MIDC) also. However, for an existing MIDC industrial area where land has been acquired and developed, but the plot allotment has not been done, in such case the restrictions for developing industries shall be applicable up to 500 m from HFL of the river on both sides in AII class area (www.mpcb.gov.in).

Table-9.2. Restrictions of activity in River Course of Maharashtra

<table>
<tr><th>Classes</th><th>No Development Zone for any type of Industries</th><th>Only Green category of Industries with Pollution Control Devices</th><th>Only Orange category of Industries with Pollution Control Devices</th><th>Any type of Industries (Red, Orange, Green) with Pollution Control Devices</th></tr>
<tr><td colspan="5">i. Industrial Location Policy, 2009</td></tr>
<tr><td>A-I</td><td>3 Km</td><td colspan="2">From 3 Km to 8 Km</td><td>Beyond 8 Km</td></tr>
<tr><td>A-II</td><td rowspan="3">1/2 Km</td><td rowspan="3">From 1/2 Km to 1Km</td><td>From 1 Km to 2 Km</td><td>Beyond 2 Km</td></tr>
<tr><td>A-III</td><td rowspan="2">From 1/2 to 1 Km</td><td rowspan="2">Beyond 1 Km</td></tr>
<tr><td>A-IV</td></tr>
<tr><td>MIDC with CETP</td><td>1/2 Km</td><td>From 1/2 Km to 3/4 Km</td><td>From 1/2 Km to ¾ Km</td><td>Beyond 3/4</td></tr>
<tr><td colspan="5">ii. River Policy, 2000 (Scrapped)</td></tr>
<tr><td>A-I</td><td>3 Km</td><td colspan="2">From 3 Km to 8 Km</td><td>Beyond 8 Km</td></tr>
<tr><td>A-II</td><td>1 km & 500m for MIDC</td><td colspan="2">From 1 km to 2 km</td><td>Beyond 2 Km</td></tr>
<tr><td>A-III & A-IV</td><td>0.5 km</td><td colspan="2">From 0.5 km to 1 km</td><td>Beyond 1 Km</td></tr>
</table>

9.5.3. Tamil Nadu:

As early as 1884, The Tamil Nadu Rivers Conservancy Act was enacted for conservation of rivers in the state of Tamil Nadu. The Act has empowered the state Government to notify any river that requires conservation by conducting a survey and determining the limits within which this Act is to be applied. The Act stipulated that charts thereof all existing cultivation, buildings, plantations, constructions, or obstructions within the surveyed limits of the river be prepared and exhibited for public information at the district offices for a period of 90 days, asking for any objection. After the expiry of such period and taking into consideration the objections, the State Government may declare notification that the provisions of this Act shall apply to the said river within the boundaries and limits prescribed in the said charts. Also the Act has provided for appointment of Conservators of Rivers defining the limits of their jurisdiction. **The Act provided for regulation of cultivation, within river-bed area. The conservators were also empowered to direct removal of constructions, plantations, etc. if they deem to be an obstruction to the course of the stream of such river. It is to be noted here that this Act is very strong and is very similar to the Indian Forest Act.**

Government of Tamil Nadu in 2006, in order to protect the lakes and rivers in Chennai from dumping of solid waste and disposal of waste water and also in order to provide healthy environment, formed Chennai Rivers Restoration Trust (earlier named Adyar Poonga). Kosasthalayar, Cooum and Adyar are the 3 rivers flowing between north and south boundaries of Chennai City the capital of Tamil Nadu and the Trust has taken up the Cooum and Adyar river under the project Eco-Restoration of Adyar Creek (Phase-I and Phase-II), and Integrated Cooum River Eco-Restoration Plan. The objective of Eco–restoration of Adyar Phase-1 included restoration of degraded area, rehabilitation of the watershed of Adyar Creek with minimum interface of public for sustainable maintenance, increase of water spread area by excavation, control of sewage discharge from outfalls, recreating vegetation, and gaining animal diversity through implementation of these measures. The Cooum river eco-restoration programme includes promotion of inter-sectorial co-ordination through comprehensive planning and management to ensure effective abatement of pollution and protection of rivers, maintaining minimum ecological flows in the rivers, creation of River Front Development within urbanized areas, identification of projects for pollution abatements and after river restoration exploration of possibility of navigation purpose is also under consideration.

9.5.4. Andhra Pradesh:

Government of Andhra Pradesh, in order to protect the two surface reservoirs, Osmansagar and Himayathsagar, which meet a part of drinking water requirement of the twin cities namely the Hyderabad and Secunderabad of Andhra Pradesh has passed several notifications with different objectives. The Himayathsagar has been built on Musa River, a tributary of Musi and Osmansagar has been built on Musi River. To maintain the continuous inflow of water into the reservoirs Government of Andhra Pradesh vide order dated: 28.01.1989 had **prohibited the interception of any inflows of water into the two lakes and removal of unauthorized check dams, tapping of groundwater in the catchment area and prevention of unauthorized occupation of land etc**.

Further the Govt. vide order dated: 31.03.1994 **prohibited the establishment of polluting industries, major hotels, residential colonies or other establishments that generate pollution in the catchment area within 10 Km radius of Full Tank Level of both the two lakes. Further vide Govt. order dated 08.03.1996, the Government has notified 84 villages falling within 10 kms distance in**

the catchment area as prohibited zone. Both on the upstream and downstream side within 10 km radius polluting industries were prohibited.

Finally, Government in 2007 issued notification (Memo. No. 261/2006, dated 16 -07-2007) to regulate the recent development activities in the downstream of the two reservoirs as per the recommendations of Technical Committee to control direct pollution likely to be caused by such development activities. **Area up to 500 m from the bund/full tank level has been declared as prohibited zone and no development is to be allowed here, beyond this zone (500 m) up to 1000m (1 km) only low rise residential development (ground + 2 floors) is allowed, and beyond 1000 m in the downstream all developments such as Residential, Commercial, Hotels, public and semi public developments are to be allowed and apart from 68 industries listed other industries are allowed 10 kms in the downstream of the reservoirs. A distance of 100 ft. has to be maintained from the raw water channel and the layout or building etc.** Zonal Development Plan incorporating the regulations has to be prepared and strictly enforced by the Hyderabad Urban Development Authority, while MD, Director Hyderabad Metro Water Supply and Sewerage Board to constitute a watch committee to supervise enforcement of these regulations.

Andhra Pradesh Government further in 2009 enacted Andhra Pradesh Water Resources Regulatory Commission Act, 2009 to provide for the establishment of the Andhra Pradesh Water Resources Regulatory Commission for regulation of water resources within the state of Andhra Pradesh, to facilitate effective utilization of water resources within the state to ensure its sustainable and scientific management for drinking, agriculture, industrial and other purposes and matters connected therewith. Further the commission follows the principle that **"the person who pollutes shall pay"** while supporting and aiding enhancement and preservation of water quality within the state in close coordination with the relevant State Agencies. Compared to the Maharashtra Water Regulatory Water Authority the Commission is advisory in nature.

9.5.5. Kerala:

Kerala is networked by 44 rivers of which 41 are west flowing and 3 are east flowing rivers (tributaries of river Cauvery). Of all rivers, Periyar is the longest river followed by the Bharatapuzha and the Pampa rivers. Pampa river is considered a Holy river for both the Sabarimala temple and its pilgrims. For the conservation of the river Pampa and its river basin the Government of Kerala enacted The Pampa River Basin Act, 2009.The Act provides for constitution of Pampa River Basin Authority – a statutory body to prepare policies and co-ordinate and take decisions relating to the matters and implementation of projects under the Pampa Action Plan (PAP), prepared by the State Government of Kerala to execute projects with the objectives of curbing of pollution, integrated planning, monitoring, management and development of water resources in the river and its river basins. The Authority also controls and restricts on over exploitation of natural resources and encroachments which affects the water resources and reservoirs of the Pampa River.

Recently The Revenue Department, Government of Kerala has declared to launch a project called 'Puzha Muthal Puzha Vare' meaning from river to river named after the title of a book by C Radhakrishnan to protect and conserve rivers in the state. **The project would be initiating afforestation measures and converting them into river parks so as to prevent encroachment and pollution of river banks with emphasis on beautification of rivers**. The project will be implemented in Bharathapuzha and Achenkovil rivers on a pilot basis. Local river protection committees will be formed to nurture and protect the rivers and their banks, with the village officer of the selected areas as conveners. The project is expected to curb the encroachment of embankments and illegal sand-mining. (The Hindu, November 21, 2014)

Earlier, Govt. of Kerala in order to protect the river banks and the river beds from large scale removal of sand, the Kerala Protection of River Banks and Regulation of Removal of Sand Act, 2001 was enacted. The removal of river sand is regulated through the formation of Kadavu (river bank) committee in every district by the District Expert Committee which in turn is constituted by the Act. The Kadavu committee supervises and monitors the activities of sand removal and recommends the District Expert Committee on matters related to sand removal such as suitability of the river banks, quantity of sand to be removed, additional actions to be taken for the protection of the river bank, ban on sand removal during any season in a year, etc. and fixes the price of the sand for each Kadavu. Further to control sliding of river bank plantation of bamboo and Attuvanchi is recommended. Sand removal operation within 10mt. of the river bank and parking of loading vehicles within 25mt. of the river bank is not allowed, while allowing only designated amount of sand removal in the river bed only. District Expert Committee apart from protecting the river bank and keeping them free from encroachment has to prepare a River Bank Development Plan for establishing, co-ordinating and protecting river banks within the district giving importance to the bio-physical environment of the river banks.

As per The Kerala Irrigation and Water Conservation Act, 2003 and as per the provisions of section 218 of the Kerala Panchayat Raj Act, 1994 (13 of 1994) and section 208A of the Kerala Municipality Act, 1994 (20 of 1994) the water courses meaning a river, stream, springs, channel, lake or any natural collection of water other than in a private land and including any tributary or branch of any river, stream, springs or channel and the water in it is the property of the Government, hence entitling Government to conserve and regulate the use of water courses and the water in them for irrigation purposes and for generation of Electricity and matters connected. No person or agency is allowed to abstract water from a water course without the prior permission of the officer authorized by the government in this behalf or on payment of such fees as may be prescribed. Also, no person or agency or local authority or any other authority is allowed to divert any river or interlink two or more rivers or effect inter-basin transfer of water from such rivers without obtaining prior permission from the Government. Prohibition of quarrying of sand in water courses within a distance of 500 mts from any dam, check dam, reservoir or any other structure or construction on or across such watercourse, owned or controlled or maintained by Government for the purpose of irrigation. Though the field channel and technical specification responsibility lies with the Government, the field channel has to be maintained by land owners in whose field the channel is present. No person shall let out any industrial effluent or domestic effluent to any water course without proper treatment. Further no person shall, without the previous permission in writing of the Irrigation Officer and except in accordance with such terms and conditions and subject to the payment of such fees, as may be prescribed, fish in any reservoir owned, maintained or controlled by the Government.

9.5.6. Manipur:

The Manipur Loktak Lake (Protection) Act, 2006 was passed by Government of Manipur to protect the lake through a holistic approach. The Loktak Lake comprises of large pockets of open water and marshy land formed at the southern part of the Imphal valley up to the confluence of Manipur River and Khuga in the districts of Imphal West. The lake measures 236.21 km. The lake consists of Phumdis (heterogeneous mixture of vegetation, organic debris and soil in floating condition) because of which it gets the name 'Floating Lake'. The lake serves for irrigation, water supply, hydro generation and supports the fishermen who are also found living in the huts or houses on the phumdis. **The lake is divided into 2 zones (i) The core zone a totally protected zone or a No – Development zone of 70.30 sq km and (ii) Buffer zone– 165.91sq km.** Discharge of sewage, domestic waste into lake, rearing of fish, building of hut or house on phumdis inside the lake, and without the prior permission from the Loktak Development Authority fishing in lake, use of any fishing feeds and pesticides into the lake is prohibited.

