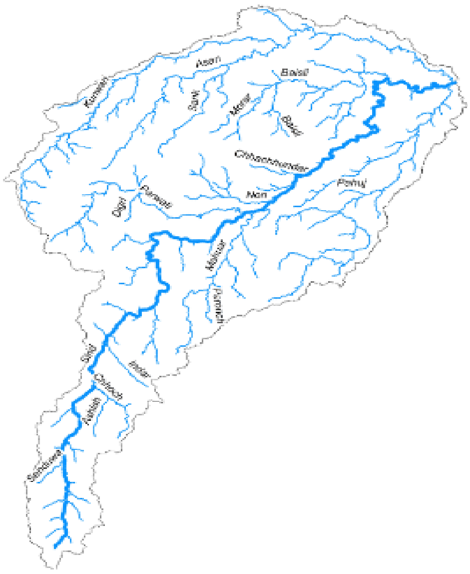

Sind River Basin Plan

Draft, January 5, 2015

TMT Group- WRD, GoMP, INDIA

UNESCO-IHE
Institute for Water Education

Name of the Client	**Water Resources Department** **Government of Madhya Pradesh, INDIA**
Agency	**UNESCO-IHE, Institute for Water Education,** **Delft, the Netherlands**
Duration	**11.12.2013 to 05.01.2015**
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Ya Apaodivya Ut Va Sravanti Khanitrima ut va yah swayamjah |
Samudrartha Yah Shuchayah pavakasta Apao Devirih Mamvantu ||
Rig Veda VII.49.2

The water which is created in the universe, the water which flows in the form of river etc, the water which comes from the digging of the wells, canals etc., the water which is self created in the form of waterfalls etc, who enters into the ocean and who is pure and full of light, who is full of divine characteristics, help me in this world and be received by me.

National Water Policy 2012 *of India* lays down 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".

Madhya Pradesh State Water Policy 2003 states that "The water resources development shall be planned on the basis of river basin or sub-basin. Each development project shall be designed in such a manner that each basin or sub-basin is inherently integrated water resources planning so that the best alternative can be identified."

As an initiative to water resources planning on basin scale without undermining the role of administrative units, Sind River Sub-Basin Plan would constitute situation analysis leading to strategy formulation for improving the current situation. The plan would aid in action formulation for addressing the relevant water challenges in the river basin for now and in future.

Disclaimer

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Our sincere thanks go to Madhya Pradesh Water Resources Department (WRD), in particular to Mr. R. S. Julaniya, IAS, Principal Secretary for the insights on the inception and throughout the tenure of this training program. We would like to thank Mr. Manish Singh, IAS who during his tenure as the Secretary to GoMP, WRD and Project Director PICU envisioned this unique output oriented capacity building program. We would like to show our gratitude to Mr. M.G.Choubey, Engineer-in-Chief WRD who guided us through the process of data collection, field visits and stakeholders' workshops. Our deepest gratitude is due to Mr. M.C. Gupta, Secretary WRD, Mr. M.S. Dhakad IFS- Commissioner CADA, Mr. S.K. Khare-Chief Engineer BODHI, Mr. N.P. Kori- Chief Engineer (YB, Gwalior) and Mr. Sanjeev Shrivastava-Chief Engineer (Rajghat, Datia). We would also like to expand our gratitude to all Superintending Engineers, Executive Engineers, Assistant Engineers and Sub-Engineers who were involved in the process of this program.

The support from the World Bank (IBRD) funded Madhya Pradesh Water Sector Restructuring Project (MPWSRP) to the program is acknowledged. Mr. Salilendra Shrivastava SE PICU, Mr. Shirish Mishra SE, Mr. D.C.Garg EEBVPP and Mr. Neeraj Khare associated with the project office have tirelessly worked for the success of the program.

Sincere thanks to Mr. Sanjiv Das, EE of MP WRD Data Center for providing the available data pertaining to the sub-basins and sharing his water modeling experiences. We would also like to acknowledge the help extended by the CGWB North Central region particularly by Mr. Parvinder Singh- Regional Director, Mr. Seraj Khan and Mr. R.M. Verma. We would also like to thank to the officials and staff of State Pollution Control Board, Indian Meteorological Department, MP PHED, Municipal Corporations of Gwalior.

We would like to extend our sincere thanks and appreciation to the UNESCO-IHE Staff who contributed towards this training and capacity building program. Special thanks are due for Prof. Pieter van der Zaag for his constructive comments and oversight that was instrumental to improve the quality of this river basin plan. Dr. Ilyas Masih is acknowledged for coordinating the program and for his committed involvement with the capacity building and plan formulation process. Dr. Nora van Cauwenbergh is acknowledged for guiding us through the IWRM planning and stakeholder consultation process. Special thanks are due to many staff members who have significantly contributed in teaching and plan formulation, few to mention are Susan Graas, Dr. Biswa Bhattacharya, Dr. Paolo Paron, Dr. Ioana Popescu, Prof. Ken Irvine, Dr. Andreya Jonoski, Dr. Yong Jiang, Jeltsje Kemerink. Our sincere thanks and gratitude is extended towards UNESCO-IHE support staff, Arno Heins, Marlies Baburek, Caroline de Ruiter, Stephanie Petitjean, Mariëlle van Erven, for their help and guidance on practical matters such as accommodation and social and cultural integration to the UNESCO-IHE family.

The international trips to Turkey, Spain and Portugal were helpful to compare the water management practices in these countries with those in MP, India. We sincerely thank Ms. Simla Ozkaya of Govt. of Turkey and DSI for arrangements and hospitality during visit to Turkey especially Mr. Hasan Basri Yüksel who accompanied us during the visit. Dr. Nora van Cauwenbergh is appreciated for her leading role in arranging trip to Spain and Portugal.

Foreword

The Sind sub-basin plan has been drafted as part of a one year training and capacity building program for 10 staff members of Water Resources Department of Madhya Pradesh state, India. This program was conducted by UNESCO-IHE Institute Delft, the Netherlands during December 2013 to January 2015. The main aim of this program was to provide training on river basin planning and management with preparation of river basin plans for the Sind and Chambal sub-basins of Madhya Pradesh as the deliverables of this program.

Sind sub-basin plan is prepared by the participants under the guidance of UNESCO-IHE staff members. The plan display application of part of the knowledge, skills and experience gained by the participants during this training program. The document is the first ever made sub-basin plan for the Sind and first ever made plan in Madhya Pradesh which is underpinned by integrated water resources management approach.

The water resources management context and emerging issues in India and Madhya Pradesh are outlined in the first chapter on introduction. A pragmatic approach was adopted in the plan preparation that reflected major steps in an integrated and participatory planning process while remaining within the constraints of this training program. The lack of available literature, analytical tools and water resources model applications on Sind sub-basin warranted a lot of analysis to be carried out from the scratch which became more challenging due to scarcity of data and its poor quality. The chapter on situation analyses provides a comprehensive analysis of the water resources system at sub-basin level with detailed description of the natural, socio-economic and administrative and institutional sub-systems. While describing these systems, the existing situation and water management issues are thoroughly examined. This chapter provides the basis for identifying major issues and challenges and setting up of goal and objectives for the Sind sub-basin plan. This is followed by the chapter on measures and strategy which builds on the expert knowledge and judgment, a pragmatic examination of the suitability of available options to the local context and building on the existing technical, social, economic, environmental and institutional context within Sind sub-basin and Madhya Pradesh. The final strategy recommended for the Sind sub-basin is presented in the next chapter. The limitations encountered during the preparation of this plan are also outlined. The last chapter indicates the expected way forward on the pathway of the integrated river basin planning and management process.

I appreciate the originality and creativity demonstrated by the training participants and UNESCO-IHE staff members which makes this plan a good foundation for the water management in the Sind sub-basins. Moreover, It is our expectation that this document will significantly contribute in furthering the process of integrated water management in

Madhya Pradesh. The 10 staff members trained under this program will hopefully play an instrumental role in this regard.

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List of Abbreviations

AIS	Administrative and institutional system
AKVN	Audyogik Kendriya Vikas Nigam
BCM	Billion cubic metre
BIS	Bureau of Indian Standards
BOD	Bio-Chemical Oxygen Demand
BODHI	Bureau of Design for Hydel & Irrigation projects
COD	Chemical Oxygen Demand
CDP	City Development Plan
CGWB	Central Ground Water Board
Cm	Centimeter
CPCB	Central Pollution Control Board
CRMC	Chambal Right Main Canal
CWC	Central Water Commission
CWR	Crop Water Requirement
°C	Degree Centigrade
DEM	Digital Elevation Model
DLWUC	District Level Water Utilization Committee
DO	Dissolved Oxygen
DPAP	Drought Prone Area Program
E_p	Water Use Efficiency for a project
E_r	Reservoir filling efficiency
E_c	Conveyance efficiency
E_f	On-farm application efficiency
E_d	Drainage efficiency
EC	Electrical conductivity
EFR	Environmental Flow Regime
ET_o	Potential evapo-transpiration
FAO	Food and Agriculture Organization
GEC-1997	Ground Water Resources Estimation Committee, 1997
GD	Gauge Discharge
GDP	Gross Domestic Product
GoMP	Government of Madhya Pradesh
GIS	Geographical Information System
GW	Ground Water
ha	Hectare
ham	Hectare metre
HEC-HMS	Hydrologic Engineering Center's- Hydrologic Modeling System
IBT	Inter Basin Transfer
IIT	Indian Institute of Technology

IMD	Indian Meteorological Department
IMT	Irrigation Management Transfer
IPC	Irrigation Potential Created
IPU	Irrigation Potential Utilized
IRS	Indian Remote Sensing
IWRM	Integrated Water Resources Management
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
Kg/ha	Kilo Gram per Hectare
Km	Kilo Meter
Km/h	Kilo Meter per Hour
Km^2	Square Kilo Meter
lps	Litres per second
lpcd	Litre per Capita per Day
m	Meter
m^3	Cubic Meter
m^3/s	Cubic Meter per Second
m bgl	Meter below ground level
mg/l	Mili Gram per Litre
m ham	Million hectare metre
MAR	Mean Annual Runoff
MLD	Million Litre Per Day
mm	Millimeter
MCM	Million Cubic Meter
MCM/ha	Million Cubic Meter per Hectare
MAPCOST	Madhya Pradesh Council of Science & Technology
MoEF	Ministry of Environment and Forests
MOWR	Ministry of Water Resources, Govt. of India
MP	Madhya Pradesh
MP CLR	Madhya Pradesh Commissioner of Land Records
MW	Mega Watt
NA	Not Available
NABARD	National Bank for Agricultural and Rural Development
NIR	Net Irrigation Requirement
NRS	Natural resources system
NSE	Nash Sutcliffe Efficiency
NWM	National Water Mission
NWP	National Water Policy
OW	Observation Well
PCI	Per Capita Income
PIM	Participatory Irrigation Management
PRI	Panchayati Raj Institution

PZ	Peizometer
RBC	Right Bank Canal
RCC	Reinforced Cement Concrete
SAR	Sodium Adsorption Ratio
SES	Socio-Economic System
SLWUC	State Level Water Utilization Committee
SMA	Soil Moisture Accounting
SPCB	State Pollution Control Board
Sq Km	Square Kilo meter
STP	Sewage Treatment Plant
SWaRDAC	State Water Resources Data Analysis Center
SWP	State Water Policy
TDS	Total Dissolved Solids
Th ha	Thousand Hectare
TRMM	Tropical Rainfall Measuring Mission
UADD	Urban Area Development Department
WALMI	Water and Land Management Institute
WRD	Water Resources Department
WQ	Water Quality
WQM	Water Quality Monitoring
WUA	Water Users Associations
WUE	Water Use Efficiency
YAP	Yamuna Action Plan

EXECUTIVE SUMMARY

Executive Summary

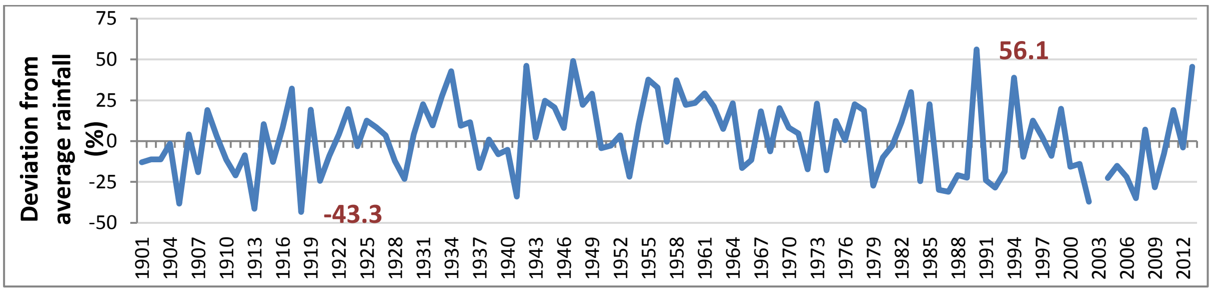
Government of Madhya Pradesh's (GoMP) commitment to capacity building of its staff and the unprecedented initiative in river basin planning has led to this draft document, the Sind sub-basin plan. Madhya Pradesh Water Resources Department has collaborated with UNESCO-IHE Institute for Water Education, Delft, the Netherlands for capacity building and training on integrated water resources planning. This river basin plan was developed as a part of one year training and capacity building program that aimed to train 10 staff members of Madhya Pradesh Water Resources Department, India on river basin planning and management.

Madhya Pradesh which is among the fastest growing states in terms of economic growth has also consistently achieved high agricultural growth. An expansion in irrigation service delivery in the recent years has greatly contributed to State's agricultural growth as have timeliness of other inputs and farmer-centric procurement mechanisms.

The situation analysis attempts to describe the Sind sub-basin in terms of:

1. Natural Resources System (NRS)
2. Socio-Economic System (SES), and,
3. Administrative and Institutional System (AIS)

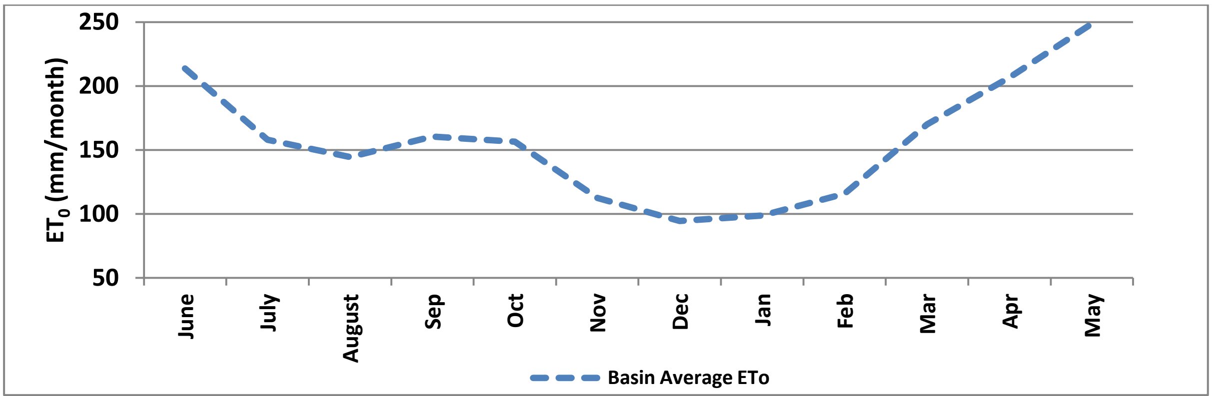
Natural Resources System NRS: Sind is among the 10 river basins in the State and is a sub-basin of the Yamuna and Ganga River basins. Sind River originates in Madhya Pradesh and meets Yamuna River after crossing the State boundary with Uttar Pradesh. The total drainage area of Sind sub-basin is 27,948 km^2, in Madhya Pradesh 26,082 km^2 and in Uttar Pradesh 1866 km^2. A total of 9 districts of Madhya Pradesh constitute the sub-basin. Datia and Gwalior districts completely fall under Sind sub-basin, whereas part of Vidisha, Ashoknagar, Bhind, Guna, Morena, Sheopur and Shivpuri come under the Sind sub-basin. The entire sub-basin receives precipitation from south-west monsoon between June and September. The annual average rainfall in the sub-basin is 875 mm/ year. The analysis of annual rainfall anomaly shows that the percentage deviation from the mean annual rainfall in the sub-basin varies from -43% to 56%.