9.5.7. Uttarkhand:

The Ministry of Environment and Forests has issued a notification on 18th December 2012 under Sub-Section (2) of Section 3 of the Environment (Protection) Act, 1986. This notification aims to maintain the environmental flow and ecology of the river Bhaghirathi, a major tributary of river Ganga. The notification has declared entire watershed of about 100 km stretch of the river Bhaghirathi from Gaumukh to Uttarakhasi covering a total area of 4179.59sq.Km as Eco-sensitive zone. The MoEF, GOI has also asked the state Government to prepare zonal master plan within two years involving all concerned Departments.

Zonal Master Plan to be prepared in consultation with local people particularly women based on watershed approach involving all concerned state department. The Zonal Master Plan shall provide for conservation of existing waterbodies, management of catchment areas, watershed, groundwater, soil and moisture conservation, needs of local community etc. and other aspects concerned with ecology and environment that need attention. The Zonal Master Plan needs to regulate the development in the Eco-sensitive zone to meet the requirement of the local people without affecting the rights and privileges of the bona-fide of residents and also to allow limited conversion of agricultural lands to meet the residential needs of natural growth of existing population.

Lists of the activities to be prohibited in the eco-sensitive zone are, setting up of new hydro-electric power plants, expansion of existing plants on the river Bhagirathi and all its tributaries, abstraction of river water for any new industrial purposes, mining of minerals and stone quarrying and crushing except for the domestic needs of bona fide local residents, setting up or expansion of polluting industries, discharge of untreated sewage and industrial effluent, use of plastic carry bags and further prohibition of hazardous waste processing units. Implementation of a scheme for the buy back and recycling of the plastic containers and or packaging is recommended. Regulated activities in the Eco-sensitive zone shall be extraction of ground water as per the prevalent acts and rules –for the agricultural and domestic consumption of the bona fide.

9.5.8. Gujarat:

The Government of Gujarat implemented Sabarmati River Conservation Project Phase-I, under the NRCP and JNNURM. Further the 'Sabarmati River Conservation Project Phase-II' under NRCP has been sanctioned in October, 2014 at a cost of Rs.444.44 on 70:30 funding pattern between Govt. of India and Govt. of Gujarat. Laying of new sewers, strengthening/rehabilitation of the existing sewerage system, construction of sewage pumping stations and 4 nos. STPs having a total treatment capacity of 210.5 mld is envisaged under the project. The project is planned to be completed within a span of 4 years from the date of sanction.

Ahmedabad Municipal Corporation formed the Sabarmati Riverfront Development Corporation Ltd (SRFDCL) in 1997 to implement the project to preserve the river Sabarmati and also to promote tourism. Construction work on project started in 2005. The river has been channelled to a uniform width of 263 mts and a waterfront developed along both banks, each covering a distance of about 11 km. About 10.5 km stretch of the banks of the River is reclaimed creating a new public space for socio-cultural amenities and markets. Sewage is captured from 38 discharge points along both banks and diverted to treatment plants. Water from Narmada river is drawn to fill up the Sabarmati full time. Other cities including Vadodara and Surat in Gujarat, Pune, Varanasi and Chennai propose to replicate this urban infrastructure project (www.sabarmatiriverfront.com).

9.5.9. Orissa:

Chilika lake of Orissa is a natural brackish water lake, designated as Ramsar site is influenced by the three subsystems distributaries of Mahanadi River system, Western Catchment and the Bay of Bengal. The lake supports large biodiversity. Chilika had been facing multidimensional ecological and anthropogenic pressure, leading to an overall loss of biodiversity and productivity. The degradation of the lake also adversely affected the livelihood of local community. Government of Orissa created Chilika Development Authority (CDA) in 1991 for restoration and management of the lake. The root cause of degradation were identified and addressed through adoption of appropriate strategy, restoration plans involving integrated watershed management with community participation, monitoring and assessment etc. CDA has been successful in restoration of the lake as a result of which Chilka was removed from the Montreux record by the Ramsar bureau from 11th Nov 2003. The restoration of Chilka also has improved the livelihood of the local community due to increase in the productivity.

9.5.10. Rajasthan:

Rajasthan is setting an example of rejuvenation of dead rivers through the community driven river-basin focused approach. It includes simple two step programme - revive vegetation on barren hill slopes by allowing regeneration of denuded hills by controlling animal browsing and second step is building of small water catchments – micro-structures (Johad – dug out pond) to trap water in the valleys and the plains. Through these methods seven rivers – Arvari (dead for four decades), Ruparel (dry for three decades), Sarsa, Bhagani, Sabi, Jahajwali, Maheshwari have been rejuvenated. The programme was initiated and implemented by Tarun Bharat Sangh (TBS) pioneered by Mr Rajendra Singh, Magsaysay award-winning water conservationist. **Today the dead rivers are flowing, agriculture has become possible, there is enough of water and fodder. Villagers through their participation, contribution and protection and maintenance of resources have made it possible.** TBS starts its work with mobilising communities around the issue of water, and supporting them in reviving and revitalising the traditional systems of water management through construction of 'Johads' for rainwater harvesting. The community contributes their labour; TBS arrange some funding and provide support to the villagers in construction and management of the Johads (http://www.goodnewsindia.com/pages/content/inspiration/tbs.html).

Further Arvari Sansad (River Arvari Parliament) is formed to safeguard Integrated and Water Management efforts of the community of river catchment. It follows Gandhian ethos of participatory, equitable and decentralised paradigm for water management (Jal Swaraj), where decisions are made at the grassroots not by centralized institutions. Thus Arvari Sansad develop policies and enforce rules to govern the integrated management of interlinked natural resources like water, soils and the forest for the wellbeing of the villagers as well as other forms of life-flora and fauna. The Sansad has framed 11 rules for the river basin conservation and management on following issues:

i. **Arvari basin shall not have sugarcane, paddy & chilli. People growing these are penalised.**
ii. **No one shall draw water from the river after Holi (March and April) up to monsoon (July).**
iii. **Borewells not be allowed in Arvari catchment.**
iv. **Recommended crops – barley, makka, bajra in upper and vegetables in lower reaches.**
v. **No axe can be carried to Bhairodev people's sanctuary, catchment of the source of Arvari.**
vi. **Fishing can be done only for food.**
vii. **Large-scale trade of food grains and vegetables was banned. Local production and consumption to be emphasised.**
viii. **Village people to help people from other areas for implementing water harvesting structures.**
ix. **Cattle outside the region are not permitted for grazing.**

x. **Rotational grazing to be followed by farmers in their own pasturelands.**

xi. **Industrial units prohibited in 405 sq.km of Arvari basin.**

Later, it was permitted that the farmers in his land in the Arvari basin may cultivate only 25% of water intensive crops (such as sugarcane, paddy & chilli) while the rest of land would be under less water intensive crops. Though this 'River Sansad' has no legal status and its decisions are not legally binding, the moral force of people makes its survival possible. The workers of Tarun Bharat Sangh have served as facilitators. This success has been a product of contributions, participation and sharing as every member of the rural community bear ownership of river and its waters thereby ensuring the safety and maintenance of the resources (http://tarunbharatsangh.in).

9.5.10a. Eco-restoration of Ahar River, Udaipur:

A successful restoration of heavily polluted Ahar River (Ayad) is achieved through implementation of ecotechnology. Ecotechnology involves the engineering applications of ecological principles & succession of biological communities such as bacteria, fungi, micro-invertebrate and green plants to consume organic and inorganic pollutants from the water and convert them into non-toxic form (Sayali Joshi and Sandeep Joshi, 2008). Ahar River a tributary of Berach River passes through the city of Udaipur and drains into - Udaisagar near Sukha Naka. The river is polluted by domestic and industrial wastewater of Udaipur. Green Bridge System (horizontal eco-filtration system) is constructed alongside Ahar River to remove the pollutants. Green Bridge technology uses locally available materials like coconut coir or dried water hyacinth or aquatic grasses in combination with sand and gravels with various consortia of microorganisms and root systems of green plants. The process does not require any electricity/machinery/skilled labour making it a cost effective approach of pollution treatment. After implementation of the green bridges on the river improvement in the quality of river water was observed. This purified river water has resulted in the improvement of quality of ground water in the nearby wells. People and cattle are able to use this water for bathing and drinking. The return of the predators like crocodile and water snakes with plenty of fish production was also observed in the river.

9.5.11. Punjab:

Buddha stream/nallah a tributary of Sutlej River runs parallel to the Sutlej on its south and ultimately joins the Satluj at Gorsian Kadar Baksh. Ludhiana a highly populated and industrialized city situated to the south of the Buddha Nallah is a major polluter. A number of industries including textile, automobile, paper and leather industries established in Ludhiana are polluting the nallah. Despite operational STPs from last few years, there is no improvement in the quality of Buddha nallah. High levels of solvents, toxic carcinogenic chemicals and heavy metals and high levels of Radioactive Uranium than the prescribed standard limit are found in the water samples from the stream as well as ground waters. Given the urgent need for restoration of the Buddha Nallah, the "Buddha NEER Project" (Buddha Nallah Ecological and Economic Restoration Project) by the Srishti Environment & Sustainability Society (SES) was finalized in February 2011. Central Pollution Control Board (CPCB) has approved for installation of Green

Bridge technology for cleaning the Nallah. The treated water of the drain would be used for agriculture and to reduce the toxicity in the water getting mixed with Sutlej, which is used for drinking purposes (Planning Commission, GoI, 2013).

9.5.12. Jharkhand:

The concern and initiative by the people towards conservation of the rivers can be seen in Ranchi city where the Harmu River flows. The river stretches across 17.5 km in the city, of which 10.5 km lies in the urban area. The river is dying due to illegal settlements and garbage. Voices for the conservation of this river rose which subsequently led to the filing of Public Interest Litigation (PIL) at Jharkhand High Court in 2010 from the activities. As a result MoU under the headline Harmu Nadi Ke Jirnodhar Aor Sarakshan (Harmu River's Survival and Protection) has been signed between the chief engineer of the state urban development department and Mumbai-based private company for restoration and conservation of Harmu river. The work of restoration has to be done in the urban stretch. **The first step would be installation of sewage treatment plant (STP), removal of solid waste and placing of grill chambers to collect the solid waste in drains. The drain water treated in the STP will be released to the river. Further the beautification of river banks will be done in the identified empty land near river banks by making parks, planting trees, making jogging tracks etc.** (Times of India, February 26, 2015 and Jharkhand State News, February 2, 2015).

Further good practices which are unique in nature were observed in different cities such as separation of the storm water disposal system and waste water disposal system in Navi Mumbai, while comprehensive sewerage system including sewage treatment plants of different types and different capacities was observed in Surat city.

9.6. International Methodologies:

In recent decades, with more attention to sustainability and quality of life, there is a greater understanding of the vital role of urban rivers and riverfronts. In this chapter an attempt has been made to appreciate the rehabilitation efforts made at international level and the best practices adopted for some major urban rivers. In order to study best practices/ approaches of rivers in urban agglomeration in other countries, 90 reports/documents of various countries have been searched and analyzed. Some of them have been reviewed in detail depending on the applicability to the context of the present study. It is observed that local governments have a significant role in implementation of such projects. And the projects have mostly adopted a comprehensive multi-sectoral approach and implemented as a package project.

Most of the examples of rivers considered here are suppliers of drinking water to their cities and run in one of the most populated urban agglomeration where anthropogenic activities had significantly altered the river and its catchment area, degrading their health and biological diversity by waste disposal from households and industries making the water-bodies an open sewer. The most common tool used internationally to set protection of reservoir and steams is that of buffer zones along and around these water bodies.