This study finds that incidence of rainfall deficit has been more frequent in the last 40 years and apart from Shivpuri and Sheopur districts, 7 districts in the sub-basin are drought-prone.

The mean maximum temperature varies between 41.6°C to 23.4°C while mean minimum temperature varies between 26.4°C to 8.3°C. The average temperature varies in the range of 34.5°C to 15.5°C. The mean monthly maximum and minimum wind speed in the basin is estimated as 5.0 Km/h and 1.4 Km/h respectively. The maximum and minimum observed wind speeds are in the range of 46 Km/h to zero. The mean monthly maximum and minimum humidity for the Sind sub-basin is 82.0% and 29.5% respectively. The daily humidity in the basin ranges from 10% to 100%.

The range and variation of average monthly potential evapo-transpiration (ET_0) is shown in the figure below, the annual average ET_0 for the sub-basin is 1875 mm.



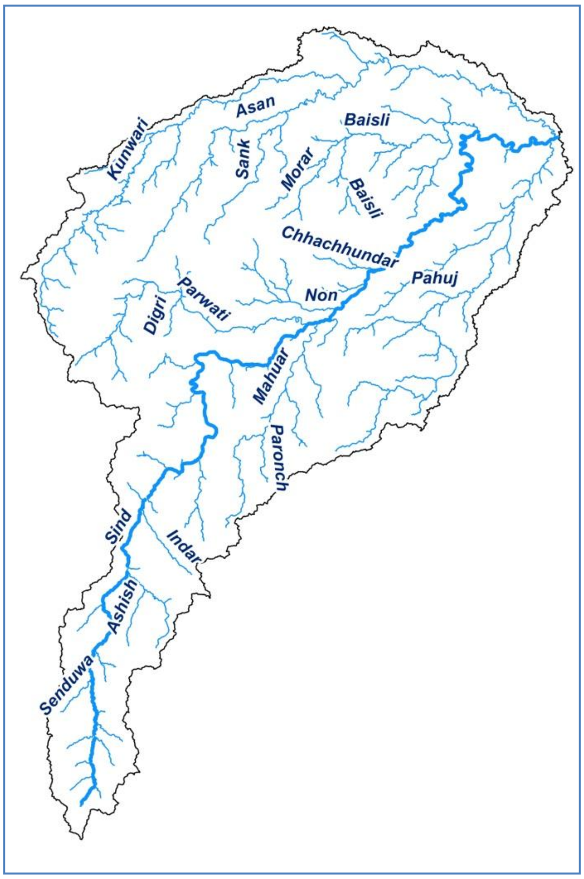
There are three agro-climatic zones in the sub-basin and the basis of the classification is given in the table below:

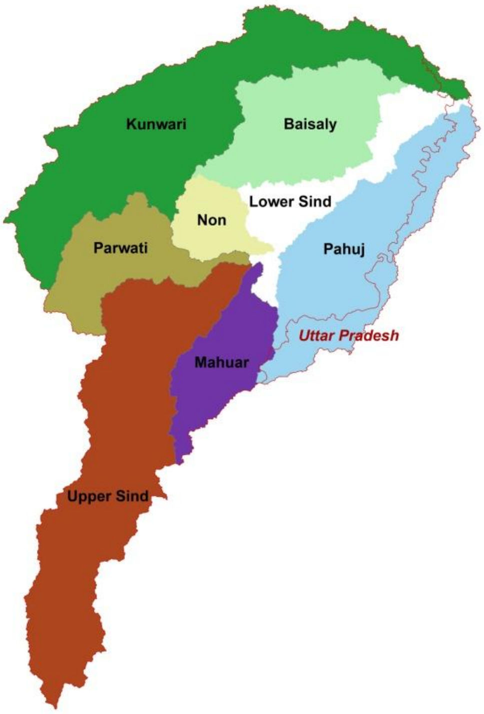
Agro climatic Zone	Districts	Soil Type	Annual rainfall (mm/year)	Crop zone
Gird region	Morena,	Alluvial	800-1000	Wheat-Jowar
	Bhind,	Alluvial		
	Sheopur,	Alluvial		
	Shivpuri	Alluvial		
	Gwalior	Alluvial		
	Guna	Medium & Deep Black		
	Ashoknagar	Medium & Deep Black		
Bundelkhand	Datia	Mixed Red & Black	700-900	Wheat-Jowar
Vindhya Plateau	Vidisha	Medium & Deep Black	1000-1200	Wheat

The land use pattern in the sub-basin is dominated by agriculture followed by forests. In Sind sub-basin 52% land is under cultivation, 19% land comes under forest, 15% of the land is not available for cultivation (including habitation) and 14% is fallow land (grazing land, pastures).

River system:

Mahuar, Parwati, Pahuj, Kunwari, Non and Baisli are among the larger tributaries of Sind river.





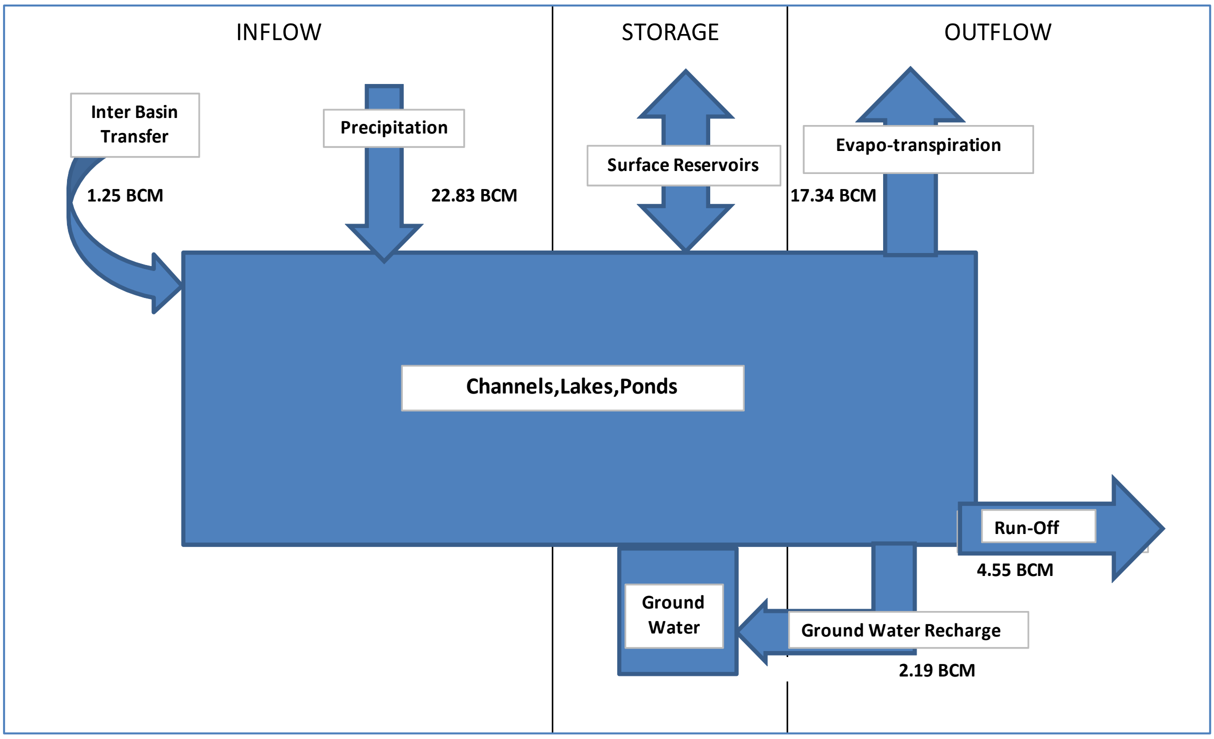
Drainage areas of sub-catchments

SNo	Sub catchment name	Drainage area in MP (km²)
1	Mahuar	1,818
2	Parwati	2,181
3	Pahuj	2,466
4	Kunwari	6,770
5	Non	1,019
6	Baisili	3,145
7	Upper Sind	6,688
8	Lower Sind	1,995
	Total	26,082

The important dams and water resources infrastructure in the sub-basin include Madikheda, Upper Kaketo, Mahuar, Paronch, Pehsari, Akhajhiri, Harsi, Tigra, Pillowa, Kaketo, Pagara, Harsi, Chandpatha, Madhav lake and Kotwal. Most of the dams were created during the pre-independence era but the construction of Madikheda in 2008 has added the most in terms of storage in the sub-basin.

Water Balance:

The Madhya Pradesh portion of Sind sub-basin has estimated average water resources availability of 9.44 BCM/ year based on mean annual runoff (non-naturalized). The water balance of the sub-basin is depicted below.

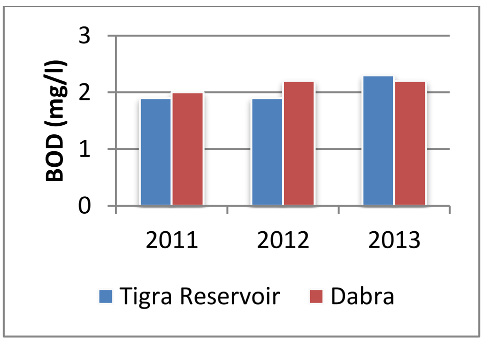


A SWAT model was setup to confirm the water availability and its result estimate a water availability of 9.70 BCM without taking into account the receipts from Chambal canal system.

A catchment model in HEC-HMS based on soil-moisture accounting method (SMA) was set up to arrive at the rainfall-runoff correlation. This model yielded an average runoff of 6.23 BCM compared to 4.55 BCM computed using non-naturalized river flow. Both of these models provide some additional insights but need to be improved to get more reliable hydrology and water balance of the sub basin.

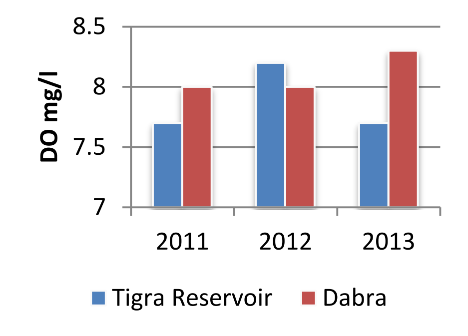
The annual groundwater availability in the sub-basin is 2.70 BCM as estimated by the Central Groundwater Board (CGWB).

Water Quality:



Different agencies monitor water quality in the sub-basin and from the two monitoring stations (one at Tighra reservoir, another in Sind near Dabra) of the Central Pollution Control Board, the class of water is B with designated best use for bathing. The comparison of 2011 to 2013 water quality data (BOD and DO) for these stations is shown.

There are not enough monitoring stations on Sind River and its tributaries to give idea of water quality of the entire sub basin. Only limited parameters are being measured at these stations. Some important parameters like fecal and total coliform, chlorides, phosphates, etc. also need to be monitored. The data available shows only mean annual values of the water quality parameters and not the seasonal variations.

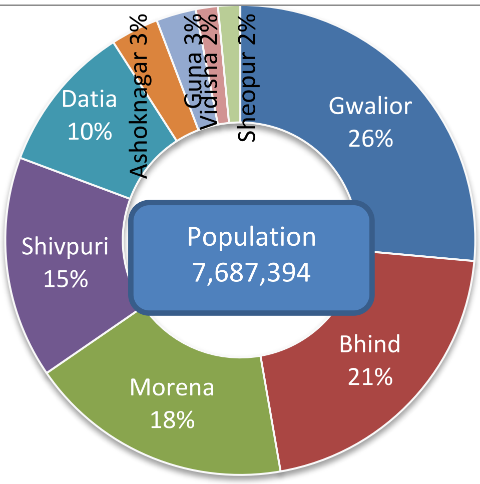


In contrast there are sufficient numbers of CGWB groundwater quality monitoring stations in the sub-basin. Analysis of ground water quality data within the Sind sub-basin reveals that overall quality of ground water is within the permissible limits set up by BIS, except in some pockets of the Sind sub-basin. The major areas of concern are:

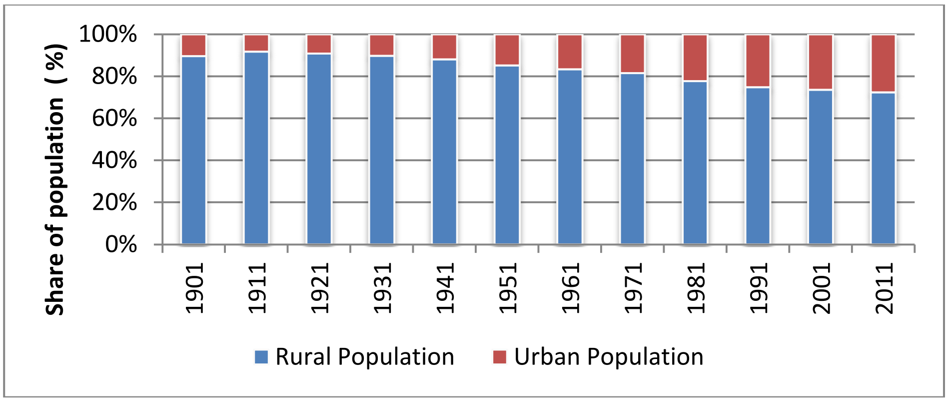
1. Gohad block of Bhind district where most of the parameters such as hardness, calcium, magnesium, nitrate, EC and SAR are outside permissible limits.
2. Parts of Shivpuri where fluoride and nitrate concentration is high.
3. Hard water with high concentration of calcium and magnesium ions is found in parts of Gohad block of Bhind district and Joura block of Morena district.

Socio-Economic System SES: According to Loucks et al (2005) conceptualization the SES mainly includes water-using and water-related human activities. The main consumptive uses in Sind sub-basin are domestic, agriculture and industries, whereas the fisheries and hydropower are non-consumptive users.

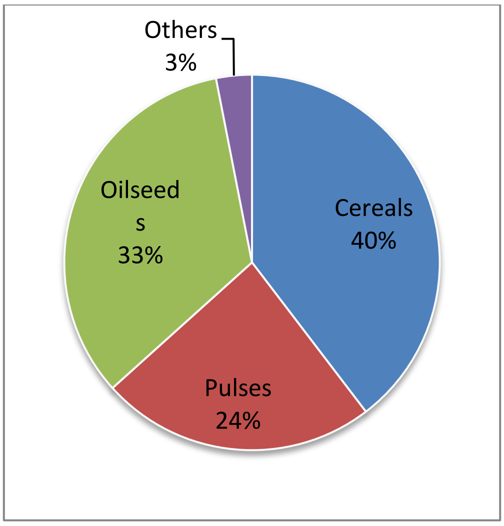
As per Census 2011, total population of the Madhya Pradesh is 72 million (in 2011). The total population of Sind sub-basin is 7,687,394. Districtwise share of population is shown in this figure.



The analysis of census data from 1901 to 2011 of Madhya Pradesh shows a clear trend of urban agglomeration



The cropping pattern of the sub-basin is quite similar to the State's average cropping pattern except a slight preference of oilseeds. The cropped area in Rabi and Kharif seasons are tabulated below



	Total Area ('000 ha)	Rabi	% Area of Rabi ('000 ha)	Kharif	% Area of Kharif ('000 ha)
Madhya Pradesh	**30825**	**10554**	**34%**	**11923**	**39%**
Sind sub-basin	**2608**	**1277**	**49%**	**684**	**26%**

The current annual demand for domestic, agriculture and industrial use is estimated at 199, 5819 and 23 MCM respectively. Most of this demand when met comes back to the river stream in the form of return flows.

Administrative and Institutional System AIS: The Constitution of India recognizes water resources as a state subject except for trans-boundary disputes (both intra- and inter-national) and major river valley development. In general, water law in India has largely been state based due to the constitutional scheme. Yet water sector or the subject of water exists in multi-level institutional setup- central, state and local institutions are involved. At the state level, Madhya Pradesh Water Resources Departments is primarily responsible for water resources development and management. Other state-level public departments viz. Agriculture, Urban Development, Rural Development, Forests, Public Health Engineering are also involved in the way water is managed. Panchayats, municipal bodies, district administration and WUAs play important water management role at the local level.

Goal:

Based on situation analysis, system analysis, scenarios and interaction with important stakeholders and decision makers, the proposed overarching goal of the planning process for Sind sub-basin to meet efficiency, equity and ecological sustainability principles of IWRM is:

"to protect and develop water resources for present and future needs to ensure the health of the citizens, securing food production through agriculture use and participation in economic development by agriculture, energy and industrial sectors."

Issues and Problems:

In the chapters describing Situation Analysis, System analysis and scenario, a number of challenges and issues in Sind sub-basin have been mentioned.

The shortlist of the current and potential issues can be summarized as below:

1. Poor Scientific Knowledge base for Planning
2. Un-balanced Water Supply & Demand
3. Low Water Use Efficiency
4. Ground Water Depletion
5. Water Quality Deterioration
6. Drought & Flood
7. Poor Co-ordination & Participation
8. Soil Erosion

These issues were discussed with a group of 141 Water Resources Department engineers in Bhopal on 21st July 2014. These issues were also tested in a small group of stakeholders at Shivpuri on 26th July 2014 comprising 3 WUA Presidents, 14 farmers, Deputy Directors of Agriculture, Fisheries and Horticulture, representatives of Municipal Council of Shivpuri, Public Health Engineering Department and Water Resources Department. The latter meeting showed the stakeholder opinion on these issues:

Stakeholder Opinion on Identified Issues

Issues	Agree	Disagree	No opinion
Low Water Use Efficiency	44%	4%	52%
Poor Co-ordination & Participation	40%	0%	60%
Drought & Flood	32%	4%	64%
Ground Water Depletion	36%	12%	52%
Poor Scientific Knowledge base for Planning	40%	44%	16%
Un balanced Water Supply & Demand	4%	4%	92%
Soil Erosion	4%	60%	36%
Water Quality Deterioration	0%	64%	36%

Though some valid stakeholder interaction has occurred during the formulation of the basin plan and visits to the basin, there is scope for wider consultation in future to enrich the plan.

Objectives:

This goal can be achieved only through small but significant objectives in every aspect of water resources plan. Pursuant to the situation, system and problem analysis, specific objectives for the Sind River basin plan have been identified as below:

1. Ensure availability of water resources data, to improve scientific database and assessment.
2. Improve coordination in management of water resources.
3. Supply of suitable quality of water as per designated best use within the basin to ensure health of citizens and to sustain ecosystem.
4. Reliable and adequate supply of water especially to the water scarce and drought prone regions of Sind basin for agricultural use.
5. Improvement of water use efficiency in agriculture use.
6. Promote sustainable ground water use.

Measures:

Although the overall availability of water in the sub-basin is abundant, spatial and temporal variations in availability and demand pose challenge for allocation decisions. Agriculture is by far the dominant user but the sub-basin is also witnessing a trend of urban agglomeration. Urbanization presents its own challenges more so for the health of the river. Through ongoing projects and schemes, public agencies are striving to ensure treatment of sewage before discharge to the river system but providing last-mile connectivity of households to sewerage system continues to remain a task in hand.

Water use efficiency (WUE) for agriculture in storage projects are a little over 40%. To achieve GoMP's vision for a 10% increase in WUE, a faster adoption of improved agricultural practices like zero-till, raised-bed or ridge & furrow, systemic crop intensification, farm mechanization, sprinkler and drip irrigation is needed.

Vigilant monitoring of the river system's health in terms of quantity and quality is one of the suggestions of the plan. This would help in preventing and guarding against future problems and enforcing the government's commitment to the health and well-being of the citizens. The sub-basin study also brings forth that there exists scope for further surface water resource development of at least 1.5 BCM depending upon the environmental and economic feasibility of projects. A study on the e-flow requirement of the sub-basin based on scientifically accepted methods like building block method or SWIFT led by EPCO to gauge if more development of water resource is recommended.

In terms of groundwater development potential, 17 of 24 blocks in the sub-basin are under "safe" category in terms of their groundwater status which presents the opportunity for further regulated development whereas in the remaining 7 blocks under "semi-critical" category, protection of groundwater is necessary to prevent these area slipping into criticality or over-exploitation.

Integrated approach to water resources extends to coordinated implementation of actions. The institutional framework in the State is favorable to coordination between various departments and agencies related to water management and could be developed further. Sharing of data between the partnering departments on water related use and development within the existing framework can further enrich the knowledgebase of the public agencies.

Each of the suggested measure is also ranked by considering the likely impact on the plan objectives and IWRM targets of equity, economic efficiency and environmental sustainability. This may facilitate prioritization of measures. For instance, the most promising top ten measures with highest scores are noted below:

1. M6 (score: 18): irrigation management transfer (institutional), recommended for short, medium and long term strategies
2. M8 (score: 17): completion of city development works (infrastructural), recommended for short term strategy
3. M9 (score: 16): assessment of EFR (environmental), recommended for medium term
4. M5 (score: 16): expanding district and state level water committees (institutional), recommended for short term strategy
5. M19 (score: 16): artificial recharge (infrastructure), recommended for short and medium term strategies
6. M 18 (score: 15): efficient irrigation technology/practices adoption (environmental), recommended for short, medium and long term strategies
7. M3 (score: 14): common data portal (infrastructural): recommended for short and medium term strategies
8. M10 (score: 14): continuation of Khet and Balram Talab programmes (infrastructural), recommended for short, medium and long term strategies
9. M 11 (score: 13): completion of stop dams (infrastructural), recommended for short term strategy
10. M 12 (score: 13): scoping studies for water resources development for Kunwari and Sind rivers (infrastructural), recommended for short term strategy

Based on the categorization of the measure, they are listed as under in order of their score (top on the list with highest score).

Awareness

- Improved agriculture practice
- Groundwater management
- Environmental and water quality

Environment

- Study on e-flow

Infrastructure

- Safe urban sewerage disposal
- Artificial recharge of GW
- Common state data portal
- Strengthening Khet Talab & Balraam Talab
- Completion of ongoing WRD schemes
- Scoping studies for Kunwari and Sind rivers
- River gauging & WQM stations
- Canal lining
- Micro-irrigation
- Seepage measurement at dams
- Inter-basin transfers to water deficit areas
- Dam rehabilitation
- GW development in safe blocks

Institutional

- Irrigation management transfer (IMT) in selected schemes
- Expanding the scope of DLWUC and SLWUC in water management
- Enhanced inter-department data dissemination
- Restructuring SWaRDaC

This draft plan provides a basis for embarking upon integrated river basin planning and management for the Sind sub-basin. The plan will improve further based on the inputs from the peer review process and contributions from colleagues from WRD and other stakeholders.

INTRODUCTION

Introduction:

India is the seventh-largest country in geographical area and the second-most populous country in the world with over 1.2 billion people. India has witnessed a decent economic growth over the last few decades, with economy growth rates of 8.0% in Eleventh Five Year Plan (2007-2012) compared to 5.7% in Ninth Five Year Plan (1997-2002)[1]. The exploitation of natural resources has contributed significantly besides other factors like industries, services sectors etc. For instance, development of water resources for agriculture and hydropower has played an important role in this rapid growth. The contribution of agriculture in GDP stands at 15.2%[2], where irrigation area is 28.8 % of the total cultivated area[3]. Currently, the hydropower contributes 21.5 % (end of 11th plan in year 2012) of the total electric supply in the country[4]. Water sector in India faces daunting challenges in meeting the demand of its ever increasing population coupled with rapid urbanization and industrialization. There is a large spatial and temporal variation in the surface and ground water resources of the country. The problem is further aggravated due to over abstraction of ground water causing water table depletion, low water use efficiencies, pollution of the surface and ground water due to untreated or partially treated sewage being discharge into surface and ground water[5].

The state of Madhya Pradesh, located in central part of India (Figure 1) reflects most of the above mentioned challenges, Madhya Pradesh is a source of ten major river basins (Figure 2) providing water for the state as well as adjoining states and further downstream. The rivers namely, Chambal, Sind, Betwa and Ken flow northward and meet with Yamuna River whereas the river Tons, Sone falls directly into Ganges. Narmada, Tapi and Mahi rivers flow westward crossing through states of Maharashtra and Gujarat and eventually drain into the Arabian Sea. Wainganga and Pench rivers meet Godavari River in the south which drains into Bay of Bengal after passing through states of Maharashtra and Andhra Pradesh. According to Government of Madhya Pradesh (GoMP) WRD administrative report 2013-14[6], the mean annual runoff of

Figure 1: Location of Madhya Pradesh in India

[1] *12th Five year plan Vol. 2*
[2] 12th Five year plan Vol. 2
[3] *http://www.fao.org/ docrep/009/a0257e/a0257e02.htm*
[4] *http://www.eai.in/ref/ae/hyd/hyd.html*
[5] *Planning Commission Government of India, 2013*
[6] Administrative report 2013-14 of Water Resources Department

these rivers generated in Madhya Pradesh is estimated at 81.5 BCM. In addition, 34.5 BCM of ground water is available in the state. The total mean annual availability of water in the state is 116 BCM[7].

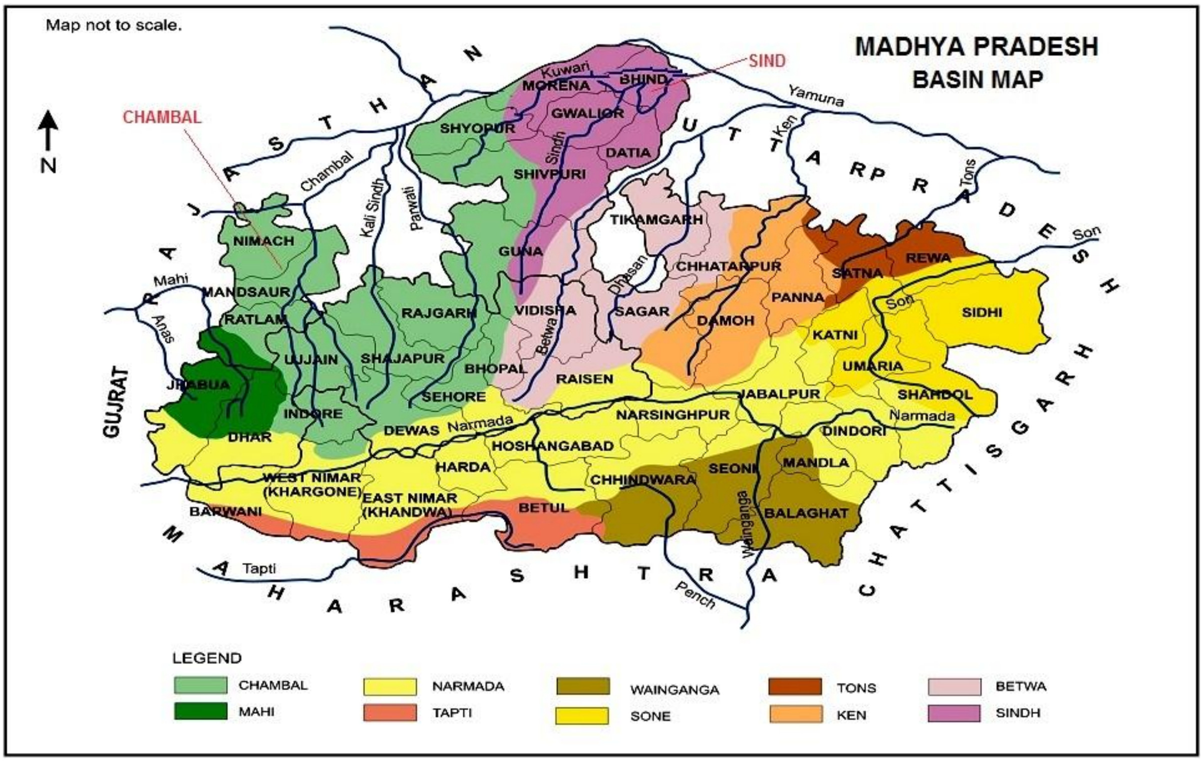


Figure 2: Map of Madhya Pradesh showing Major River Sub-Basins and administrative districts

One of the major water issues in the state is very high inter-and-intra annual variability of surface water resources. All of the ten rivers are sourced through rainfall in monsoon season (e.g. June to September) carrying most of the water during these months. The river flows during December to May are very low and most of the rivers get dry during this period. The state has high potential of cultivated land. However, with natural rainfall and flow regime, a full crop in monsoon seasons is difficult to reach through to the full harvest potential and supplemental irrigation is essential for some crops like rice. The winter season (*Rabi*) crops (mainly wheat as dominant crop) fully depend on irrigation. The state has embarked upon many irrigation and water storage infrastructure projects to develop irrigated agriculture. Currently, about 2.50 million ha is irrigated, supplied through irrigation infrastructure (dams, tanks, diversion weirs and canal system). The growth in irrigated area has sharply increased over the last decade, with total irrigated area increased from 0.925 million ha in 2000 to 2.50 million ha in 2014. However, the efficiency of water use in agriculture sector is still low (about 38%) despite efforts. This needs to be further improved given the increasing water demands. Moreover, the pressure on groundwater resources is rising and water tables are declining rapidly, specifically in west and north western part of the state[8].

[7] http://www.mp.gov.in/en/ web/ guest /infrariver
[8] http://cgwb.gov.in

The population of Madhya Pradesh is 72 million (in 2011) with decadal growth rate of 20.3%[9]. About three-fourth of the population is rural and largely depend on agriculture sector. However, trends in migration to urban centers and agglomeration in urban centre is rapidly increasing. This increased urbanization will pose additional problems for water management, since the urban population need to be serviced with drinking water systems accompanied by sewerage systems, to ensure cleaned water is returned to rivers. The water quality in the state is generally good, also in comparison with other parts of the country. However, water pollution is an emerging issue, especially in some areas due to disposal of untreated or partially treated wastewater from domestic and industrial sources. The use of groundwater with high fluoride and arsenic contents is also a localized issue in some region.

The average (net) per capita water availability (1497 m^3/capita) at present is above the water scarcity threshold (1000 m^3/capita, *see Falkenmark and Lindh 1976 'Water Stress Indicator'*), but with increasing population, the state will reach nearly to the water scarcity level by the year 2050 (Figure 3). This will increase water demands in all sectors of economy. Additionally, much faster urban and expected industrial growth will add to the challenges of water supply and quality of return flows.