Most of the countries reviewed like France, United States, United Kingdom, Australia, Sri Lanka etc., have adopted a scientific method of buffering the water-bodies by adopting Riparian Buffer Guidelines, which is site specific and independent to their country. A riparian buffer is the area of land along streams and rivers and other open water bodies. Riparian buffers are essential to the ecology of aquatic systems. The buffer begins at the normal water's edge of a lake or reservoir, and at edge of the bank of an active stream channel. There are many factors that influence the effectiveness of this buffer that includes slope, rainfall, soil type, vegetation and other characteristics specific to the site. Some of the case studies reviewed are as follows:-

9.6.1. The Pasig River in Philippines:

The Pasig River is about 27 km long situated in Philippines. The Pasig River system runs through five cities and four municipalities (Figure-9.1) and connects two large, important bodies of water; Manila Bay in the west is the country's main port of maritime trade and travel and Laguna de Bay in the east is the largest freshwater lake in the country and connects 30 suburban towns to the Metropolitan center. Advancements in land transportation have changed the landscape considerably. Industrial pollution accounts for 45% of the total pollution in the Pasig River. About 315 of the 2,000 or more factories situated in the river basin have been determined as principal polluters of the river, dumping an average of 145t of Biochemical Oxygen Demand (BOD) per day. This was established by determining the suspended solids in their treated and untreated waste-waters. According to records, the textile and food manufacturing industries are the greatest water polluters among those considered in the study.

The objectives of Pasig River Rehabilitation Program (PRRP) are given below:

- To improve the quality of the water in the Pasig River.
- To improve the environmental conditions in and along the river.
- Physical clean-up of the river in the short-term.
- Stopping pollution at source in the long-term.
- Reducing the amount of solid waste dumped into the rivers and creeks of the Pasig River System with regular waste collection activities.
- To increase and control the flow of the water through the Pasig River system especially during the dry season.
- To relocate the squatters living along the Pasig River and its main tributaries
- The government has adopted "Waste to Energy and Secondary Industry by waste recovery concepts, liquid and solid waste management and water quality monitoring", to improve the environmental conditions of the river (http://www.who.int/water_sanitation_health/resourcesquality/wpccasestudy3.pdf).

Figure-9.1: Pasig river before and after Pasig River Rehabilitation Programme

9.6.2. Kallang River in Singapore:

Kallang River (10km long) is situated in highly populated area of Singapore (Figure-9.2). Hence to clean up the polluted river, the Government adopted ABC (Active, Beautiful, Clean) Programme and one of the main features of redevelopment is restoration of the concrete canal running through the park into a naturalized river with bioengineered river edges using a variety of plants and bedding materials which act as cleansing biotope which help to treat water from the river (http://www.academia.edu/4970120/Changing_Urban_Rivers_The_History_and_Modern_value_of_Singapores_Urban_Canals).

Figure-9.2: Kallang River, before and after restoration

Under NEWater (new water) scheme, Singapore has quickly gained an international reputation for efficient recycling of wastewater. The initiative already supplies around one third of the country's water demand, and that number is expected to grow more than half by the year 2060. There are now four purification plants across Singapore producing 430 million liters of NEWater a day. The majority of what's produced is consumed by industry or by big cooling facilities. The rest is combined with nutrient-rich reservoir water, purified again and filled into bottles (***Source***: Singapore's 'toilet to tap' concept, 25.06.2013, Roxana Isabel Duerrss/ http://www.dw.de/singapores-toilet-to-tap-concept/a-16904636).

9.6.3. Best Practise in New York, USA:

9.6.3.a. Bronx River:

Bronx River is approximately 39 km long, flows through the urbanized zones of South East New York. The water was highly polluted due to industrial effluents, raw human waste, medical garbage, and random floating objects. The main restoration activities for this polluted river is a eight mile long green pathway linear park that provides green space to the community, Bronx river conservation crew maintains a full time presence on the river for monitoring its condition and carrying out ecological restoration. The New York state enforces law through the office of Attorney General to prevent environmental damage.

Figure-9.3: Bronx river clean up

Ecological restoration and management plan is the result of the collaborative efforts of the more than 80 Bronx River Alliance partners to develop a framework that will ensure a consistent and comprehensive approach to restoring wildlife habitat and water quality in the lower Bronx River—the eight-mile stretch within New York City (Figure-9.3). Although restoration efforts have been underway since the 1970s, the intensified focus since 2001 on restoring wetlands and wildlife habitat and on improving storm water capture in the watershed requires technical guidance and integrated vision. This plan details a comprehensive, consensus-based approach to improving the environmental health of the river by setting overall restoration goals, creating a context for evaluating future restoration projects and strategies, and addressing specific pollutants that compromise habitat restoration. Few other important management strategies are storm water management and developing bioengineering plant material, harvest sites as sources of native vegetation for plantings, managing river corridor trash removal, woody debris management, invasive control, and bank stabilization, regulation of small industry and maintenance operations to reduce illegal discharges, identify sources and enforce controls at storm water outfalls to reduce water quality degradation at storm water outfalls and develop incentives and procedures to educate and promote pollution prevention and storm water capture practices among business and property owners, designers, engineers and contractors (Bronx river alliance, Ecological Restoration and Management Plan, New York, 2006).

9.6.3.b. Watervliet Reservoir:

Watervliet Reservoir, New York is one of the city's drinking water sources. The reservoir watershed encompasses an area of approximately 115 Sq.Miles. There are three main tributary streams to the reservoir i.e., the Normans Kill, the Bozen Kill and the Black Creek (Figure-9.4). There are 700 rural residential lots in the watershed. The reservoir provides a safe yield of 12 Million gallons per Day. The main water pollutant found in the reservoir was trihalomethanes which was above the new MCL (Maximum Contaminant Level) of 80µg/L. People who drink water containing trihalomethanes in excess of MCL over many years may experience problem with their liver, kidney and central nervous system and many have a risk of getting cancer. Trihalomethane is formed by the reaction of chlorine with water that contains large amount of organic matter.

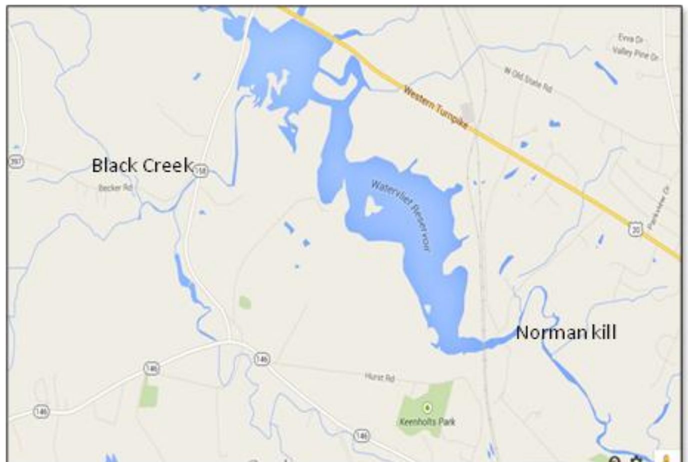


Figure-9.4: Streams of Watervliet Reservoir

There are direct threat to the reservoir water quality through the two side bounded highways (Figure-9.5) and by larned gravel quarry, mined directly adjacent to the reservoir (Figure-9.6).

To conserve the Watervliet Reservoir and other waterbodies in the State, The New York State Department of Health Watershed has developed Rules and Regulations as given below:

- No garbage, putrescible matter, kitchen waste or any polluted water or liquid of any kind shall be thrown or discharged directly or indirectly into any reservoir or water course with in a distance of 200ft. from any reservoir or within 50ft. from any water course tributary.
- No person shall be allowed to bathe in any reservoir nor shall any animals or poultry be allowed to stand, wade or swim in any reservoir nor be washed.
- No temporary camp, tent, building or other structure for housing labourers shall be located or placed within a distance of 500f.t in the reservoir or 100ft. from any water course tributary and also no cemeteries shall be made within a distance of 300ft. from

any reservoir or 100ft. from any water course tributary. The board of water commissioners of the city of Watervliet, New York shall make regular and thorough inspection of the reservoirs, streams and drainage area tributary thereto for the purpose of ascertaining whether the above rules and regulations are being complied and also it is the duty of the board to see if any rules or regulations are violated.

- In accordance with section 70 of Chapter 45 of the public health law, the penalty for each and every violation of these rules and regulations to the permanent water resource or any act of contamination is fixed at $100.

Figure-9.5: Highway-185 crossing Norman kill river & Industrial garbage piled next to black creek

Figure-9.6: Gravel quarry next to reservoir and the Watervliet Reservoir

9.6.3.c. Management of the New York City Watershed:

The watershed covers some 1,900 square miles in the Catskill Mountains and the Hudson River Valley. The watershed is divided into two reservoir systems: the Catskill/Delaware watershed west of the Hudson River and the Croton watershed east of the Hudson (Figure-9.7). Together, the systems deliver approximately 1.4 billion gallons of water each day to nearly 9 million people in New York City and Westchester Orange, Putnam and Ulster counties.

Figure-9.7: New York City Watershed

The Catskill Water Supply System, completed in 1927, and the Delaware Water Supply System, completed in 1967, provides about 90% of New York's water supply. The combined Catskill/Delaware watershed covers 1,600 square miles. Drinking water from the Catskill/Delaware system is of high quality and is delivered to New York consumers unfiltered (http://www.epa.gov/region02/water/nycshed/).

The Croton Water Supply System was completed prior to World War I. Consisting of 10 reservoirs and three controlled lakes, the Croton system has the capacity to hold 95 billion gallons of water, and normally provides 10% of New York City's daily water supply. The Croton Watershed covers approximately 375 square miles east of the Hudson River in Westchester, Putnam, and Duchess Counties and a small section of Connecticut. In the densely developed Croton watershed, which contains extensive NYC suburbs, development pressures and the high cost of land have limited the Department of Environmental Protection (DEP's) ability to undertake protection mechanisms such as land acquisition. As a result, although water from this system currently meets health standards, the City is constructing a filtration plant, that will correct aesthetic issues with colour, taste and odour (that primarily occur in the summer) and to ensure the Croton supply's continued compliance with surface water regulations.

On July 30, 2007, EPA, in consultation with the New York State Department of Health (DOH), released its most recent New York City Filtration Avoidance Determination (FAD) for the Catskill/Delaware Water Supply. EPA and DOH determined that New York City has an adequate long-term watershed protection program for its Catskill/Delaware water supply that meets the requirements for unfiltered water supply systems.

On September 26, 2007, EPA transferred the authority to oversee the Catskill/Delaware water supply system to DOH. The Catskill/Delaware Watershed region is facing an increasing threat of contamination from pathogens linked to expansion of agriculture and development because the impervious cover of roads from development has provided a direct pathway for faecal matter to runoff into water bodies. Filtration of the Catskill/Delaware system would cost NYC upwards of $4 - $6 billion. To avoid that expenditure, the city was willing to invest approximately $1 billion on an integrated water resources management approach for protecting the Catskill/ Delaware watershed. EPA Region 2 continues to work with New York City and New York State on programs to protect the watershed and to monitor the success of these programs, both from the water quality perspective and from a public health perspective. The watershed programs fall into four main categories:

i. **Watershed Agricultural Program (WAP)**

Since 1992, to date, 254 large farm operations in the Catskill/Delaware watersheds have signed up for the WAP, representing 96% of identified large farms, and 98% of these have written their Whole Farm Plans. In 1998, the City augmented the program with the addition of a City-federal cost-sharing effort known as the Conservation Reserve Enhancement Program (CREP), **which pays farmers to take sensitive riparian buffer lands out of active farm use and re-establish a vegetative buffer.** To date, 2,030 acres of riparian buffers have been enrolled in CREP and nearly 11,000 head of cattle have been excluded from streams (2011 watershed Protection Program Summary and Assessment, New York City Department of Environmental Protection).

ii. **Land Acquisition Program (LAP):**

Purchases are undertaken selectively, with properties prioritized for purchase based on the presence of key natural features such as streams and wetlands, proximity of land to reservoirs, and potential for development. Land is only purchased from willing sellers, and at fair market prices. Since 1997, the City has acquired or contracted easements for approximately 70,000 acres of land at a cost of $168 million. Prior to purchasing the land, the City consults with the municipality to ensure the community's interests are taken into account. Watershed communities are able to exempt certain areas from solicitation under the LAP.

iii. **Land Management:**

The DEP has numerous programs designed to encourage private landholders to protect watershed lands. These programs are operated in consultations with watershed municipalities and non-profit partners, including the Watershed Agricultural Council (WAC) and the Catskill Watershed Corporation (CWC). Management programs include Stream Management, Wetlands Protection, the Watershed Forestry Program, Waterfowl Management, public outreach and education, and agricultural pollution prevention plans.

iv. **Capital Programs:**

On its own or with its partners, DEP undertakes numerous capital projects in the Catskill/Delaware watershed designed to preserve and improve water quality. These include:

a. **Wastewater Treatment Plants (WWTP) Upgrades**

At its own cost, the City has upgraded and operates over 100 non-city treatment plants to ensure the highest degree of wastewater treatment; the DEP has also funded the construction of new WWTPs or septic systems where existing systems were failing.

b. **Septic System Rehabilitation and Replacement**

In partnership with the CWC, the City has fixed over 2,000 failing septic systems in the watershed and helps cover the cost of pump-outs, maintenance, and inspections of single- and two-family septic systems.

c. **Storm water Retrofit Program**

Jointly administered by the DEP and the CWC, the program encompasses storm water infrastructure assessments, maintenance, planning, and capital expenditures.

d. **Sewer Extension Program**

Working with watershed municipalities, the DEP has extended sanitary sewers where systems were failing or likely to fail.