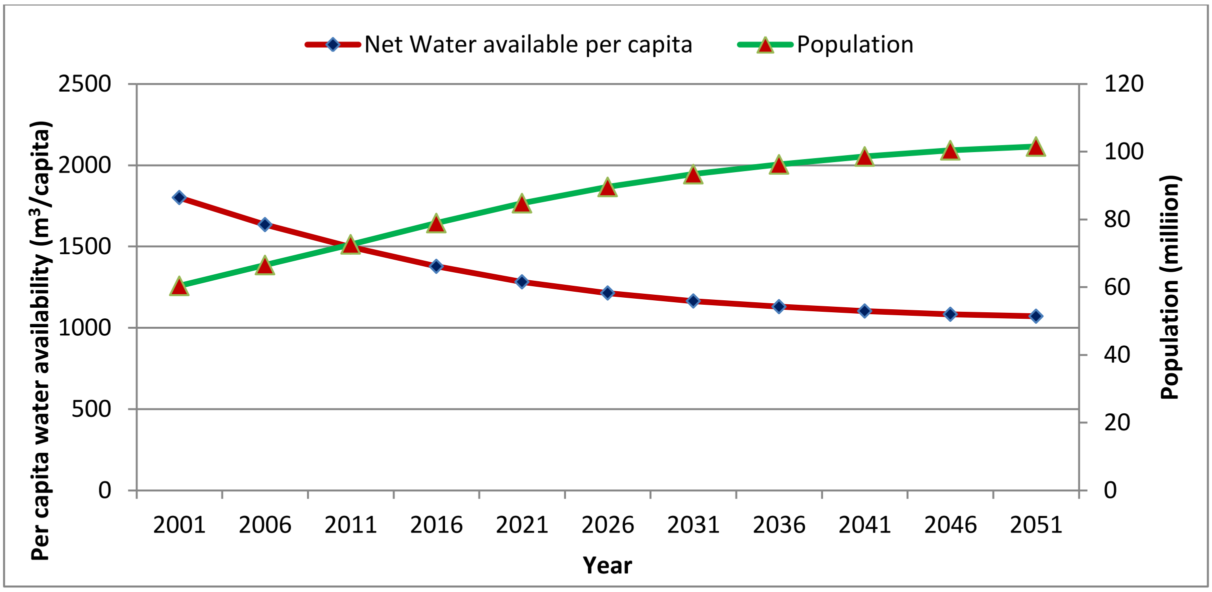


Figure 3: Mean annual per capita water availability in Madhya Pradesh during 2001-2051 (Source-http://www.mp.gov.in/en/web/guest/infrariver)

The average Per Capita Income (PCI) for Madhya Pradesh (at 2004-05 prices) is Rs. 22,382 in 2010-11[10] which is substantially lower than PCI of India (at 2004-05 prices) Rs. 35,917[11]. This is largely due to high dependence on agriculture, traditional methods of cultivation, large areas under forest cover, tribal predominated demographic profile of the State and limited

[9] *Census of India, 2011*
[10] *District Wise skill gap study for the State of M.P-2013 by N.S.D.C.*
[11] *http://pib.nic.in/newsite/erelease.aspx?relid=72400*

accessibility to road and rail network in many parts[12]. Despite, rapid growth after 2000, the state still stands behind in PCI compared to the national average. The annual growth rate in the Gross State Domestic Product (GSDP) of the state from 1999-2000 to 2010-11 was 5.87%, which has risen to 10.06% during Eleventh Five Year Plan 2007-2012. The major contributing sectors to GSDP are agriculture (8.75%), industry (11.11%), service (10.08%)[13].The water sector, in addition to growth in other sectors, will continue to play a pivotal role in maintaining the current economic growth of 11.81%[14].

However, water development should be sustainable, which demands careful matching of supply with demands and also keeping enough resources for the environment and ecology. Madhya Pradesh is a home of very important biodiversity. The aquatic biodiversity in the state is very rich. There are 105 species of fish, two species of crocodiles (Mugger and Ghariyal), seven species of freshwater turtles, more than 120 species of wetland birds and two species of aquatic mammals (Gangetic dolphin and otter)[15] . Similarly, the forestry and wildlife are important features, with many forests declared as reserved (wildlife sanctuaries: Kanha, Bandhavgarh, Panna, Pench Tiger reserve, National Chambal Sanctuary). Any future water developments should not threaten the sustainability of these aquatic and terrestrial ecosystems.

Furthermore, Madhya Pradesh state is fully committed to honor water allocations agreed to the neighboring states from different rivers. This poses an additional challenge to ensure that the future developments are not in contradiction with the existing interstate agreements. Additionally, the planning should also ensure compliance with national regulations when it comes to interstate and international Rivers. This is important for rivers draining to Ganga basin.

Considering the complexity and importance of water related issues, there is an ongoing paradigm shift in development and management of water resources. The importance of a holistic and integrated basin level plan has been emphasized both at National and State level. The same has also been stressed in the National Water Policy[16], National Water Mission and State Water Policy. The earlier approach towards basin planning was more focused on harnessing the available water with engineering solutions. For instance, two master plans for Narmada and Godavari river basins in Madhya Pradesh, prepared during 1970s were mainly focused on supply side development strategies with development of irrigation and storage infrastructure[17]. With time and growing recognition of the need for

[12] *www.dolr.nic.in/dolr /downloads/ spsp/Madhya%20Pradesh_SPSP*
[13] *Annual Plan 2012-13, State Planning department - Vol 1 pg 9*
[14] *http://mpplanningcommission.gov.in/ annualplan/ap-2013-14/ annual_plan1314.htm-Vol-I pg 7*
[15] *RJ Rao - Status of conservation of aquatic species*
[16] *National Water Policy 2012 - para 9.2, National Water Mission- Goal 5, State Water Policy 2003-para 3*
[17] *Engineer-in-Chief, MPWRD publication*

integrated water resources planning with basin as a hydrological unit, Government of Madhya Pradesh envisaged taking up the preparation of two river basin plans.

In contrast to the daunting water challenges mentioned above, the scientific knowledge base, human and institutional capacity is lacking and needs to be significantly enhanced. This is very important to ensure fast, inclusive and sustainable development. Inclusive and sustainable development can be defined as development of all marginalized and excluded groups of stakeholders in the development process, without depletion of natural resources. Realizing these needs, Madhya Pradesh has decided to promote in-house capacity for holistic and integrated water resources planning as well as to develop the first river basin plan for Sind sub-basin.

Realizing these needs, Government of Madhya Pradesh decided to promote in-house capacity for holistic and integrated water resources planning. A small, but important, project on training and capacity building on river basin planning was initiated. The main objectives of this one year training program (December 2013 to January 2015) are: (1) Capacity building of 10 staff members of Water Resources Department of Madhya Pradesh on river basin planning, and, (2) deliver two river basin plans for Sind and Chambal sub-basins. The training program was conducted by UNESCO-IHE Institute for Water Education, Delft, the Netherlands. This plan for Sind sub-basin and another for Chambal sub-basin has culminated from this training program.

Outline of this document

This document presents the River Basin Plan of Sind sub-basin of Madhya Pradesh. The Chapter 2 gives the planning framework used for preparing this basin plan. Chapter 3 describes the natural resources system of the sub-basin and its infrastructure; the socio-economic system and administrative and institutional system involved in the management of water resources of the basin. Chapter 4 contains the system analysis and scenarios to understand the issues and problem. Chapter 5 describes the problems and their possible solutions. Chapter 6 summarizes the objectives and long term strategy of the plan.

PLANNING FRAMEWORK

Planning Framework

The Government of Madhya Pradesh is committed to reclaim the lost irrigation potential as well as to protect and sustain its forests and vegetative cover. Much of the investments in the water related sectors have been directed towards rehabilitation of existing irrigation infrastructure and water conservation programs. The State has operationalised elected Water Users Associations (WUA) by enactment (PIM Act) in 1999. More than 2000 WUA are involved with decentralized water management in the State.

Madhya Pradesh has striven to work united and harmoniously with its neighboring states in various subject related and project related water organizations like the Inter-state Chambal Committees, Betwa River Board, Narmada Control Authority and Bansagar Control Board.
The National Water Policy, 2012 of India emphasizes on water resources planning with river basin as basic hydrological unit. Madhya Pradesh has also adopted the State Water Policy 2003 in line with the National Water Policy which highlights the need for comprehensive IWRM based river basin planning on basin and sub-basin scale.

"The water resources development shall be planned on the basis of river basin or sub-basin. Each development project shall be designed in such a manner that each basin or sub-basin is inherently integrated water resources planning so that the best alternative can be identified." -

GoMP, State Water Policy 2003

"All the elements of the water cycle, i.e., evapo-transpiration, precipitation, runoff, river, lakes, soil moisture, and ground water, sea, etc., are interdependent and the basic hydrological unit is the river basin, which should be considered as the basic hydrological unit for planning." -

National Water Policy 2012

Though Madhya Pradesh is involved with various inter-state water organizations, the current initiative of river basin planning for Sind sub-basin is an effort to have a first such plan at state level in line with the spirit of the national and state water policy which emphasize on IWRM principles. This small but significant initiative could also contribute to a larger Yamuna and Ganga river basin plans as well to long-term national water resources master plan.

Planning Framework

Water resources planning is a multi-facetted process and there is not one generally accepted model of how to conduct it. In practice, the process depends upon the circumstances and is to be adapted while the planning proceeds, rather than following a clearly defined theoretical path. A framework of analysis is generally meant to help to structure the planning process, and is not unique per se to water resources planning. (Masih 2013).

Two typical framework for water resources studies as suggested by Loucks et al (2005) and Cap-Net (2005) are shown in Figure 4 and Figure 5 .

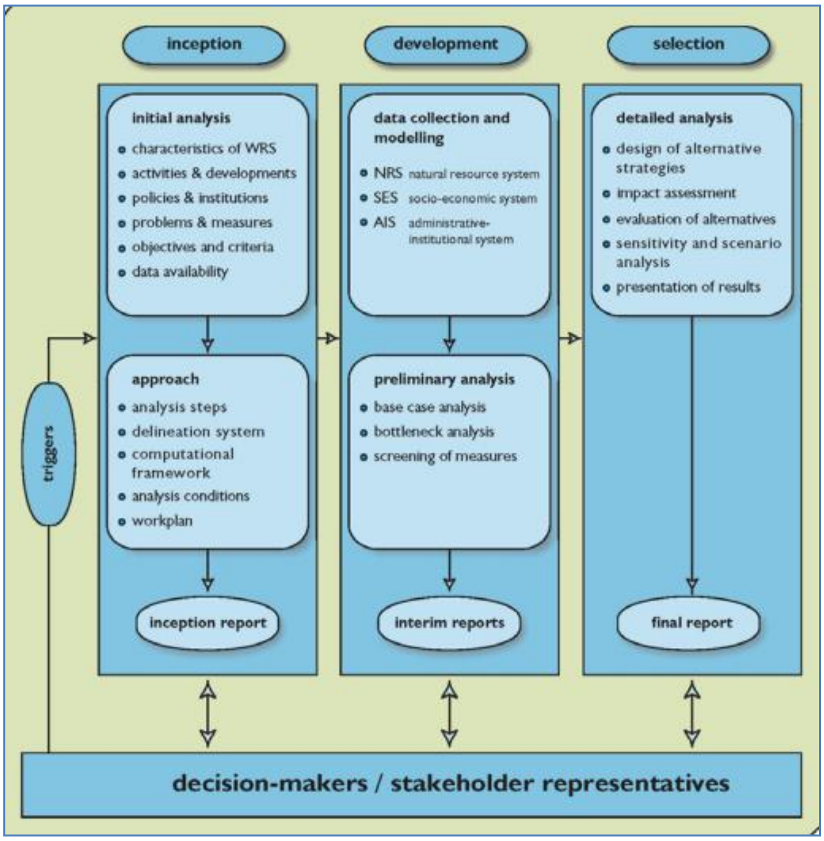


Figure 4: Typical analytical framework (Loucks et al, 2005)

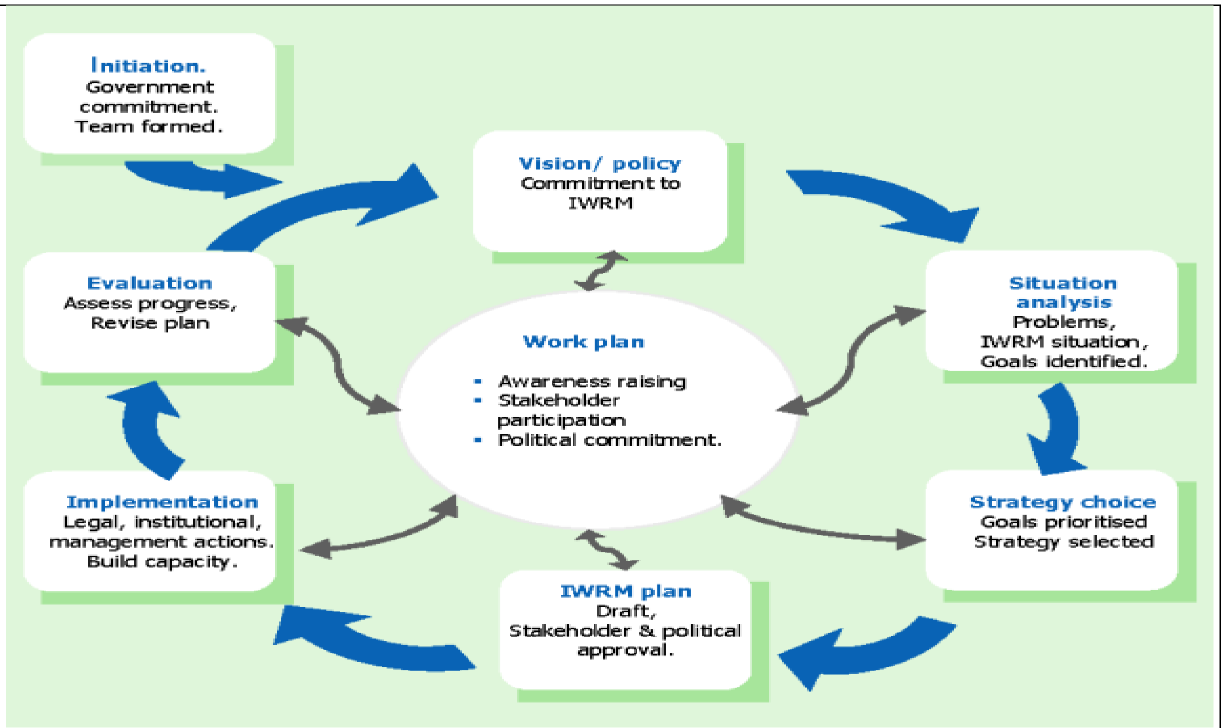


Figure 5: Typical Planning framework Cap-Net (2005)

The planning framework adopted for the Sind sub basin is based on Heun & Cauwenbergh 2012 (Figure 6). As such, the framework adopted is very similar to most planning frameworks and is as shown in Figure 7.

The river basin planning is contemplated as continuous and cyclic in nature, getting richer and refined with new data inputs and re-planning. The framework (Figure 7) is so chosen that the process does not end with the first river basin plan or implementation of some proposals. It is a continuum in which the divisional/ zonal offices of WRD, other stakeholders such as users and related departments work together to update the plan.

Within the framework, consideration of the natural resources system (NRS), the socio-economic system (SES) and the administrative and institutional system (AIS) have been made as suggested by Loucks.

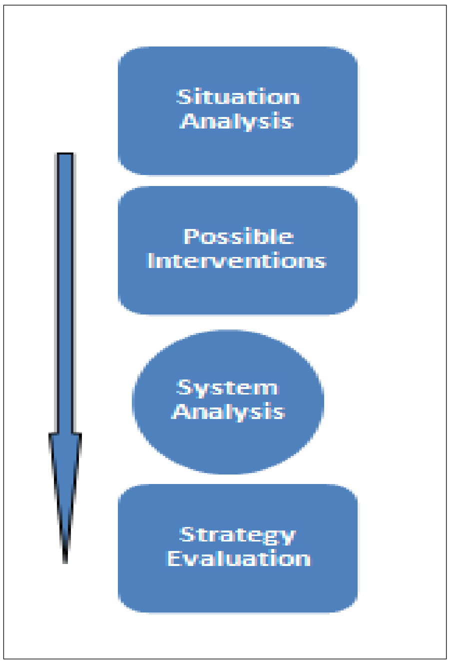


Figure 6: Schematic diagram of a planning framework suggested by Heun & Cauwenbergh 2012

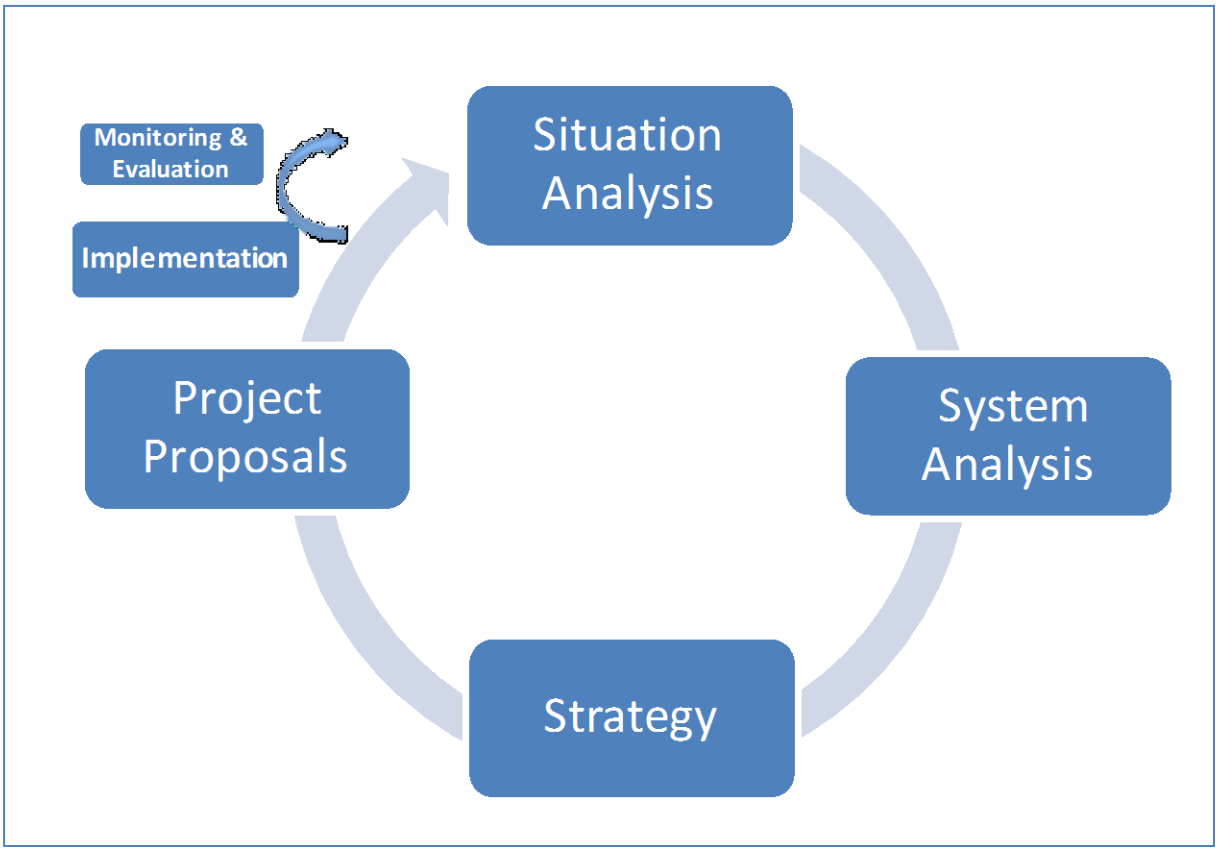


Figure 7: Framework adopted for Sind sub-basin planning

Methodology

The training program conducted at UNESCO-IHE Institute for Water Education included 14 modules, of which Modules 1 to 8 has theoretical foundation and provide knowledge and skills on analytical, modeling and planning process, tools and method.

To develop a basin plan it is necessary to get acquainted with the current situation of the basin resources, uses, institutions, pressures, driving forces. The details of these will lead to the problem identification and listing of measures.

The data and information available were used for developing an outline for the sub-basin in May-June 2014. This outline contained the framework of the plan, some likely issues/ problems based on expert judgment and the plan of action for data collection during the field visits. As procedures of data sharing by different agencies are varying, the time taken in completing the data collection took more time than anticipated- nearly 2 months till mid-August.

For assessing the resources within the basin, geographical boundary of the basin has been used. The basin as a large watershed is taken as unit. However, data for many of the hydrological parameters, socio-economic features are not available for the hydrological boundary area but at the administrative unit level -district in most cases. Therefore, such data has been proportioned to the geographical area in the basin. For this purpose, the proportion of the district falling in the Sind sub-basin is shown in Table 1. Total geographical area of Sind sub-basin is 26082 km^2. The share of area of the districts in Sind sub-basin is shown in Figure 8.

Table 1: Area of District falling under Sind sub-basin

S.No.	District	Total area of the district (in Km^2)	Area of district in Sind sub-basin (in Km^2)	% of total area of district in Sind sub-basin
1	Ashoknagar	4,732	1,396	30%
2	Bhind	4,475	4,195	94%
3	Datia	2,524	2,524	100%
4	Guna	6,315	1,065	17%
5	Gwalior	4,586	4,586	100%
6	Morena	4,993	3,562	71%
7	Sheopur	6,545	1,091	17%
8	Shivpuri	10,485	7,092	68%
9	Vidisha	7,316	571	8%
	TOTAL	**51,971**	**26,082**	

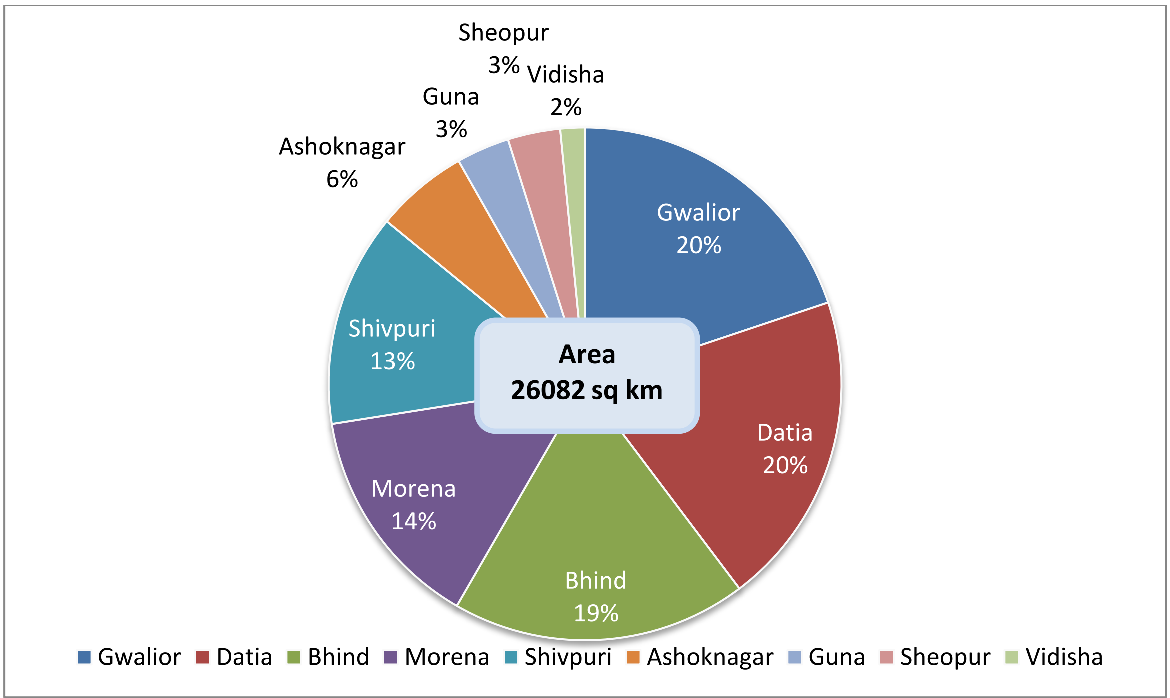


Figure 8: District wise share of area in Sind sub-basin

Data Collection:

During the field visit to the state and to the Sind sub-basin, data was collected from various sources during mid-June to mid-August 2014. Also a stakeholders' workshop in the sub-basin was organized at Shivpuri comprising users, various public agencies and departments. The main purpose of the workshop was to assess stakeholders' view about the current and anticipated problems in the sub-basin and to later on review the list of issues identified in the outline of the plan. Another workshop comprising WRD engineers was held at Bhopal during this phase. IHE experts in water management joined the training participants for 10 days during the field visits and workshops.

A number of meetings with WRD Principal Secretary, Engineer-in-Chief, Chief Engineers, experts at BODHI, District Industries Center, Narmada Valley Development Department, State Pollution Control Board, Central Ground Water Board and World Bank mission team to MPWSRP were also held during the data collection phase.

A comprehensive list of data collected with type of data, source of data and other details are given in Table 2.

Table 2: List of Data Collected and source

Sno	Data source	Data/ Report name	Details	Remarks
1	State Data Center, Bhopal	Discharge data - Daily	10 Stations - from 1988 to 2011 (23 years)	With data gaps
		Rainfall data - Daily	181 Stations - from 1961 to 2012 (53 years)	With data gaps
		River Water Level Data - Hourly data	2 Stations - from 1999 to 2006	With data gaps
		River Water Level Data - Thrice daily data	10 Stations - from 1989 to 2011 (22 years)	With data gaps
2	State Ground Water Organization, Bhopal	GW - Water level Monthly (PZ & OW)	289 Stations- from 2000 to 2013 (13 years)	With data gaps
		GW - Assessment Reports	Year 2004 for all districts	
		Dynamic GW Assessment Reports	Year 2009 for all districts, Blocks	Assessment & abstractions
4	Central Ground Water Board - Bhopal	Ground water level	609 sites - from 2007 to 2014	With data gaps
		Ground water quality data	364 site - from 2007 to 2012	With data gaps
5	Central Ground Water Board - Website	Surface Water Quality data	Year 2011 - for 28 sites	Parameters - Temp., D.O., pH, Conductivity, B.O.D., Nitrate, Fecal Coliform, Total Coliform.
		Ground Water Quality data	Year 2011 - for 7 sites	Parameters - Temp., pH, Conductivity, B.O.D., Nitrate, Fecal Coliform, Total Coliform.
		Ground Water Aquifer system of Madhya Pradesh	Published in the Year 2013	Describes the location, extent, aquifer characteristics of all the important aquifers in the State.
6	Census Department - Website www.censusindia.gov.in	Demographic data	Year 2011 - District wise population, growth rate, etc.	
7	IIT Delhi	GIS data of Ganga River basin	DEM, Land use, Soil, Districtwise fertilizer data, Districtwise domestic water demand, Administrative boundaries, Dam Location, Well location, Irrigation project, Hydro	

Sno	Data source	Data/ Report name	Details	Remarks
			power project, Canal network , CWC Guage sites etc	
8	Urban Development Department, Indore, Bhopal, Gwalior	City Development Plan (CDP)	Bhind, Datia, Guna, Gwalior, Morena, Raghogarh, Ashoknagar, Sheopur, Shivpuri	
		Text	Urban Scenario	
9	Weather data - Website	Temperature, Humidity,	From 1960 to 2014 - Gwalior, Guna	With data gaps
10	MP WRD	Existing Irrigation schemes	Major, Medium and Minor	
		Policy documents	National Water Policy State Water Policy Vision document 2018 12th Five Year Plan PIM act and Irrigation act	
11	Other	GIS	DEM - 30x30 : MP	
			Economic survey of india	

During the data collection process, it was experienced that it is difficult to obtain data from departments or agencies. The process of getting data from the department is lengthy and tedious. The data is not easily accessible even for the departmental use and most of the departments do not publish the data. Wherever data is available, its consistency and quality of data is not up to the mark. In most of the datasets received, preliminary analysis and data validation has not been done to ensure the reliability of data.

It was also experienced that more workshops involving stakeholders' are required for inclusive planning, which could not be organized due to time constraint and monsoons.

All the agriculture and land related data has been taken from department of agriculture website www.mpkrishi.org and department of land records website www.landrecords.mp.gov.in used for agriculture. Few more websites like http://www.tutiempo.net/en/Climate/; http://www.e-mpcdp.com/CDPSynopsis.aspx and www.mpwrd.gov.in also used for different data.

SITUATION ANALYSIS

Situation Analysis

The National Water Policy envisages that water resources development and management should be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin, taking into account surface and ground water for sustainable use, incorporating quantity and quality aspects as well as environmental consideration.

Keeping with overall objective of integrated water resources management for river basin plan of Sind sub-basin, it is important that the current status of the basin resources are studied to know the baseline conditions of the resource. In this chapter Situation Analysis has been presented which provides a comprehensive understanding of the natural resource system, current availability of surface and ground water, its status of quality at various locations, socio economic indicators and condition of the Sind sub-basin has been done. The administrative & institutional system of the state and the Sind sub-basin has also been discussed to understand how the water sector is managed at basin and state level. This will help in holistic understanding of the present and projected changes in the catchment condition of the basin.

To develop a basin plan it is necessary to get acquainted with the current situation of the basin resources, uses, institutions, pressures, driving forces. The details of these will lead to the problem identification and listing of measures.

Loucks et al (2005) have conceptualized the Water Resources System (WRS) to consist of the following:

- The natural resource system (NRS)
    - the natural sub-system of streams, rivers, lakes, groundwater aquifer
    - the infrastructure sub-system such as dams, canals, weirs, wells, pumping plants, treatment plants
    - the water itself, including its physical, chemical, biological components (ABC components: abiotic or physical, biological and chemical)
- The socio-economic system (SES)
    - water-using and water-related human activities
- The administrative and institutional system (AIS)
    - the system of administration, legislation and regulation, including the authorities responsible for managing and implementing laws and regulations

For the purpose of the situation analysis of Sind sub-basin, the above components are further discussed.

Natural Resource System (NRS)

General:

Sind River is a tributary of Yamuna River which further meets the Ganga (Figure 9). Both Ganga and Yamuna rivers are deeply entrenched in the minds, culture and religion of India. Yamuna and Ganga are old and sacred rivers with so many traditions and rituals connected with them. Both rivers, for their cultural and spiritual value for Indian civilization, find mention in Vedic scriptures, hymns, folksongs and also the Indian national anthem. Yamuna is entrenched in the minds of Hindus due to its association with Lord Krishna. Ganga has been and continues to be veneered as the pristine Goddess. Despite the values attached to the two rivers, the current state of the water quality in the rivers especially in the floodplains is alarming mainly due to human activities.