The filtration avoidance criteria include quality standards for coliforms, turbidity, and disinfection by-products; operational criteria requiring that pathogens (like *Giardia* and virus) be deactivated with a minimum of chlorine residual in the system; and watershed control criteria to minimize potential contamination of source waters (http://www.pwconserve.org/issues/watersheds/newyorkcity/).

With funding from USDA forest service, the watershed Agricultural Council (WAC) began a riparian buffer program in 1999 as the watersheds in this area are heavily forested but contains substantial agricultural lands and numerous small towns and villages. The project has resulted in the establishment of miles together of new riparian buffers in targets watersheds adopting the Buffer Zone Model provided by Department of Environmental Protection (DEP) Operation and Engineering Division.

Core ongoing programs depend on vital support from and cooperation with the City's watershed partners, with particular concentration on implementation of several key watershed protection initiatives: the Watershed Agricultural Program, the acquisition of watershed lands, the enforcement of improved watershed regulations, the Stream Management Program, and the continuation of environmental and economic partnership programs that target specific sources of pollution in the watershed.

Through the programs and partnerships described above, NYC's drinking water has maintained its reputation as one of the finest supplies in the United States. The innovative combination of watershed programs and partnerships limits the need for filtration and disinfection, and supports the adage "*an ounce of prevention is worth a pound of cure*".

9.6.4. Rivers of Japan:

Rivers of Japan like River Tama (Figure-9.8), Batch (Figure-9.9), etc. that were under high pollution risks, are restored by developing database and guidelines of projects and knowledge of international experts in river restoration, to link the sustainable use of river and wetlands with human wellbeing, continuous survey of water quality, improvement of urban landscaping and also by developing sewerage system and Wastewater Treatment Plants (River Restoration in Asia and Connection between IWRM and River Restoration, Japan 2008).

Figure-9.8: Tama River, before and after restoration

Figure-9.9: Batch River, before and after restoration

9.6.5. Urban Rivers of Malaysia:

Urban Rivers of Malaysia like Sangai Juru, Sungai Panchala, Klang (Figure-9.10), etc. has a long history of river pollution problems related principally to land use changes. The main components of restoring these rivers are beautifying and preserving the river corridor making the river as tourist attraction, construction of Sewage treatment plant, dredging of river and river bank protection. Controlling pollution sources is a long process; there is considerable scope for treatment strategies through bioremediation, wetlands, installation of Gross Pollution Traps in the river stretch etc. (http://www.narbo.jp/data/01_events/ materials/tc03_ 051114_01.pdf).

Figure-9.10: Polluted Sangai Juru, Sungai Panchala River and rejuvenated Sungai Klang River

9.6.6. Jordon River in Israel:

70-90% of Jordon River water in Israel was used for human consumption leading to an extreme flow reduction from 1.3 Billion Cubic Meter (BCM) to 70 Million Cubic Meter (MCM), and it was extremely polluted by the discharge of raw sewage and industrial effluents directly into the river (Figure-9.11). Main ideology followed for the river rejuvenation was that the rehabilitation cannot be achieved over night, 20 years is a conservative estimate for the time needed to achieve desired goals.

Figure-9.11: Pollution in Jordon River and restoration activity

Few concepts of rejuvenation used in rejuvenation efforts of Jordon river are (i) treated water should be returned to the river so as to ensure the steady and clean flow (ii) deepening the river bed (iii) planning, surveying and supervision of river (iv) anchoring the river banks (v) solid waste management and developing parks along the river course (vi) Restoration of the natural flow regime by releasing approximately 500-600 mcm from other rivers into the Jordan River that simulates natural seasonal flooding which would act to flush the fine sediment and pollutants providing significant habitat improvement in short term. The water flow is restored by a meandering activity in the lower Jordon River to naturally re-establish the river. From these rejuvenation activities 70% of the original annual flow is restored in the lower Jordon River.

9.6.7. Nairobi River in Kenya:

Nairobi River, Kenya was facing rapid urbanization (highly congested informal settlements) and industrialization challenges (Figure-9.12). The implementation strategies adopted are creating awareness and assessing social impacts, surveying and delineation of riparian buffer, relocating economic activities and informal settlements with compensations, repairing and installing sewage infrastructure, 180 ha of trees planted along the stretch and developing an integrated solid waste management system (Nairobi Rivers Basin Rehabilitation and Restoration Program, 2010).

Figure-9.12: Rejuvenation of Nairobi River

9.6.8. Regulations of Beijing Municipality on Administration of Urban Rivers and Lakes:

Beijing Municipality has adopted Regulations for Urban Rivers, Reservoir (Figure-9.13) and Lakes since 1999. These Regulations are formulated for the purposes of strengthening the protection and administration of urban rivers and lakes, ensuring the flood prevention of urban rivers and lakes and the water supply in this Municipality, improving water environment and promoting national economic and social development, in accordance with the Water Law of the People's Republic of China. There are 58 articles in this regulation (Table-9.3), but only few articles are mentioned here because of their relevance to the present study (http://www.bjcg.gov.cn/english/laws/ t20070123_163224.htm).

Figure-9.13: Huairou Reservoir, China

Table-9.3. Important Regulations of Beijing Municipality

Article No.	Regulations
Article 9	To commend and reward the units and individuals who make contributions to the protection of urban river-and-lake water resources and water environment
Article 15	In urban river-and-lake management ranges*, the following actions are banned • Establishing buildings irrelevant to water projects; • Dumping or piling refuse, slug and other wastes; and randomly piling up materials; • Opening all kinds of commodity trading markets and business outlets; • Random blasting, well-digging, excavating sand or drawing earth; • Poisoning, blasting and electrifying fish, setting fish screen across a river and fishing and angling in the non-designated water area; • Enclosing dykes or building water-retarding channels or roads; • Randomly building dams; • Growing crops with high stalks or trees in watercourses; • Arbitrarily exploiting underground resources, conducting archaeological excavations.
Article 18	Trees and grasses shall be planted in the urban river-and-lake management and protection ranges except in watercourses and greening areas shall be increased to gradually form waterfront greening belts
Article 20	Any illegal buildings and structures in the urban river-and-lake management and protection ranges shall be dismantled within the time limit. And also, all kinds of commodity trading markets shall be moved, closed or dismantled within a time limit.
Article 25	Where any buildings and facilities obstruct flood passage, flood protection administrative organ shall order to convert or dismantle them within a time limit.
Article 28	Ban of random water drawal from urban rivers and lakes
Article 31	It is banned to discharge raw industrial waste water that has not been treated into urban rivers and lakes.
Article 32	Urban sewage must reach standards through centralized treatment before being discharged into urban rivers and lakes.
Article 33	The completed projects without sewage treatment facilities constructed shall construct sewage facilities within a time limit by order of the water administrative department.
Article 35	Has forbidden the following harmful activities: to directly or indirectly discharge or dump noxious and hazardous chemicals and preparations; to dump sewage and pollutants contaminating water-body; to raise livestock and poultry or to wash vehicles, clothes and other utensils in the urban river-and-lake management ranges; to use fish drug and highly toxic and highly residual pesticides that are harmful to water-body; to swim, skate or launch other water activities in non-designated waters.
Article 40	The municipal environmental protection administrative department should regularly publish to the public the urban river-and-lake water quality.

* Urban river-and-lake management and protection ranges shall be specified by the municipal planning department together with the water administrative department and other relevant departments according to relevant provisions of the Municipal People's Government.

9.7. Conclusions:

9.7.1. National Methodologies:

Different states in India have adopted region specific policies and rules to manage their water resources, especially rivers. There is no River Regulation Zone policy in the lines of CRZ, in vogue, to regulate developments across rivers. In the states with many agencies to look into sectoral needs, there is no coherent action plans to conserve and manage water resources. There is little coordination between different pollution monitoring and controlling institutions. No holistic parameters that would indicate overall health of river (or water bodies) is used. While individual efforts have been made for conservation of certain rivers, these are mostly after much of the damage have been done due to unregulated developments and pollution.

The analysis of methodologies adopted by various states for the conservation of lakes shows a basic uniformity of objectives, but the actions and implementation varied as per specific needs and local conditions. Some of them were government initiatives while others were community involved programmes. The common causes for river deterioration are same and hence a holistic view of the problem will help in finding unified management options.

The National Water Policy recommends taking the river basin/ sub-basin as a unit for planning and management of water resources and proposes that departments/ organizations at the Centre and the States be restructured and be made multi-disciplinary. It also proposes the establishment of water regulatory authorities in centre and in each State and a national forum to deliberate upon issues relating to water and evolve consensus, cooperation and reconciliation amongst the various States. There is a suggestion that a broad over-arching national legal framework of general principles on water is necessary to pave the way for essential legislation on water governance in every State to implement an integrated and coherent water policy. The National Water Policy takes into cognizance the reality with regards to water resources and their management and has attempted to present a comprehensive policy for the States to follow and adopt as per their situations. The following are some of the important conclusions or suggestions that should be implemented for better management of rivers and water resources in the different states of India:

i. Need for creating National and State Level Water Regulatory Authorities for dealing with water issues in a holistic way in accordance with national water policy, 2012.

ii. Framing Unified national rules for the conservation and rejuvenation of waterbodies.

iii. Constituting River Basin Level Institutions to have a holistic and multi-disciplinary approach for management.

iv. Develop specific strategies for each of the major rivers especially in urban set ups.

v. Establishing national and regional institutes for research and training in river ecology.

vi. Involvement of public in the decision making and implementation of water management activities.

9.7.2. International Methodologies:

From the analysis of case studies it can be concluded that rivers and water bodies have been polluted all across the world, particularly where the population density is more and extent of urbanization and industrialization is more. With regards to the preservation zone around rivers, there is no uniform principle guiding the same. However in the efforts towards rejuvenation of the rivers certain common approaches have been found as given below:

i. Improvement of relationship between river and human community and nature-public participation – by creating awareness i.e. to educate the general public, local peoples groups, local elected representatives, farmers and other stakeholders on the need & techniques of preserving water, rain water harvesting, conservation & resource development.

   Eg. In Singapore school education and public campaigns are used as tools to raise public awareness of water policy and programs. These activities boost public support for the government's water policy and initiatives.

ii. It is important to develop a database of projects and knowledge of international experts in river restoration, and this activity should be supported by engineers, scientists, ecologists, managers and public.

iii. Interact with Government & elected bodies for effective implementation of existing schemes & policies & if necessary formulate new schemes/measures.

   Eg. Political Will - The Singapore government has been an essential force behind the successful water policy, strategy, planning and implementation.

iv. Acceptance and ownership of the project is key to Sustainability.

v. Participatory approach in decision making.

   Eg. More than 80 partner organizations make up the Bronx River Alliance. These partners engage in ecological restoration and management work both along the river banks and within the watershed, from organizing volunteer garbage clean-ups to designing and executing major salt marsh restorations, advocating for waterfront access and coordinating large-scale watershed studies (Bronx River, New York).

vi. It is important to plan river landscape studies for protecting landscape characteristics and alleviating the effects of rising population and urbanization pressure in order to hand them down to the future generations. The main aims of landscape studies planned on different scales should be to meet increasing demands of future population growth.

vii. To develop reservoirs and waterways into vibrant and aesthetically pleasing lifestyle attractions that integrate the water spaces with the surrounding parks, estates and even commercial developments.