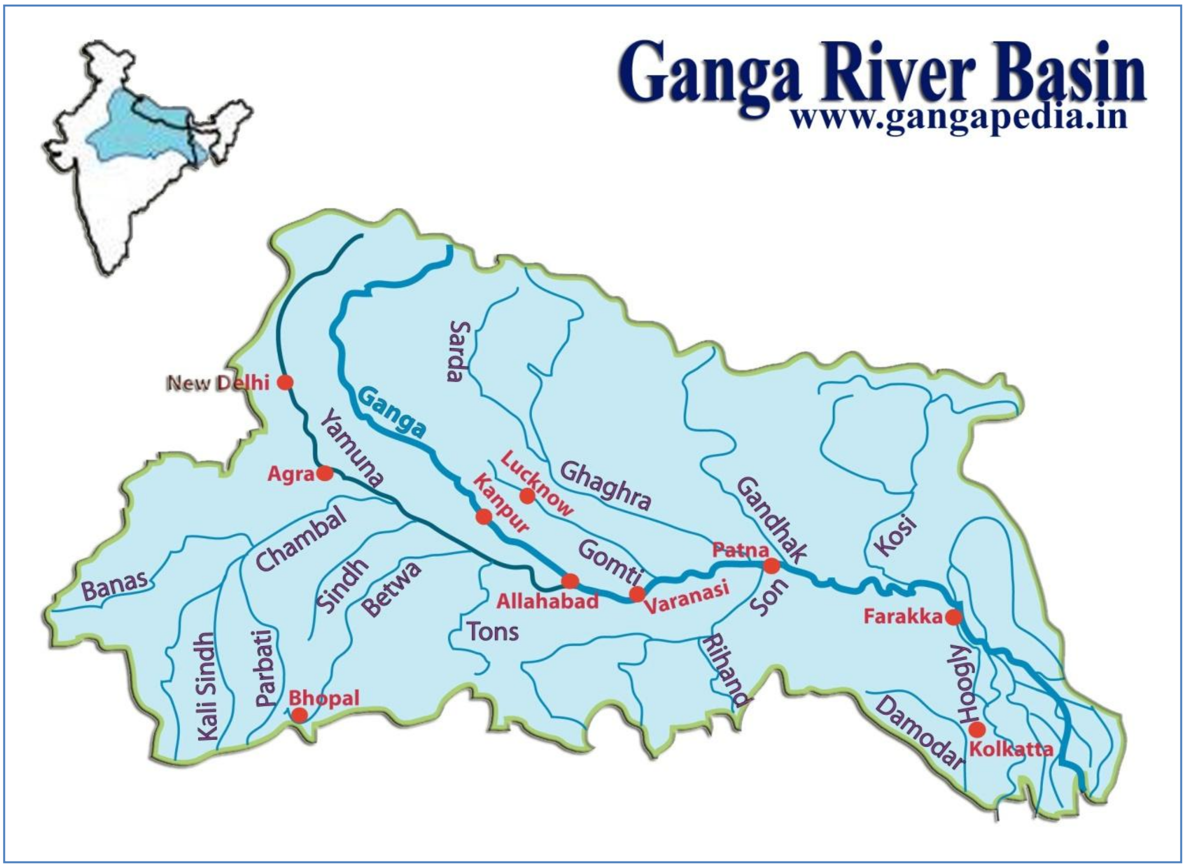


Figure 9: Map Showing Ganga, Yamuna and Sind Rivers (Source-*gangapedia.iitk.ac.in*)

Yamuna in recent years has been termed as a river in peril and also a dead river. As it flows down from Haryana state towards the national capital Delhi most of its flow is diverted for different use. Nearly all flow at Delhi is sewerage water which reaches Uttar Pradesh where it further gets polluted with untreated sewerage and industrial effluents. (Figure 10) The dissolved oxygen levels are nearly a nil and fecal coliform indices are very high (MoEF-Baseline Report on YAP-II).

Ganga River also faces the brunt of pollution which alleviates to some extent until it meets the Yamuna. Restoring the health of Ganga is one of the foremost priorities of political and administrative leadership. For the restoration of the quality of Yamuna and Ganga back to its glory requires attention also to all their tributaries and hence a clean Sind river with sufficient flow is essential in this regard.

Figure 10: Foaming in Yamuna River at Delhi

A small portion of the basin lies in the adjoining Uttar Pradesh State as shown Figure 11.

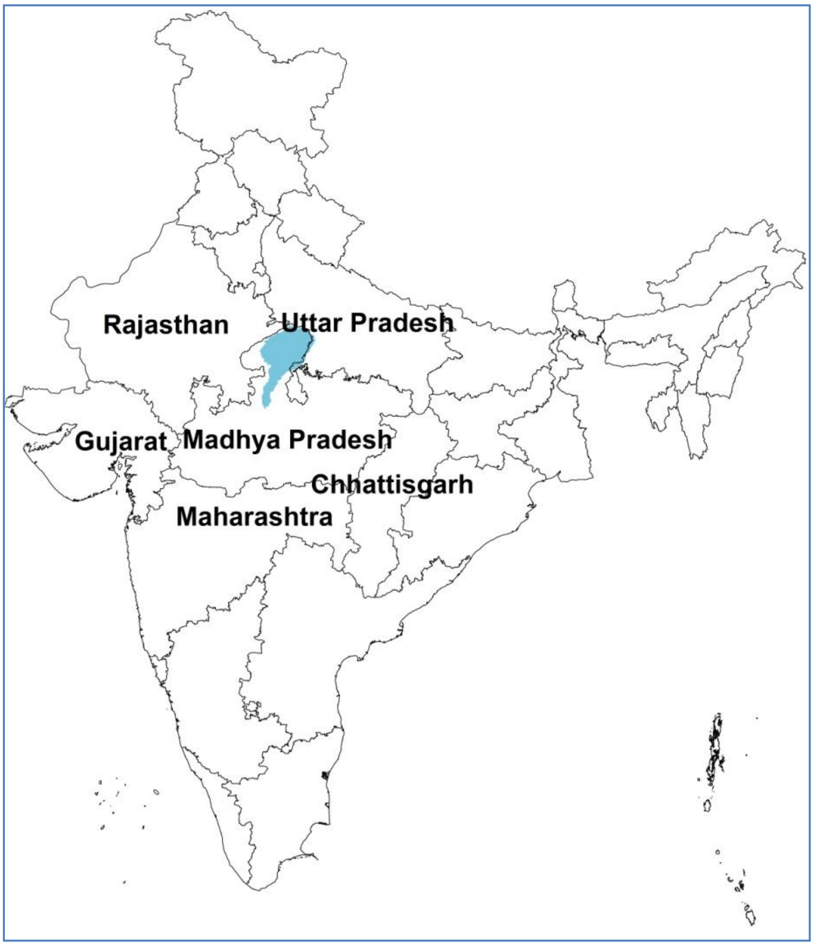


Figure 11: Location of Sind Sub-basin in India

Administratively, Sind sub-basin contains the area of 9 districts. Datia and Gwalior districts completely fall under Sind Sub Basin, whereas part of Vidisha, Ashoknagar, Bhind, Guna, Morena, Sheopur and Shivpuri also comes under the Sind sub basin (Figure 12).

Figure 12: Administrative districts in Sind sub-basin

Hydrological Cycle:

It can be described as major physical processes which form a continuum of water movement. Complex pathways include the passage of water from the gaseous envelope around the planet called the atmosphere, through the bodies of atmosphere, through the bodies of water on the surface of earth, such as the oceans, glaciers and lakes, and at the same time passing through the soil and rock layers underground. Later the water is returned to the atmosphere. Typically, the hydrological cycle is represented as per the schematic illustrated in Figure 13.

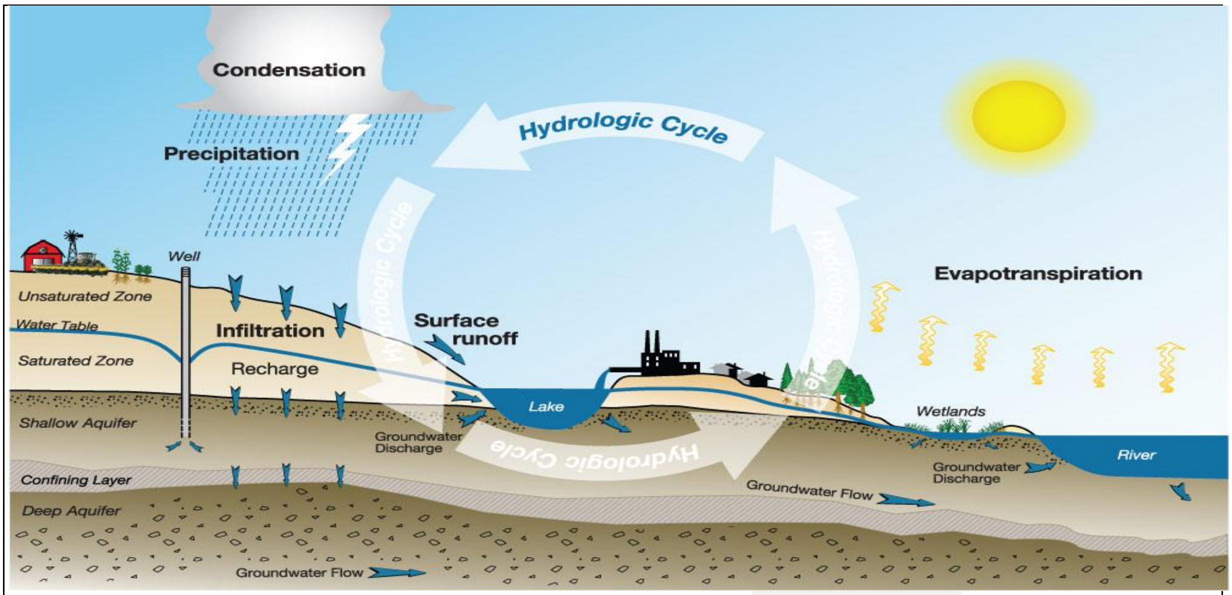


Figure 13: Typical Hydrological Cycle (Source***: www.sws.uiuc.edu*)**

The hydrological cycle of Sind sub-basin does not include snow melt inflow or drainage into the ocean. For Sind sub-basin, however, all other physical processes remain same. The description of major components of the hydrological cycle is given in the following sections.

Climate:

Climate of Sind sub-basin includes three main seasons; monsoon or rainy season (July to September), winter season (October to January) and summer season (February to June). Winter and rainy seasons are short, while summers are comparatively long. The summer season starts setting up from middle of March and ends in June, when the first breakout of monsoon takes place. During the summer season, temperature levels are more than 45^{0}C during daytime. Gwalior, Morena, Datia and Bhind are the hottest places in the Sind sub-basin where temperature exceeds 48^{0}C.

Rainfall:

The precipitation pattern in the sub-basin is governed by a monsoon weather pattern. The basin comes under the influence of the south-west and south-east monsoon. The duration of rainfall in Sind sub-basin is from last week of June to mid September. The average annual rainfall of the basin is 875 mm. Nearly 90 % of annual rainfall, precipitates in monsoon season from June to September which is evident in the monthly variation expressed as percentage in Figure 14.

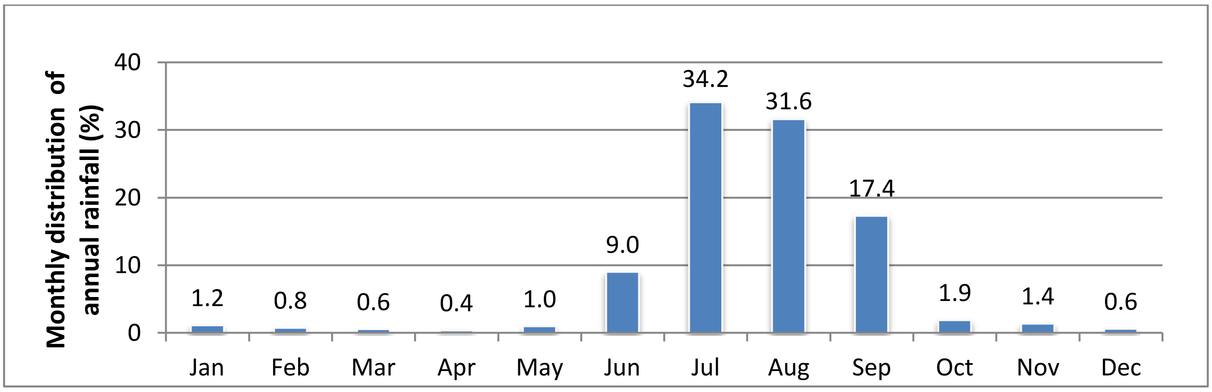


Figure 14: Monthly variation of Rainfall in %

Spatial variation of annual rainfall in the basin ranges from 798 mm (in Sheopur district) to 1057 mm (in Vidisha district). The district-wise annual rainfall variation in the basin is shown in Figure 15.

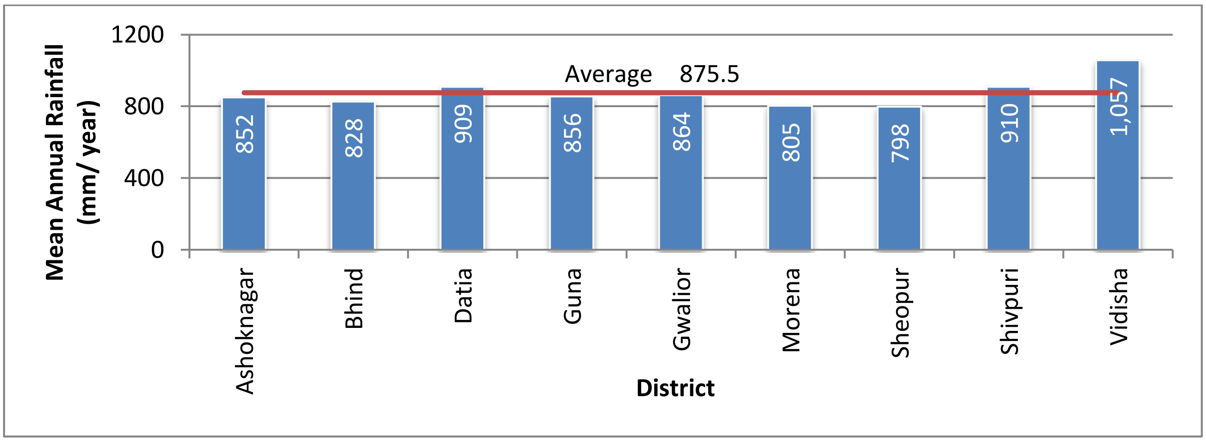


Figure 15: Average Annual Rainfall in Sind sub-basin

Temporally, the average annual rainfall of the basin shows variation in the range of 497 mm to 1366 mm over the period 1901 to 2012 (Figure 16).

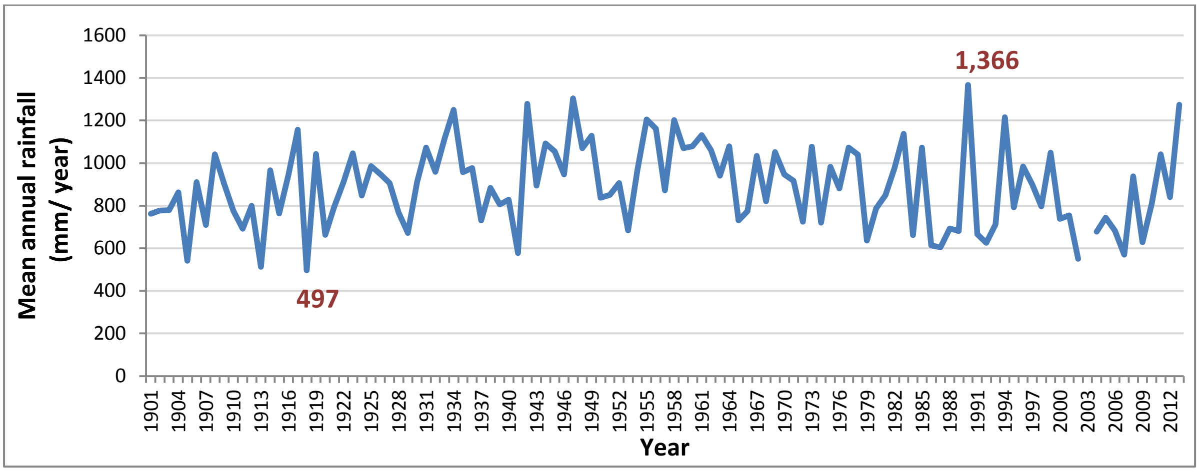


Figure 16: Average Annual Rainfall Pattern of Sind sub-basin during 1901 to 2012

The analysis of annual rainfall anomaly shows that the percentage deviation from the mean annual rainfall in the sub-basin varies from -43% to 56% (Figure 17).

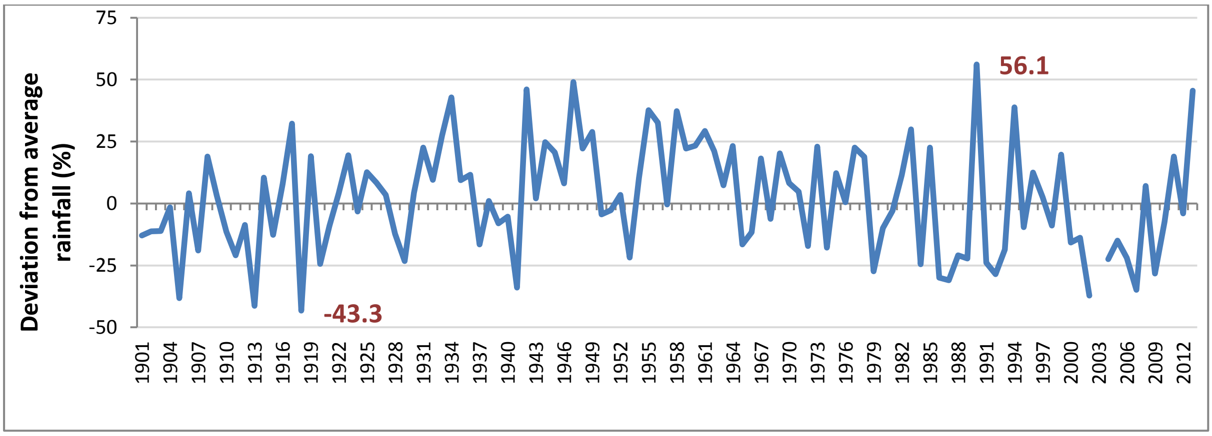


Figure 17: Rainfall Deviation

Temperature:

Temperature is a driving climatic variable that governs the hydrological cycle. It directly affects the magnitude of evapo-transpiration, water use, and water quality in the river. Guna and Gwalior stations, where temperature data is available, are representative of the upper and lower zones of the basin.

In Sind sub-basin, the mean maximum temperature varies between 41.6°C to 23.4°C while mean minimum temperature varies between 26.4°C to 8.3°C. The average temperature varies in the range of 34.5°C to 15.5°C (Figure 18).

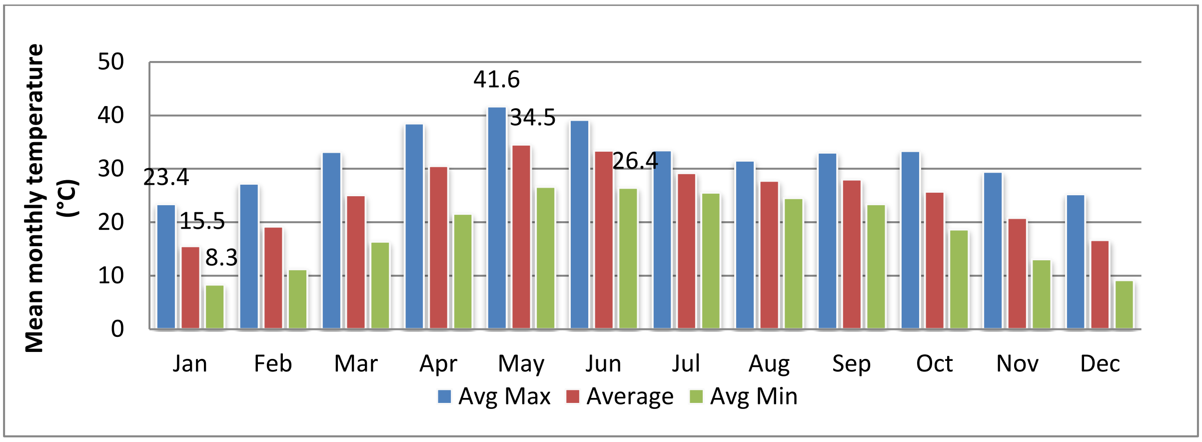


Figure 18: Average Monthly Temperature

Spatial variation of maximum and minimum temperature in the upper reach (Guna) and lower reach (Gwalior) in the basin as depicted in Figure 19 and Figure 20, which indicates no significant variation in the mean maximum and minimum temperature.

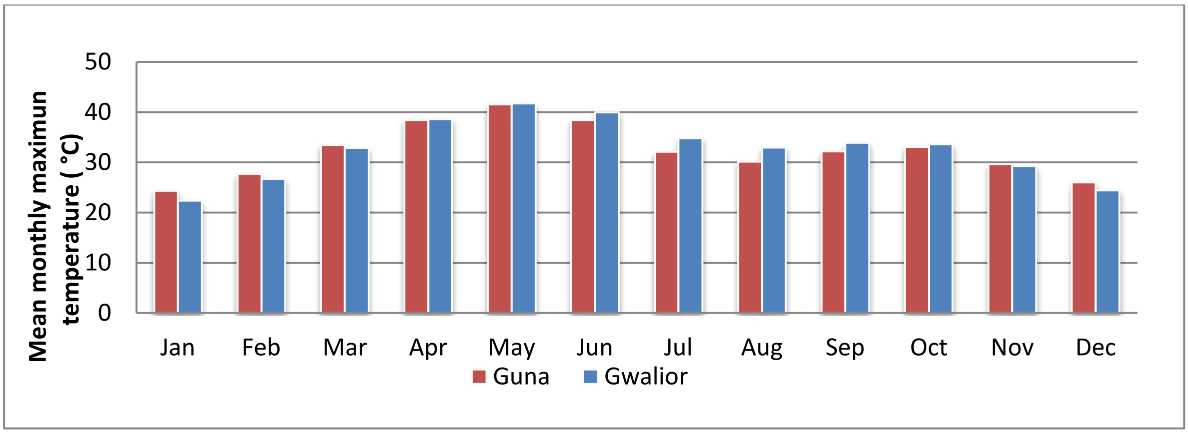


Figure 19: Mean Maximum Temperature

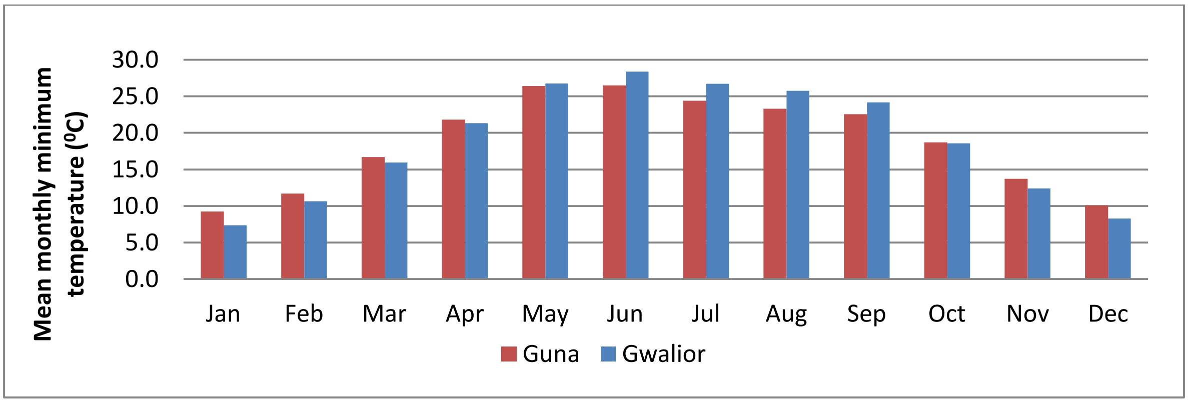


Figure 20: Mean Minimum Temperature

Wind:

Using the daily values of wind speeds observed at Gwalior and Guna stations in the Sind sub-basin, the mean monthly wind speed in the basin is estimated as 5.0 Km/h and 1.4 Km/h respectively (Figure 21). The maximum and minimum observed wind speeds are in the range of 46 Km/h to zero.

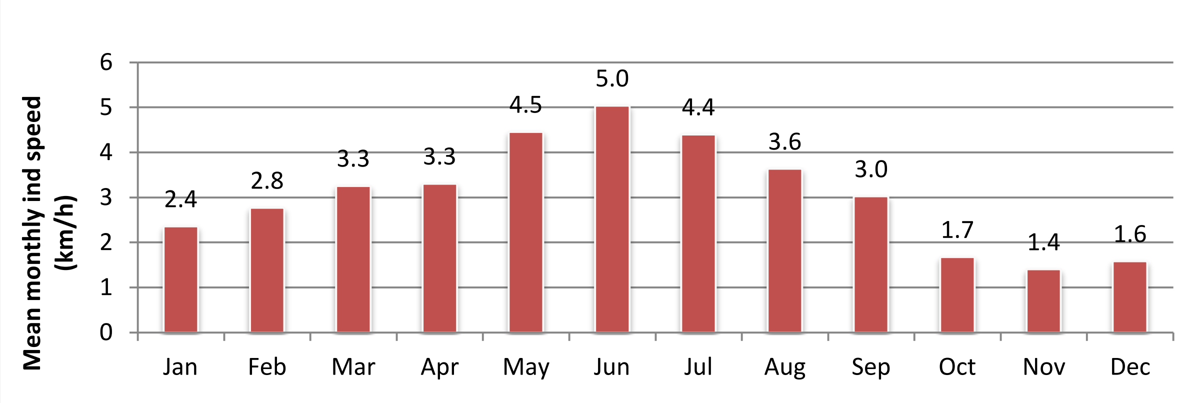


Figure 21: Mean Monthly Wind Speed

Humidity:

Based on daily values of humidity of Guna and Gwalior stations in the Sind sub-basin, the maximum and minimum humidity is estimated and interpolated at basin scale. The mean monthly maximum and minimum humidity for the Sind sub-basin is 82.0% and 29.5% respectively (Figure 22). The daily humidity in the basin ranges from 10% to 100%.

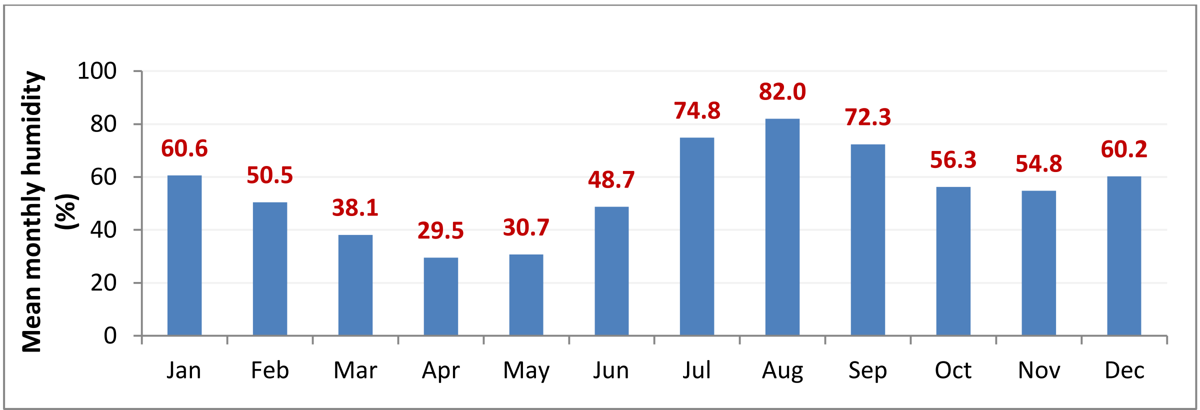


Figure 22: Mean Monthly Humidity (%)

Evapo-transpiration:

The minimum "average monthly potential evapo-transpiration" (ET_o) is 81 mm in the month of December and the maximum ET_o is 254 mm in the month of May, both in Vidisha district as seen in Figure 23 which shows the district-wise average monthly potential evapo-transpiration variation over a year. Range of potential evapo-transpiration in the Sind sub basin is also shown in Figure 24.

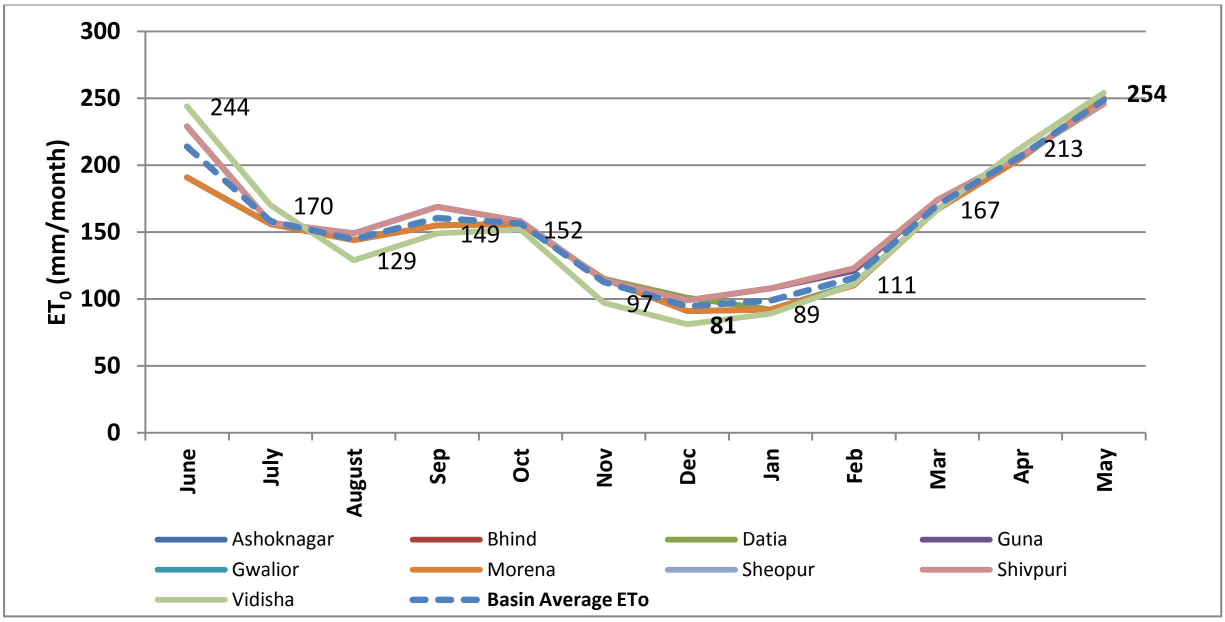


Figure 23: Average Monthly Evapo-transpiration (Source: this study)

Figure 24: Potential ETo in mm/year in Sind sub-basin

The average annual ET_o ranges from 1832 mm to 1933 mm in different districts (Table 3). The average monthly ET_o in the basin ranges from 95 mm in December to 248 mm in May (Table 4).

Table 3: District-wise average annual ETo

	Ashoknagar	Bhind	Datia	Guna	Gwalior	Morena	Sheopur	Shivpuri	Vidisha	Av. annual
ET_o in mm	1931	1833	1843	1931	1833	1832	1933	1933	1856	1881

Table 4: Average monthly ETo of Sind sub-basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Et_o(mm)	98	116	170	206	248	208	157	146	161	157	114	95	1875

Soil Classification:

The soil texture in Sind sub-basin is primarily calcareous clayey and loamy. Calcareous loamy soils are found along the rivers. Most of the basin has deep well drained soils. However, excessively drained soils are also found in ravines and areas with loamy soil texture. These areas and the river stretches also have high soil erosion. Salient features of soils are shown by maps[18] in Figure 25 to Figure 28.