Eg. The New York City Department of Parks (NYC Parks) manages approximately 981 acres of parkland within the Bronx River watershed. Within the river's parkland buffer, NYC Parks is assisted by the Bronx River Alliance.

viii. Planting trees along river side's and stabilize eroding river banks.

Eg. (a) In Nairobi River, Kenya, trees about 180 ha (24%) on the sides of the river were planted.

(b) In Kallang River at Bishan-Ang Mo Kio Park (Singapore) a variety of plants and bedding materials were used to stabilise the slope, to prevent soil erosion and also form natural habitats that enrich the park's biodiversity, which has since increased by 30%. In addition, the park features natural cleansing systems using plants such as a cleansing biotope, which help to treat water from the river and ponds in the park.

ix. Implement agricultural best management practices to reduce nutrient, sediment and bacteria runoff.

Eg. The Agriculture Environment Management program provides assistance to landowners to adopt best management practices like organic farming by controlling chemicals and pesticides and providing incentives through federal environmental quality incentive program, in Watervliet reservoir, New York.

x. Decommission unused wells to prevent surface contaminants from reaching groundwater.

xi. Developing and implementing an integrated solid waste management system.

Eg. The city administration of Manila (Philippines) - converted a *former waste disposal site into a park*, and 2 km of a 20 km stretch of the river has been developed by the municipal government of Marikina into a park with benches, jogging lanes and park facilities of the Pasig River.

xii. Making the River /Reservoir as one of the main tourism spot, to educate the local community and to collect funds for river conservation which directly benefits the economic development and local communities.

Eg. (a) The Bronx River Greenway is an eight-mile bike/pedestrian path and linear park in the heart of the Bronx that will provide greater access to the river itself, and bring green space to communities that have long lacked such resources. The Greenway Plan sets out guidelines for ecological performance intended to ensure that the greenway enhances and protects the ecological functioning of the river,

(b) Creating well managed riparian greenways increases access to leisure park activities.

xiii. Construction of sewage treatment plant/waste water treatment plants for the settlements located along the River stretches and also for the purification of the river course.

Eg. In Malaysia, Construction of sewerage system with bypass (Intercept) of wastewater from the existing drainage system from the nearby habitats has lead to Waste Water Treatment Plant and also Gross Pollution Traps (GPT) are installed to collect floating litter, debris and coarse sediment and some designs also collect oil, along and inside the river stretch.

xiv. Empower youths and improve livelihoods.

Eg. (a) In Nairobi, youth groups with passion for environment and waste management have been identified, and they are engaged to carryout rehabilitation activities by sensitizing the locals about river cleanliness and its management (Nairobi, South Africa).

(b) More than 1,000 families along the banks of the Pasig River have been relocated to various sites in Cavite and Marikina (Philippines).

xv. The treated water from the sewage treatment plants should be allowed to flow in the river, which enhances the water infiltration rate in the river bed, hence increasing the groundwater table.

xvi. Promoting recycling and Reusing of industrial effluents

Eg. Wafer fabrication, semiconductor and electroplating industries of Singapore; have been practicing recycling as they found it viable to recycle their process water for reuse.

River rehabilitation cannot be achieved overnight, and twenty years is a conservative estimate of the time needed to achieve our goals. The complexity of the project and the limited resources available require that priorities be set. **In some cases treating the entire length of the river at once is not feasible, so various sections of a river are restored and developed at different times** (Israel)

Chapter-10: Conclusions and Recommendations

10.1. Introduction:

As explained in earlier chapters, the TG Halli catchment has been studied using remote sensing and GIS supported by limited field verifications within the available time frame. The earlier reports about the catchment area, most important being the ISRO-INRIMT report, have been studied in depth and analyzed so that suitable inferences may be drawn and suitable recommendations may be made. Through stakeholder discussions, the opinions of the local people and the difficulties or objections expressed by them have also been taken into consideration. It is also found that the management of the entire catchment has been the responsibility of multiple Government agencies, namely, town planning authorities such as, BMRDA, Nelamangala Planning Authority, BDA, Magadi Planning Authority, respective Deputy Commissioners of the Districts, KSPCB, as well as local bodies such as Gram Panchayats, Town Panchayats, Pattana Panchayats.

Actions have also been initiated by Environment Department, Cauvery Neeravari Nigam Limited, BWSSB, KSPCB, Water Resources Department etc., towards conservation of the Arkavathi and Kumudvathi rivers as well as TG Halli reservoir. For taking necessary inputs from multiple Government Agencies/ Departments, an advisory committee was constituted for guiding the comprehensive study. The advisory committee consisted of all concerned Government Departments/ Authorities such as BWSSB, BDA, BMRDA, NPA, MPA. The proceedings of the three meetings of the Advisory Committee have been produced as Annexure-1.9. Necessary information was collected from all the stakeholders and analyzed.

An expert committee was constituted for developing suitable recommendations, looking into the various results of the present study as well as best practices adopted by other States within India as well as abroad. This technical committee consisted of officers from EMPRI as well as team of experts in the water sector or people having experience in working with communities on management of water resources. The proceedings of the meeting of the committee have also been placed at Annexure-1.10. The presentation was also made to Research and Training Advisory Committee (RTAC) of EMPRI and suggestions made by them were also taken-up. The proceeding of the RTAC meeting is annexed in Annexure-10.1. The suggestions given by the Committee members have been taken into consideration while formulating the recommendations. In the following paragraphs, the findings have been summarized briefly followed by general conclusions and recommendations.

10.1.1. Summary of findings in Zone-1 of the TGR catchment as per the 2003 Notification:

Hesaraghatta sub-catchment, Arkavathi sub-catchment and Kumudvathi sub-catchment are the three distinct sub-catchments for the TGR catchment area. Zone-1 of TGR catchment area covers 550 villages in addition to the villages of zone-2, 3 and 4. There are three industrial areas in zone-1 namely Doddaballapur Industrial Area in Hesaraghatta sub-catchment, Peenya Industrial Area in Arkavathi sub-catchment and Sompura Industrial Area and Dabaspet Industrial Area in Kumudvathi sub-catchment. Quarrying, rapid soil excavation, sewage discharged from households and industrial wastewater flowing to the storm water drains, dumping of solid waste including construction and demolition waste etc. in the lakes and its drains, possible encroachments by farmers on lake bed were some of the problems in the Zone-1 villages of the Hesaraghatta sub-catchment area (273 villages) during the field visits. Further, the series of cascading tanks from Nandi hills in the Arkavathi river course are no longer overflowing. The wastewater and trade effluents are freely flowing in the streams and storm water drains have polluted the major waterbodies and ultimately the Arkavathi river during monsoon season. In Arkavathi sub-catchment area (123 villages), the effluents are directly let into the 2nd order drain of Arkavathi river near Madavara Kere. The list of possible polluting industries located in and around the Industrial Area is deliberated elaborately in the Chapter-4. Without the implementation of proper solution to manage the flow of effluents and wastewater in the major waterbodies, the rejuvenation of three lakes are in progress. As like the Hesaraghatta and Arkavathi sub-catchment area, the Kumudvathi sub-catchment area (154 villages) also degraded by the groundwater over-exploitation, lacking in proper management of solid and liquid wastes, quarrying, soil excavation, sand mining and encroachment on tanks. The combined Industrial Area (Sompura and Dabbaspet) have increased the mushrooming of unlicensed polluting industries adjacent to the Industrial area, which are polluting the drain. Further, most of the lakes in Zone-1 have dried due to seasonal encroachments by farmers and over-exploitation of groundwater.

The observations on encroachments and to pinpoint the polluting industries should be confirmed once again by the concerned authorities through detailed survey.

10.1.2. Summary of findings in Zone-2 of the TGR catchment as per the 2003 Notification:

Zone-2 consists of 33 villages in four taluks. Foreshore of the TGR is well fenced, but the backshore of TGR has not been adequately fenced which has resulted in free access to soil excavation, sand mining. Due to influx of sewage water in TGR through the Arkavathi river stretch has resulted in the spread of aquatic weeds in the TGR due to eutrophication. Seasonal encroachments by the farmers and brick kiln activities within in the TGR and stone quarry in Bidanpalya village are some of the reasons for deterioration of TGR. Also the Zone-2 has been subjected to the development of 19 layouts, two warehouses, etc.

10.1.3. Summary of findings in Zone-3 and Zone-4 of TGR catchment as per the 2003 Notification:

As there was no demarcation of Zone-3 and Zone-4 of the Arkavathi and Kumudvathi river course, it’s very difficult to classify the Zone-3 and Zone-4 villages during the field observation. Illegal operation of granite quarrying near the rivers of Arkavathi and Kumudvathi and Chamarajasagar reservoir, sand mining, sand filtering are harming the natural valley system in the area and are directly adding the nutrients and heavy metals to the water. Further, the improper solid and liquid waste management are directly deteriorating the water quality of river water. Over-exploitation of groundwater for industrial and agricultural activities has resulted in the drying of rivers. As the Arkavathi sub-catchment area is sub- and peri-urban area of Bangalore city, the booming of real estate business is unstoppable, which resulted in the encroachment of tanks, streams and grazing lands. Additionally few industries operated near the river bed are also conveying their wastewater into the 2nd order streams of Arkavathi and Kumudvathi rivers.

10.1.4. Landuse/ Landcover Change from Remote Sensing Analysis:

Change detection analysis was performed for all four zones between the year 2003 (Notification year) and 2014 (Present situation) by using the Remote Sensing and GIS. The analysis work was entrusted to the KSRSAC (Karnataka State Remote Sensing and Application Centre), who is the Nodal Agency for the Karnataka State for Remote Sensing analysis. The entire TGR catchment area is broadly classified into agricultural land, built-up, forest, wasteland, and waterbodies. Analysis on Zone-1 infers that 114458.28 Ha of agricultural land has reduced due to the two-fold increase of built up area within the time span of 11 years. All other zones also have the same trend of increased built up area from 171.67 ha to 239.95 ha. in Zone-2, from 962.12 ha to 2039.73 ha. in Zone-3 and from 934.81ha to 2226.56 ha. in zone-4 of the Arkavathi and Kumudvathi river courses between the 2003 and 2014. Further, 23 villages located along the Arkavathy river course, have undergone remarkable change in landuse. This analysis revealed that 15 villages out of 23 identified villages have significant landuse/ landcover changes due to developmental activities. Additionally, Google imageries between the year 2004 and 2014 are used to identify the major changes in landuse such as layout development, godowns, expansion of old settlements etc. Delineation of all the superstructures and changes in the area are done for 15 villages with emphasis on encroachment of tanks for godowns, industries and layout. Changes in drainage pattern analysis between the year 2000 and 2011 from KSRSAC and 2009 from NPA infers that, many primary drainages have vanished, dried up and encroached for agricultural and developmental activities, particularly the drainages in Bangalore North taluk. Further, the road network has increased tremendously in the south eastern part of the TGR catchment area near Peenya Industrial area.

10.1.5. Survey of Writ Petitions and Summary of Findings:

Superstructures that are subject matter in the batch of 61 Writ Petitions (WP.No.38218/2013) filed before the Hon'ble High Court of Karnataka have been ground verified by the team with the representatives from the line departments and petitioners. Within 61 WP's, 60WP's are pertaining to superstructures such as 122 godowns, an industry, a college and a layout in 10 villages of Bangalore North and Magadi taluk. One WP (No.48047/2013) is connected to 870 residential houses which are distributed in 20 villages of the Bangalore North taluk, particularly in the banks of Arkavathi river course. All the litigated godowns lie within 1km buffer (Zone-3) of Arkavathi river course, mostly constructed under the Central Government scheme 'Grameena Bhandara Yojana' in the agriculture land. No Objection Certificate (NOC), general license and approval of structure plan were obtained from the respective Grama Panchayat and the loan has been sanctioned by Nationalized banks for the establishment of godowns under the scheme. Out of the 122 godowns verified, 96 godowns are in operation and 26 are not in operation. The size of the godown varies from 3,000 sq.ft. to 95,000 sq.ft. As per the information provided by the representatives and based on team observation, the godowns are rented and utilized to stock and supply the dry logistics and wet cargos by large companies. In few godowns, wastewater is directly discharged into open drain and Arkavathi river and generated solid wastes are burnt in the godown premises itself. Structural violation such as construction of multistoried buildings (G+2 to G+5), encroachment of waterbody and drains for godowns construction, disposal of solid wastes, discharge of untreated wastewater to open drain, lack of rain water harvesting system contribute to pollution of Arkavathi river.

Superstructures connected to 870 households (WP.No.48047/2013) are distributed in 20 villages located in the Zone-3 and 4 of Arkavathi river course. Major superstructures are distributed in Adakamaranahalli, Siddanahosahalli and Dombarahalli villages and within the gramathana limit. Within the 870 households, only 669 households could be identified and verified. The survey has revealed that some of the houses are built under the scheme of Ashraya Yojane and Janata Nivas Yojane. The households surveyed include multi-storied houses (G+1 to G+3) with commercial complexes or small provision for stores and mostly occupied by tenants. Electricity and water have been supplied by BESCOM and Grama panchayats respectively. Each house is facilitated with lavatory and soak pit for sewage, but generated wastewater is discharged into the storm water drains and in some villages, the solid wastes are disposed in open land or burnt because there is no proper system to manage solid waste.

10.1.6. Summary of findings in Water Yield and Availability:

Water yield in the TGR has reduced more predominantly since 2002 though the rainfall has remained more or less same with minimum of 600mm in the TGR catchment area. The rainfall runoff generated in the TGR catchment area is not reaching the TGR due to the change of land use pattern, encroachment on the 2nd and 3rd order drains and diversion of drains by the unplanned developments, water intensive agriculture practices and over exploitation of groundwater. Further, the water is not getting stored in TGR because of its leaking sluice gate. As the Arkavathi and Kumudvathi are minor rivers of Karnataka state, there was no monitoring Authority for the documentation of water availability and flow. During field visits, EMPRI team had mapped the availability of water in the Arkavathi and Kumudvathi rivers, and found that the Arkavathi river was dry from the Nandi hills to the downstream of Hesaraghatta reservoir until the Tarabanahalli village, except for blotches of stagnant water. Further downstream the river course from Alur village to the inlet of TGR had mostly the inflow of wastewater. The Kumudvathi river is not so far polluted by wastewater but the river course had only 1.58Km (approximately) of stagnant water out of a total length of 48Km during the time of field visits. The groundwater fluctuation level data collected from the DMG showed that the groundwater level is going down year-by-year. The major reasons for the depletion of water in the TGR are the natural and anthropogenic blockages of drains, over-exploitation of groundwater near the river bed, extensive sand mining, soil excavation in the river bed, etc.

10.1.7. Summary on Water Quality Deterioration and Reasons for Pollution:

Water quality data of TGR (2000-2014), Arkavathi (2010-2014) and Kumudvathi (2013 and 2014) rivers for the past years were collected from the BWSSB and KSPCB respectively. There are data gaps and non-uniformity of the parameters in the data available. The secondary data revealed that there was high count of total coliform and concentration of heavy metals in the Arkavathi river water. Class-C water has deteriorated to Class-D in Kumudvathi river and the TDS (Total Dissolved Solids), Electric conductivity and the total coliform counts are having increasing trend in TGR water. Further as part of the present study, the 25 water samples have been collected from the TGR, Arkavathi and Kumudvathi rivers and analysed in the Government approved water analysis labs. Results showed that the water quality is below class-E (Not fit for any usage) in Arkavathi river, between class-C (Drinking water source with conventional treatment followed by disinfection) and class-D water quality in Kumudvathi river and class-D (Fish culture and wild life propagation) in TGR.

Groundwater quality was also analysed for the Kumudvathi sub-catchment area based on the DMG data (1995-2014). This analysis has revealed that the concentrations of all physico-chemical parameters (particularly TDS and nitrogen) of the groundwater are increasing year by year. Additionally, the EMPRI team has analysed three parameters of groundwater in the Arkavathi river course villages, which showed that in 16 villages, groundwater TDS was above 500mg/l, the limit of BIS: 10500-2012. Arkavathi river water is heavily polluted by the sewage generated by the mushrooming layouts, wastewater from godowns and industries, improper handling of solid wastes, illegal stone quarrying, stone crushing and sand washing. Compared to the wastewater discharge from the Zone-3 and 4, the Arkavathi river is getting polluted by the sewage from the BBMP area and the industrial effluents from Zone-1.

10.1.8. Summary on Analysis of Stakeholder Meetings:

Four primary stakeholder meetings were conducted with the elected Grama Panchayat members covering all the four zones of TGR catchment area. The issues raised by them are lack of awareness about the 2003 notification, no (Surface and ground) water for irrigation and lack of co-ordination among the line departments. The suggestions received from them include the following (i) to reduce Zones-2, 3 and 4 from 2 Km to 100-300 m (ii) to prohibit the developmental activities along the river beds and around the reservoir (iii) to rejuvenate the reservoir and eviction of encroachment (iv) to rejuvenate Arkavathi and Kumudvathi rivers by ensuring free inflow of water to TGR (v) to survey and demarcate the TGR boundaries, Arkavathi and Kumudvathi river banks to maintain buffer zones (vi) to restrict the polluting activities in the TGR catchment area (vii) to take serious action on sand mining, quarrying and crushers activities (viii) to stop conversion of agriculture land for commercial activities (ix) stop the usage of pesticides/ insecticides for vegetable crops (x) to consider old village settlements and natural expansion of the older settlements (xi) to set up a separate TGR catchment area conservation authority for effective conservation.

10.1.9. Summary on Analysis of National and other State guidelines:

Different states in India have adopted region specific policies and rules to manage their water resources, especially rivers. There is no River Regulation Zone policy on the lines of CRZ, in vogue, to regulate developments across rivers. In the states with many agencies to look into sectoral needs, there is no coherent action plans to conserve and manage water resources. There is little coordination between different pollution monitoring and controlling institutions. No holistic parameters that would indicate overall health of river (or water bodies) is used. While individual efforts have been made for conservation of certain rivers, these are mostly after much of the damage have been done due to unregulated developments and pollution.

The analysis of methodologies adopted by various states for the conservation of lakes or rivers shows a basic uniformity of objectives, but the actions and implementation varied as per specific needs and local conditions. Some of them were government initiatives while others were community involved programmes. The common causes for river deterioration are same and hence a holistic view of the problem will help in finding unified management options.

The National Water Policy (2012) recommends taking the river basin/ sub-basin as a unit for planning and management of water resources and proposes that departments/ organizations at the Centre and the States be restructured and be made multi-disciplinary. It also proposes the establishment of water regulatory authorities in center and in each State and a national forum to deliberate upon issues relating to water and evolve consensus, cooperation and reconciliation amongst the various States. There is a suggestion that a broad over-arching national legal framework of general principles on water is necessary to pave the way for essential legislation on water governance in every State to implement an integrated and coherent water policy. The National Water Policy takes into cognizance the reality with regards to water resources and their management and has attempted to present a comprehensive policy for the States to follow and adopt as per their situations.

Constituting River Basin Level Institutions having a holistic and multi-disciplinary approach for management has been enunciated in the Policy. To prevent over use of water, revision of heavy under-pricing of electricity is proposed which is otherwise leading to wasteful use of both electricity and water and use of improved technologies of water use. The policy also suggested the adoption of artificial recharge projects to address the depleting ground water level and encouraging community based management of aquifers.

The National Water Policy has also enunciated preservation of river corridors, water bodies and infrastructure to be undertaken in a planned manner through community participation. Also it says that encroachments and diversion of water bodies (like rivers, lakes, tanks, ponds, etc.) and drainage channels (irrigated area as well as urban area drainage) should not to be allowed and the encroached place should be restored to the possible extent.

Establishment of National Water Informatics Center for assemblage of Hydrologic data (other than data classified as secret on national security consideration) regularly from all over the country is recommended. Further policy has recommended for establishment of an autonomous center for research in water policy to evaluate impacts of policy decisions and to evolve policy directives for changing scenario of water resources. Regular training of man power in water sector and academic courses in water management and encouragement of innovations in water resources are encouraged.

The Policy has accepted that there is need for framing Unified national rules for the conservation and rejuvenation of waterbodies. Development of specific strategies for each of the major rivers especially in urban set ups is required. Involvement of public in the decision making and implementation of water management activities has been given importance in the Policy. The Policy has also encouraged recycling and reuse of water to the extent possible.

10.1.10. Summary on Analysis of Best Practices from International examples for River Rejuvenation:

About 90 International guidelines were collected from respective websites and eight guidelines are elaborately reviewed such as Pasig River in Philippines, Kallang River in Singapore, Bronx River in South East New York, Rivers of Japan, Urban Rivers of Malaysia, Jordon River in Israel, Nairobi River in Kenya in respect to urban agglomeration. From the analysis of case studies it can be concluded that rivers have been polluted all across the world due to the population density, extent of urbanization and industrialization. Some of the best practices followed by other Countries for the conservation of rivers are (i) Develop a database on river restoration and activities (ii) Create awareness about conservation (iii) Interact with Government and elected bodies for effective implementation of schemes and policies (iv) Participatory approach in decision making (v) Plan river landscape studies for protecting landscape characteristics and to meet increasing demands of future population growth (vi) Develop reservoirs and waterways into aesthetically pleasing destination by planting trees along river banks (vii) Implement agricultural best management practices to reduce nutrient, sediment and bacteria runoff (viii) Decommission of unused wells to prevent groundwater contamination (ix) Develop and implement an integrated solid waste management system (x) Making the river /reservoir as a tourism spot (xi) Provide STP for the settlements located along the river stretches and allow the treated water to flow in the river (xii) Empower youths and improve livelihoods (xiii) Promote recycling and reusing of industrial effluents.

10.2. General Conclusions:

10.2.1. Reduction in River Flow of Arkavathi and Kumudvathi and Consequent Reduction to TG Halli Reservoir:

i. With regards to the decreased surface flow of river Arkavathi and Kumudvathi, one of the important factors appears to be over exploitation of ground water which has resulted in deepening of the water table. This has resulted in unsaturated condition of the ground water due to which, most of the rainfall is utilized for recharging of ground water leading to reduced surface flow. The over exploitation of ground water was also inferred in the ISRO-INRIMT study wherein an inventory of 9373 bore wells within the catchment had indicated indiscriminate drilling of bore wells. Water table fluctuations indicate that in parts of TGR catchment ground water tapping was much higher than the recharge. In the intervening period between the year 2000 when ISRO-INRIMT report was submitted and present study, the situation has become much more critical. In many places the ground water table has further declined to more than 600 feet.

ii. As per the report submitted by KSRSAC, the built up area has drastically increased from 2.24 % in Zone 1 in 2003 to 4.69 % in 2014. The area under layouts in Zone-1 also has increased from 1.26 % in 2003 to 4.52 % in 2014. The developments are more intensive in Zone-3, where the built up area has increased from 4.39 % (including rural and urban areas) in 2003 to 6.28 % in 2014. Similarly there has been drastic increase in layouts, particularly in zone-3, where it has drastically increased from 0.89 % in the year 2003 to 6.60% in 2014. Similarly in Zone-4 the area under layouts has increased from 1.99 % in 2003 to 9.46 %in 2014. This rapid urbanization has resulted in the blocking of the 2nd and

3rd order streams and nalas that have been cut off due to construction of buildings, levelling for layout formation as well as check dams and other obstructions etc. This was also indicated in the report submitted by ISRO-INRIMT which had concluded that due to dynamic and continuous urbanization in the TGR catchment, in certain places first and second order streams have been blocked due to construction of railway line, roads and new layouts, thereby affecting free movement of surface run-off. This problem has been further accentuated in the intervening period. The ISRO-INRIMT report had also indicated that truncated nala and minor impediments in the form of gully plugs, barriers, check dams, built-up areas hinders the flow of water.

iii. The Arkavathi river was flowing through a cascading tank system. It was found that water storage in many of these water bodies have reduced due to rapid urbanization all around the tanks leading to obstruction/ cutting off the streams, encroachments of the tank bed areas for agriculture or building construction, lack of maintenance of the tank etc. Unless the tank system is restored to its capacity and the drainage system is maintained, the problem of reduced inflow to the rivers and consequently to TG Halli reservoir is likely to continue.

iv. The ISRO-INRIMT report had concluded that the slope of the catchment (less than 3%), coarse-textured soils having infiltration rate ranging from 10-16% and the geology/ geo-morphology as a whole is not ideally suited for generation of run-off. The study also revealed that there is appreciable rise in reservoir if there is a good daily rainfall of more than 40mm continuously for few days and if few showers of short duration (more than 60 mm/day) during monsoon and post-monsoon period in Nelamangala, Bangalore North and Magadi regions. Hence it is felt that if sustained efforts are made towards rejuvenation of tanks and removal of encroachments, there would be gradual and long-term positive results in the overall water situation with enhanced ground water table.

10.2.2. Quality of Water and Consequent Hazards:

i. In the absence of substantial surface flow in the rivers, these rivers, particularly Arkavathi, has been converted to a sewage water flow. In many places untreated sewage water is being allowed to flow through the river bed. This problem was identified in the ISRO-INRIMT study which had found that presence of effluents/ sewage from Peenya to Dasanpura from industrial and urban settlements was leading to contamination of ground water. The study also had found that the ribbon development along two National Highways from Peenya to Nelamangala was polluting the Arkavathi river by their untreated effluents /sewage, which also lead to contamination of groundwater source through the open fracture systems in the country rock. Due to further urbanization in the intervening period the problem has further aggravated. This is evident from the water quality analysis undertaken by BWSSB of the water stored in the reservoir. Also water sample was collected for the current study from 25 sampling points. The presence of domestic sewage entering into the river stream is evident from the total coliform content which is above 50 MPN/100ml. Since 2012, the water stored in TG Halli reservoir is not being supplied for drinking water purpose by BWSSB for residents of Bengaluru, the storage of contaminated water in the reservoir has resulted in contamination of ground water, as reported by the local people residing around the reservoir. Also the untreated water is leaking to Manchenabele dam, where it is being used by the local population. Storage and use of such untreated water poses a major health hazard for the local people and this issue needs to be urgently addressed.

ii. The entire development outside the BBMP area that has mushroomed over the years is not connected to a sewer system. These residential houses, godowns, commercial buildings etc. are found to be using septic tanks for disposal of waste though in many cases these are not connected. At some places even septic tanks are not present and sewage directly enters the rivers. This is likely to directly or indirectly contaminate the river. This calls for immediate attention of BWSSB.

10.2.3. Institutional Mechanism:

There is multiplicity of institutions/ authorities in charge of the area. Within the catchment area there are five Town Planning Authorities. The Revenue Authorities are mainly responsible for land use conversions etc. As far as control of industrial pollution etc is concerned, KSPCB is the concerned Authority. The Institutions of local governance, such as Zilla Panchayat, Taluk Panchayat and Gram Panchayats also undertake developmental programmes and also give permission for building construction. This has led to lack of coordination between the various Government Authorities and sometimes they have worked at cross purpose with each other.

10.2.4. Initiatives undertaken by Government:

Efforts have been made by various Government Authorities to retrieve the situation. The following are some of the important steps taken by concerned authorities:

i. As per the directions of the Hon'ble High Court Order a Monitoring Committee was constituted under the Chairmanship of Additional Chief Secretary with ACS, Urban Development Department, Rural Development and Panchayat Raj Department, Commerce and Industries Department, Revenue Department, Water Resources Department, Commissioners of BDA, Chairman, BWSSB, Minor Irrigation, Major Irrigation, Finance etc as members. The Committee has met regularly and the progress with regards to the implementation of the directions of Hon'ble High Court has been reviewed.

ii. Cauvery Neeravari Nigam Limited has implemented a project for clearance of jungle growth and obstacles in Arkavathi and Arkavathi river stretches.

iii. The Nelamangala Planning Authority has notified villages and survey numbers which fall in different Zones as per the 2003 Notification for regulation of activities in accordance with the 2003 Notification.

iv. KSPCB has closed down industrial units operational in the area. BDA has served notices to structures which have not obtained necessary sanctions.

v. BWSSB has made consultations with national and international experts to find out what best can be done to improve both quality and quantity of flow to TGR.

vi. The Urban Development Department has moved the "The Karnataka Arkavathi and Kumudvathi River Basin Conservation and Development Bill, 2013" (Annexure-8.6). This Bill aims to create "Arkavathi and Kumudvathi River Basin Conservation and Development Authority". The functions for the Authority in the proposed Bill are (1) to formulate and implement schemes for conservation and comprehensive development of the Arkavathi and Kumudvathi river basin, (2) to prevent land erosion and water-logging (3) abatement of pollution and conservation of the river Arkavathi and Kumudvathi (4) development of river basin management scheme and regulation of activities, maintenance of minimum ecological flows in the said rivers (5) collection, analysis and dissemination of information etc. The Finance Department has subsequently asked for some clarifications on the matter.

10.2.5. Public Awareness and Response:

i. One of the issues raised by public during interactions was that they were not made aware about the implications of the Government Order. They were also not given an opportunity to express their objection to the Order. The boundaries are not clearly demarcated for the various preservation zones as per the Government Order.

ii. The local farmers have also expressed that agriculture has become unviable due to the groundwater depletion, lack of availability of labour etc. However in Zone-3 only agricultural and allied activities are allowed. This has created difficult for them. Some of them also expressed that they are ready to give their land if the same is acquired by Government by paying them due compensation.

iii. The local people have also expressed that the Government Order did not take into consideration the natural expansion of the habitations which already existed.

iv. Some of the local people also expressed that they are ready to adhere to any stipulations with regards to solid waste management, waste water and other sanitation measures.

10.3. Recommendations:

The entire issue of reduced inflow in Arkavathi, Kumudvathi and TGR has many dimensions, including ecological, environmental, socio-economic, political, legal and administrative. Also the process of river rejuvenation is a slow process that may require sustained efforts over a long period of time with repeated data collection, analysis and suitable amendments to course of action.

An attempt has been made to collect and analyse the available information and arrive at reasonable recommendations which can be considered as options or alternatives in the best interest of conservation of the fragile hydrological system of the area of study. These options may be utilized by concerned authorities to come up with detailed action plans for implementation. These have been arrived at in consultation with the Advisory Committee consisting of all concerned Authorities/ Departments and also the committee consisting of technical experts. The following are the recommendations:

10.3.1. Formation of Multi-disciplinary Institution for the River Basin:

It is proposed that institutional mechanism should be developed for multi sectoral comprehensive assessment, management and regulation of the entire catchment of TG Halli reservoir. Such an institution should develop the suitable regulations and a comprehensive plan for the entire catchment area and the rejuvenation of Arkavathi and Kumudvathi rivers in consultation with concerned Agencies and implement the same in collaboration with them. The creation of such an authority has also been suggested by Dr. Rajendra Singh, international water expert from Rajasthan, who is responsible for successful river rejuvenation in Rajasthan, in a meeting held by BWSSB on 24.6.2011 with regards to the subject of rejuvenation of Arkavathi and Kumudvathi.

While formulating such a comprehensive plan, best examples of successful river rejuvenation such as Ruparel and Arvari rivers in Rajasthan State, which were dead for three to four decades, can be taken into consideration for guidance and to strategize the course of action.

This is in tune with the National Water Policy 2012 which has emphasized that Integrated Water Resources Management (IWRM) taking river basin/ sub-basin as a unit should be the main principle for planning, development and management of water resources. The Departments/ organizations at Centre/ State Governments levels should be restructured and made multi-disciplinary accordingly.

The policy also emphasizes that appropriate institutional arrangements for each river basin should be developed to collect and collate all data on regular basis with regard to rainfall, river flows, area irrigated by crops and by source, utilizations for various uses by both surface and ground water and related aspects. Appropriate water accounts for each river basin with budgets and accounts should be published.

Already a proposal has been mooted by Department of Urban Development for enactment of Arkavathi and Kumudvathi River Basin Conservation and Development Authority Act (Annexure-8.6) and constitution of Arkavathi and Kumudvathi River Basin Conservation and Development Authority. The proposed Act with suitable modifications, if any, should be enacted and implemented.

10.3.2. Removal of Unauthorized Obstructions:

The Cauvery Neeravari Nigam Limited had carried out a study in 2011 in which field inventory of obstructions or encroachments along the trunk stream and important tributaries was analyzed with the help of satellite imageries and field observations. The streams were found flattened for cultivation, check dams etc. In total 83 obstructions were found in Hesaraghatta sub-catchment, 115 in Kumudvathi sub-catchment and 277 in Arkavathi sub-catchment. The CNNL has undertaken removal of obstructions in 2^{nd} order and 3^{rd} order streams of Arkavathi and Kumudvathi. The same should be continued and also monitored in future so that encroachments, levelling of the streams, unauthorized check-dams are not constructed. This was also a suggestion given by Dr. Rajendra Singh, International Water Expert, Rajasthan in the meeting held by BWSSB on 24.06.2011.

10.3.3. Stopping the Illegal Quarrying, Soil Excavation and Sand Mining:

The TG Halli Reservoir, Hesaraghatta tank, stream bed of Arkavathi and Kumudvathi rivers, and also most of the lakes in the catchment are subjected to soil excavation and sand mining activities, though these activities are restricted by the respective department in the catchment. These activities may cause lowering of riverbed level as well as river water level and also resulting in lowering of groundwater table due to excessive extraction and draining out of groundwater from the adjacent areas. The soil excavation will reduce the thickness of the natural filter materials (Top layer soil), infiltration through which the ground water is recharged. These activities induce soil runoff during monsoon season resulting in siltation in the rivers.

Quarrying has been observed in few villages in the catchment which is still in progress, though quarrying has been restricted by department. The heavy metals and other pollutants from quarrying site ultimately find its way to the river hence polluting it.

As these activities are posing a threat to the waterbodies in the catchment, concerned departments should take stringent actions against these activities by establishing a monitoring cell which regularly monitors these activities.

10.3.4. Preservation of Lakes and River Beds by removal of Encroachments of Tank Beds or River Bed:

River bed in some places and tank beds in some villages appear to have been encroached. The same has been separately covered in Chapter-5 (Annexure-5.6). The revenue Department should duly survey such areas and verify the records and remove such encroachments of tank beds/ river beds etc. The Government of Karnataka has also enacted the Karnataka Tank Conservation and Development Authority Act, 2014 that aims to preserve Lakes and Tanks by establishing Karnataka Tank development Authority. The Act has vested all necessary powers for evicting the encroachments. The Act should be implemented effectively.

The Hon'ble High Court of Karnataka, in Order dated 11.04.2012 in Writ Petition No. 817/2008 directed that (a) It is just and necessary that survey of lakes and tanks in Karnataka have to be undertaken by Demarcating the boundaries and make proper fencing (b) Unauthorized construction within the buffer of perennial lakes have to be removed. Accordingly, all feeder tanks coming under TGR catchment area should be surveyed, demarcated and fenced.

10.3.4a. Revival of Tank System:

The entire tank system should be revived by undertaking necessary repairs, desilting, connecting underutilized tanks directly, developing pisciculture, bigger tanks to be developed as recreation centres etc. The Government of Karnataka has enacted the Karnataka Tank Development Authority Bill, 2014 which has established Tank Development Authority and vested the same with necessary powers for conservation, protection and rejuvenation of water bodies. All necessary steps should be undertaken with Detailed Project Reports for revival of the tank system. This would help in replenishment of ground water.

10.3.5. Protection and Preservation of TG Halli Reservoir:

The Tippe Gondanahalli Reservoir is an important landmark and heritage that needs to be preserved by providing proper protection and also maintaining the reservoir. The sluice gates and treatment facility need to be maintained in proper workable condition. The option of creation of an artificial wetland for treating the anthropogenic or industrial wastewater which is being stored in TGR should be considered and implemented. Some experts in the field should be consulted before implementing this. Such engineered systems use natural functions of vegetation, soil and organisms to treat water. Such constructed wetlands have the capacity to act as a bio filter for removing sediments and pollutants such as heavy metals from the water. The possibility of use of treated water for industrial or agricultural purposes should also be considered. BWSSB may be asked to submit a detailed project report for preservation and use of TG Halli reservoir.

10.3.6. Control of Industrial Effluent Discharge into the River Course:

Water footprint of Indian industry is unacceptably high. There is a need to reduce consumption of fresh water through alternative water-efficient technologies or processes, reuse and recycle waste water and make the reclaimed water available for use in secondary activities within or outside the industry and thereby reduce the volume of polluted water dumped into rivers and groundwater.

Stringent action should be taken against industrial effluents being discharged into the river course with strict monitoring and enforcement. Also in relation to the industries operating in catchment area a study may be carried out regarding the water usage by the industries, their source and disposal of waste water. There seems to be lack of reliable information on the same. The industries may also be asked to contribute under the Corporate Social Responsibility (CSR) for treatment of the industrial effluents by establishing Common Effluent treatment Plants or opting for alternative water efficient technologies and reuse and recycling of water within the industries. This will be highly beneficial in reducing the requirement of fresh water. KSPCB may be asked to build up a detailed project proposal in consultation with the local industries on the possibility of reuse and recycling of water.

10.3.7. Alternative technologies for Treatment of Wastewater:

The discharge of sewage water into the river is a serious environmental concern and potential health hazard. There is a network of Sewage Treatment Plants under the control of BWSSB in Bangalore. The same should be maintained and utilized in optimum condition. The water should be collected and treated before releasing into the river, so that such sewage water does not get accumulated in the TG Halli reservoir. Alternative technologies including eco-filtration, soil-scape systems etc. may be adopted to tackle the problem of untreated sewage entering directly into waterbodies.

In one of the Expert Committee meetings dated 27[th] March'2015, it was suggested that recycled wastewater may be utilized for recharging of groundwater and rejuvenation of Arkavathi and Kumudvathi rivers. After secondary treatment, treated water may also be allowed to meander through the river bed that can be planted up with bamboo or other such species that have the ability to trap contaminants. This would further remove the contaminants and improve the water quality. The concept note as given by the member of the Expert Committee is attached in Annexure-10.2.

There are large numbers of villages outside the BBMP area which are not connected to a sewerage system. The sewage from such households/ commercial buildings/ godowns etc. are collected in soak pits. Such cluster of houses/ buildings may be connected to a decentralized sewerage treatment system such as DEWATS which is a viable and sustainable alternative approach to Sewage and waste water treatment for rapidly increasing urban areas. The advantages of such systems are scalability to any size, adaptability to varying load sizes, climatic conditions. The water can be safely reused for non-potable end uses. Such alternatives have been effectively used in many hospitals, apartments etc. This may be attempted as well (Annexure-10.3). The local people should be encouraged to adopt such alternatives at the community level.

10.3.8. Preservation and maintenance of Storm Water Drains:

With reference to the problem of discharging wastewater or greywater into the storm water drains leading to the pollution of river, the followings are recommended:-

i) Prevent the discharge of any wastewater into the storm water drains with further control on the dumping of solid waste into the storm water drain coming within the vicinity of area having stream, river or lakes.
ii) The storm water drain and wastewater disposal system should be separated.
iii) Diversion of the waste or grey water away from the river, stream and lake.
iv) Regular cleaning and maintenance of the storm water drains.
v) Installation of Gross Pollution Traps in storm water drains to trap the litter, debris, coarse sediments.

10.3.9. Management of Solid Wastes:

The dumping of solid wastes including domestic waste, agriculture waste, construction waste, biomedical waste, e-waste, etc. into the river and bank of rivers/ lakes has resulted in deterioration of TGR catchment area. The major reason for the dumping of solid wastes is due to the improper management of solid wastes in the catchment area. The generated solid wastes can be only managed by the involvement of community through the awareness. Control, monitor and regulate the collection, transport, treatment and disposal of wastes by the local bodies should be ensured by effective management schemes, which meet current social, economic, and environmental conditions of the TGR catchment area. It is important to note that no one single treatment method can manage all the waste materials in an environmentally effective way. Integrated Solid Waste Management (ISWM) should take an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. The local Gram Panchayats and Pattana Panchayats should come up with detailed plan of action.

Within the solid waste, the poultry wastes generated commercially in the sub- and peri-urban area are dumped all along the river course and the drains. These poultry waste and by-products have potential to pollute water include degradation of nearby surface and/or groundwater by increase the load of nutrients such as nitrogen and phosphorus. So, there is need to adopt effective poultry waste management practice to reduce the threats associated with it. Therefore, the poultry waste should also collect, store, handle, treat, transport and apply the waste by-products to the receiving land for application of crop nutrition.

10.3.10. Regulation and Management of Ground Water:

As per the Central Ground Water Board (CGWB) unaccounted ground water is a cause of grave concern in 28 cities of India. The catchment of TG Halli is also having the same problem of unaccounted over exploitation of ground water. Haphazard groundwater abstraction driven by individualistic pumping has filled out gaps in public water supply. However, it has also led to co-terminal depletion and contamination of aquifers.

The strategies that need to be adopted for tackling the ground water problem should include the following:

- Mapping and Registration of Key Groundwater Sources
- Participatory Aquifer Mapping
- Stakeholder database: users, driller, tanker-operators
- Groundwater Recharge Programmes
- Securing Groundwater from Waste Disposal
- Protection of Recharge Zones
- Participatory Groundwater Management
- Water Tanker Transportation should be monitored through the GPS

Prevention of further development and exploitation of ground water should be done on priority. The Government of Karnataka has enacted the Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011. Through the constitution of an empowered Groundwater Control Directorate, the Act is a key instrument for curbing indiscriminate exploitation of groundwater. However the Directorate should be supported with necessary manpower and infrastructure to effectively discharge its function as a regulatory body.

There is a need to develop ground water as a community resource rather than an individual resource. In this direction initiatives need to be taken up with the help of local communities, village level institutions, Non-Governmental Organizations, Self Help Groups etc. This is also in tune with the National Water Policy which says that, water, particularly, ground water, needs to be managed as a community resource, held, by the state, under public trust doctrine to achieve food security, livelihood etc.

In this direction, the positive interventions of WENEXA may be attempted at a larger scale. The objective of the Water and Energy Nexus (WENEXA) Project is to identify measures for reducing adverse impacts of inadequate power pricing and distribution on use of water in the agricultural, municipal, and industrial sectors. The Project is a four-year initiative financed by the United States Agency for International Development/India (USAID/India). Under the auspices of the USAID and the Ministry of Power, GoI, the WENEXA Project selected Doddaballapur Taluk of Bangalore Rural District, Karnataka, for a site-base activity in groundwater irrigated agriculture. The project attempted to imbibe efficient use of water by replacing inefficient pumpsets with efficient ones. The quality and dependability of power supply was improved at a reasonable cost. This example may be replicated in other areas of the catchment where the ground water has depleted as well. It is clear that when farmers get free power for extracting groundwater for irrigation they tend to over use and waste ground water. Hence power should be appropriately priced for agriculture.

Rainwater harnessing for domestic consumption as well as agricultural purposes should be encouraged. Also for supporting agriculture in such water scarce area, the Department of Agriculture may support drip irrigation, sprinkle irrigation through the Centrally Sponsored Schemes and State Sponsored Schemes for dry land agriculture.

10.3.11. Adoption of Rainwater Harvesting System (RWH):

As the TGR catchment area has been categorized as the Dark zone or Over-exploited zone by the Central Groundwater Board (CGWB), there is a requirement for households, warehouses and commercial buildings to adopt rainwater harvesting structures to reduce the pressure on groundwater. The State Government and Government of India encourage rainwater harvesting systems through various schemes, policy and guidelines. While the 2003 TGR preservation Notification also stressed to enforce Rain Water Harvesting systems the same has not been implemented. Hence it is recommended that guidelines related to RWH systems should be implemented by the concerned Authorities. Further, the industrialist should come forward to construct rain water harvesting structures and artificial recharge structures for recharging the aquifer.

10.3.12. Decommissioning of Abandoned Bore-wells and Tube-wells:

Abandoned bore-wells in the TGR catchment area should be filled up with the clay/sand/boulders/ pebbles/drill cuttings, etc. from bottom to ground level. Based on the Hon'ble Supreme Court of India order dated 11th February'2010, the Ministry of Drinking Water and Sanitation, GoI (No. W-11042/20/2012-Water-II; dt. 27th July'2012) asked all the Principal Secretaries of Rural water supply and sanitation, that if a bore-well/ tube-well is abandoned at any stage, a certificate from the concerned department of groundwater/public health/Municipal corporation must be obtained by the aforesaid agencies that the abandoned bore-well/tube-well is properly filled up to the ground level. Random inspection of the abandoned wells is also to be done by the Executive of the concerned Agency/ Department.

Implementation of the regulations regarding filling up the abandoned bore-well will not only prevent fatal accidents of small children but also it will stop the illegal injection of effluents/ sewage into the abandoned bore-wells/tube-wells.

10.3.13. Creation of Tree Plantation along the River Stretches:

Across the river stretches of Arkavathi and Kumudvathi, strip plantation should be created to minimize the pollution in the area. Agro forestry should be encouraged to act as an insurance against crop failures. Forest Department may be asked to come up with a detailed proposal in this regard.

10.3.14. Encouraging Climate Resilient Agriculture:

The Government of Karnataka has already undertaken many initiatives towards sustainable rainfed agriculture such as Bhoo Chethana, Bhoo Samruddhi, Niti Aayoga Krishi Bhagya (promoting micro irrigation). The Government of Karnataka is also promoting solar energy by encouraging farmers through schemes such as Surya Raitha (solar for farmer) and tapping solar energy from farm lands. All such initiatives should be encouraged by the Government to encourage agriculture. The Agriculture Department may come up with a project proposal for the area. Also all efforts should be made to implement MNREGA in the area particularly for soil and moisture conservation. The Rural Development and Panchayat Raj Department may come up with detailed proposal.

10.3.15. Implementation of Existing Conservation Zone till the Formation of Authority and Prevention of Change in Landuse pattern:

Regarding the permissibility of further developments and establishment of superstructures in the TGR catchment area, until the Arkavathi and Kumudvathi River Basin Conservation and Development Authority comes into formation, it is important that the existing Notification dated 18.11.2003 remains in operation. There is tremendous development pressure in Bengaluru. The 3rd Advisory Committee felt that if the existing Notification gets relaxed, the development of layouts and commercial buildings will come up in an uncontrolled manner. There will be very fast change in land use and very fast development of layouts and superstructure which will adversely affect the drainage system further and it may not be possible to retrieve the situation in future. This was also suggested by Dr. Rajendra Singh, responsible for rejuvenation of many rivers in the State of Rajasthan, in a meeting held by BWSSB on 24.6.2011 with regards to the subject of rejuvenation of Arkavathi and Kumudvathi.

10.3.16. Creation of Adequate Awareness among the Local People:

The local people have to be made adequately aware about the regulations and also proactive steps should be taken up to take their support in implementation of the regulations. Also as explained in the paragraphs above, a number of steps should be initiated by Government to encourage rain fed agriculture, solid waste management, rain water harvesting, agro-forestry, treatment of domestic waste water, DEWAT systems etc. The local residents should be made aware about all these initiatives and all attempts should be made to implement any Government programme in a participatory manner.

It is submitted that all the suggestions given in this chapter may be considered by the concerned Government Departments/ Authorities to develop suitable action plans for implementation.

Finally it needs to be appreciated that under the present circumstances, rejuvenation of the two rivers namely Arkavathi and Kumudvathi is a challenging and long term process that cannot be expected to happen in a short period of time. Concerted long term efforts by all Departments or Agencies in a well-coordinated manner are required to get the desired results.

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