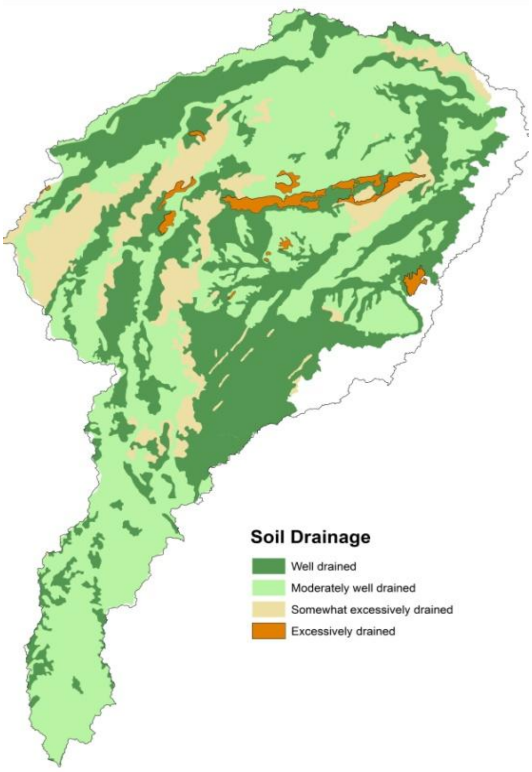


Figure 25: Soil Drainage map of Sind sub-basin

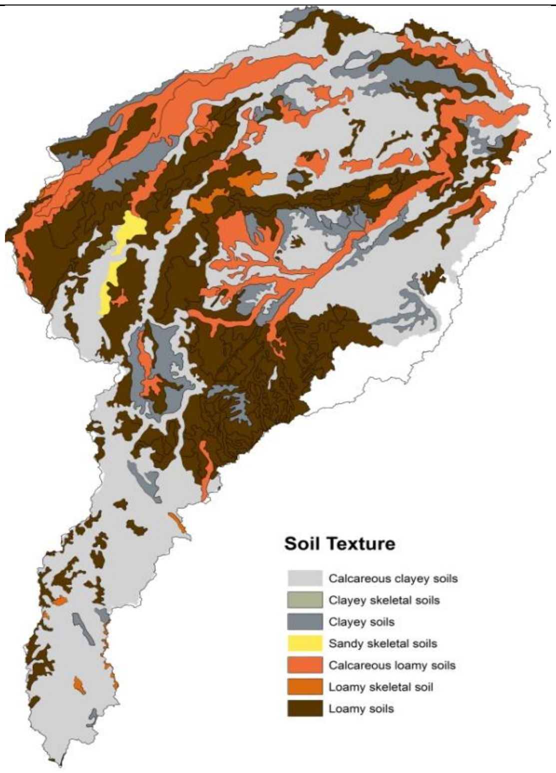


Figure 26: Soil Texture map of Sind sub-basin

[18] Source -MP WRD

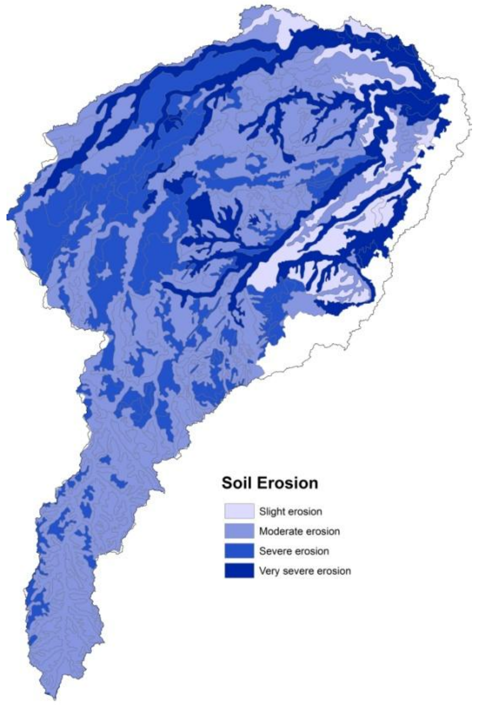


Figure 27: Soil Erosion map of Sind sub-basin

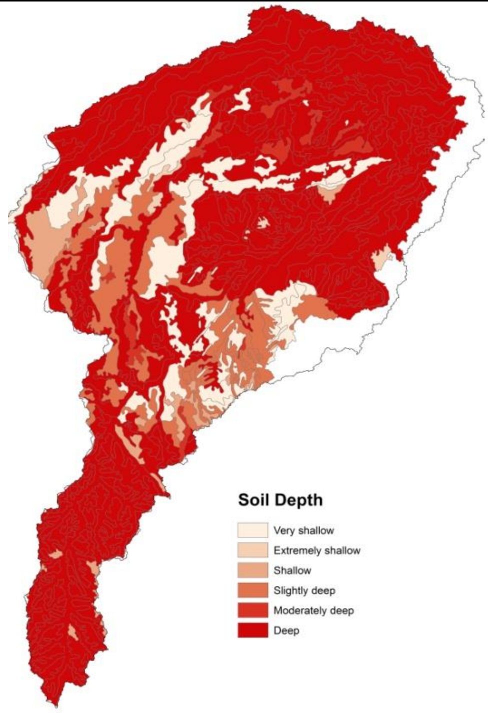


Figure 28: Soil Depth map of Sind sub-basin

Agro-climatic Zone:

The agro climate zones are defined by the Ministry of Agriculture. The area of Sind sub-basin falls in three agro-climatic zones, namely; Gird Region, Vindhya Plateau and Bundelkhand zone (Figure 29). Except Datia which falls in Bundelkhand and Vidisha in Vindhya Plateau, the majority of the basin comes under Gird region.

The Gird region is spread over Morena, Bhind, Gwalior, Sheopur, Shivpuri, Guna and Ashoknagar districts. Gird agro-climatic zone is characterized by rainfall of 800-1000 mm/ year, summer temperature breaching 48^0C and winter temperature dipping below 0^0C, alluvial, deep to medium black soils. Agriculture department defines Gird agro-climatic zone under "Wheat-Jowar" crop-zone.

Bundelkhand agro-climatic zone, which covers Datia district in the basin, has the characteristics of high proportion of wastelands, low rainfall 700-900 mm/ year, dry sub humid climate and mixed red & black soils.

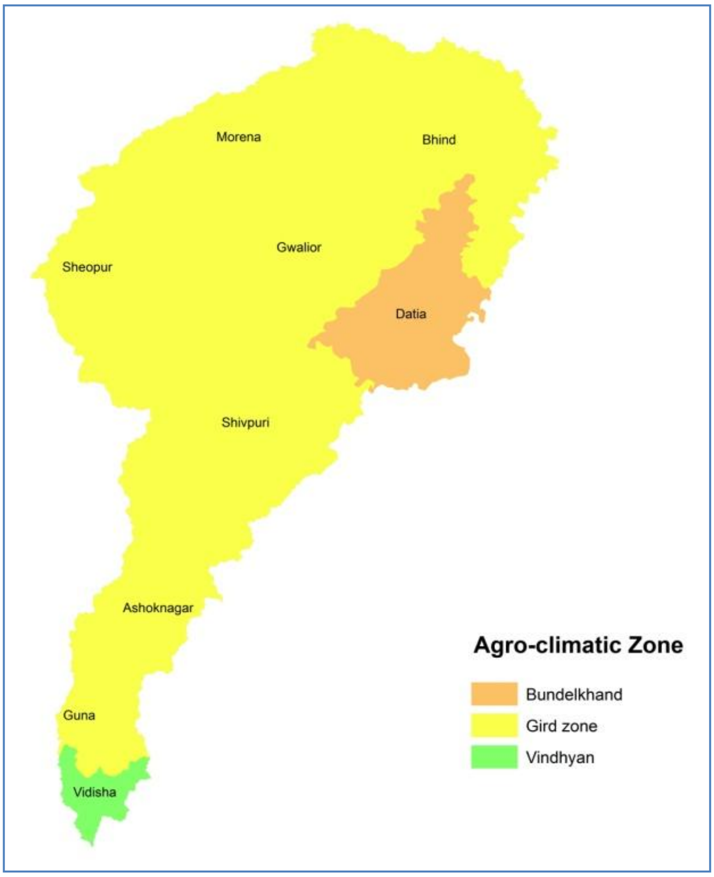


Figure 29: Agro-climatic Zones in Sind sub-basin

Vindhya Plateau agro-climatic zone in the initial stretch of Sind River is characterized by high rainfall of 1000-1200 mm/ year, large area under cultivation, medium-deep black soils and wheat crop-zone. Agro climatic zone wise characteristics in Sind sub-basin are shown in Table 5.

Table 5: Agro climatic zone characteristics

Agro climatic Zone	Districts	Soil Type	Annual rainfall (mm/year)	Crop zone
Gird region	Morena,	Alluvial	800-1000	Wheat-Jowar
	Bhind,	Alluvial		
	Sheopur,	Alluvial		
	Shivpuri	Alluvial		
	Gwalior	Alluvial		
	Guna	Medium & Deep Black		
	Ashoknagar	Medium & Deep Black		
Bundel-khand	Datia	Mixed Red & Black	700-900	Wheat-Jowar
Vindhya Plateau	Vidisha	Medium & Deep Black	1000-1200	Wheat

Land use:

The land use map of Sind sub-basin prepared by MP WRD in year 2007 is shown in Figure 30. Geographical area of Sind sub-basin is 26,082 km^2, out of which approximately 52% land is under cultivation, 19% lands comes under forest, 15% of the land not available for cultivation and 14% is culturable waste land, other uncultivated land & fallow land (Figure 31). 'Land not available for cultivation' includes land put to non agricultural uses, barren and uncultivable land. 'Cultivable waste land' includes land that can be brought under cultivation immediately, or after some improvement and uneconomical patches of land. 'Other uncultivated land excluding fallow land' includes permanent pastures & other grazing land and land under miscellaneous trees, crops & groves.

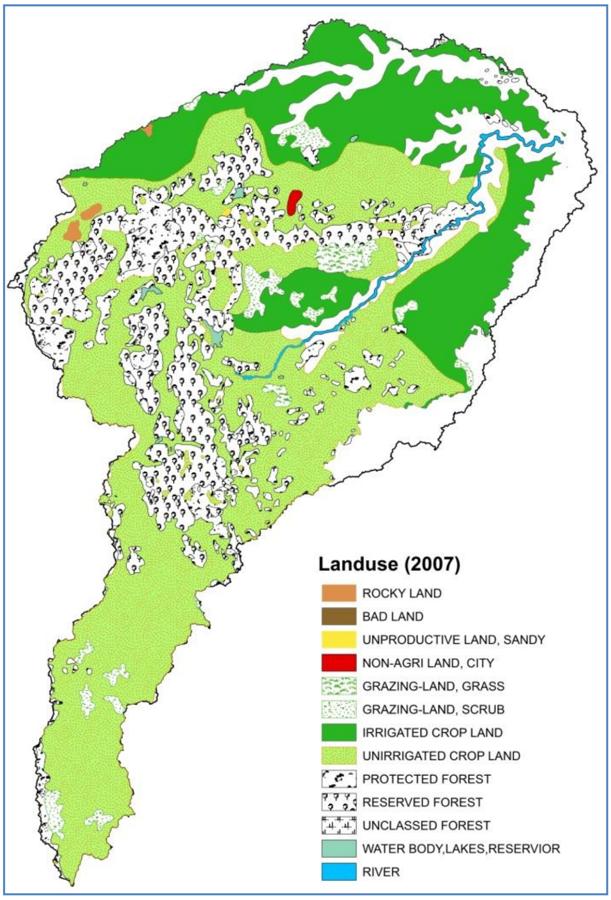


Figure 30: Land use map of Sind sub-basin (WRD 2007)

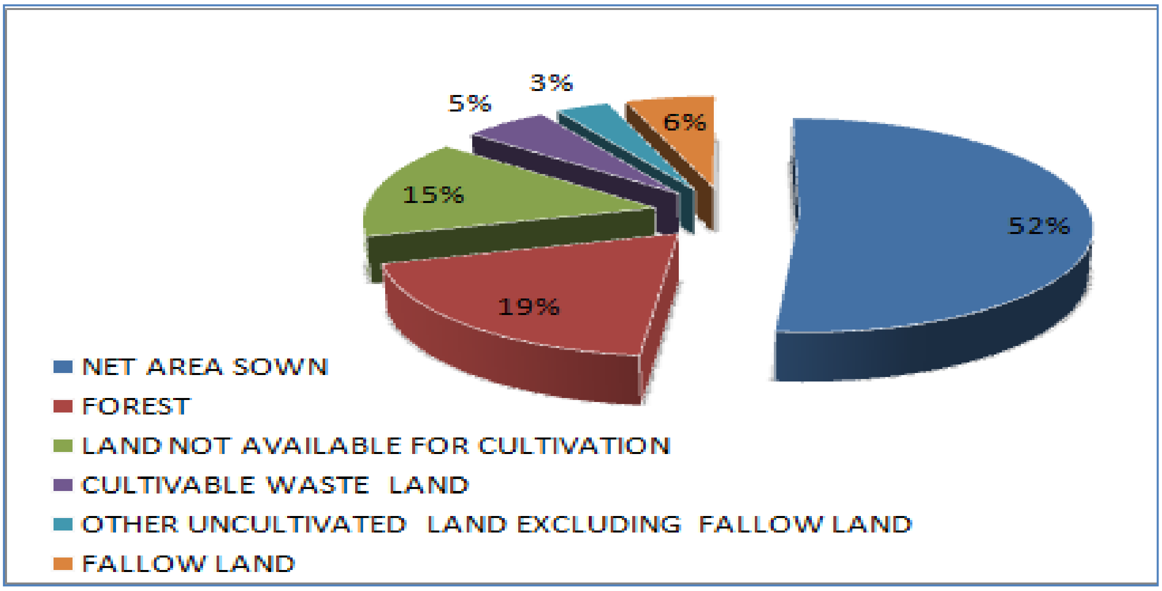


Figure 31: Different Land Use in Sind sub-basin (Commissioner Land Record 2007)

River system:

The origin of the Sind river is in Vidisha district in Madhya Pradesh from where the river flows north - north east to towards Bhind. In the interim, the river flows through the districts of Guna, Ashoknagar, Shivpuri, Datia, Gwalior and Bhind. It has a total length of 470 km out of which 461 km are in Madhya Pradesh and 9 km are in Uttar Pradesh.

Total catchment area of the river is 27,948 km^2 out of which 26,082 km^2 (more than 93% area) falls in Madhya Pradesh and 1866 km^2 falls in Uttar Pradesh. The river system of the Sind sub-basin is shown in Figure 32.

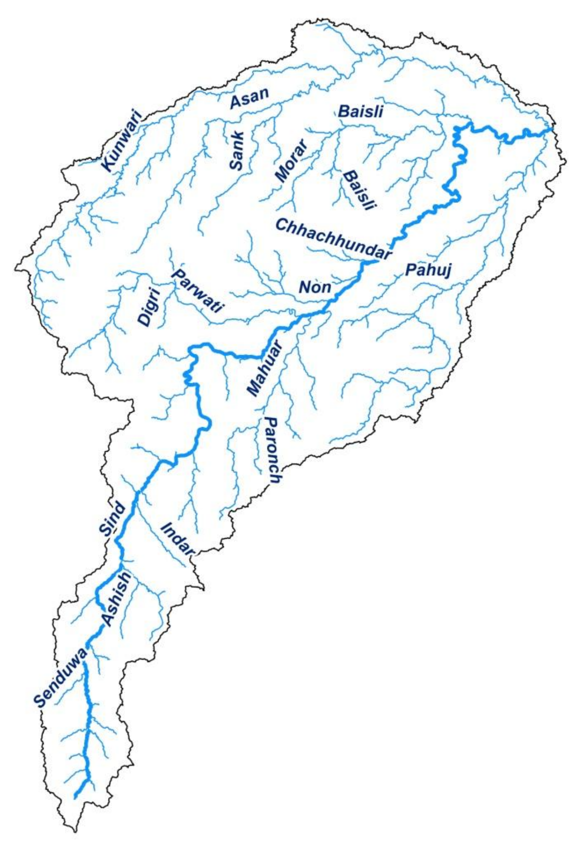


Figure 32: Sind River and its Tributaries

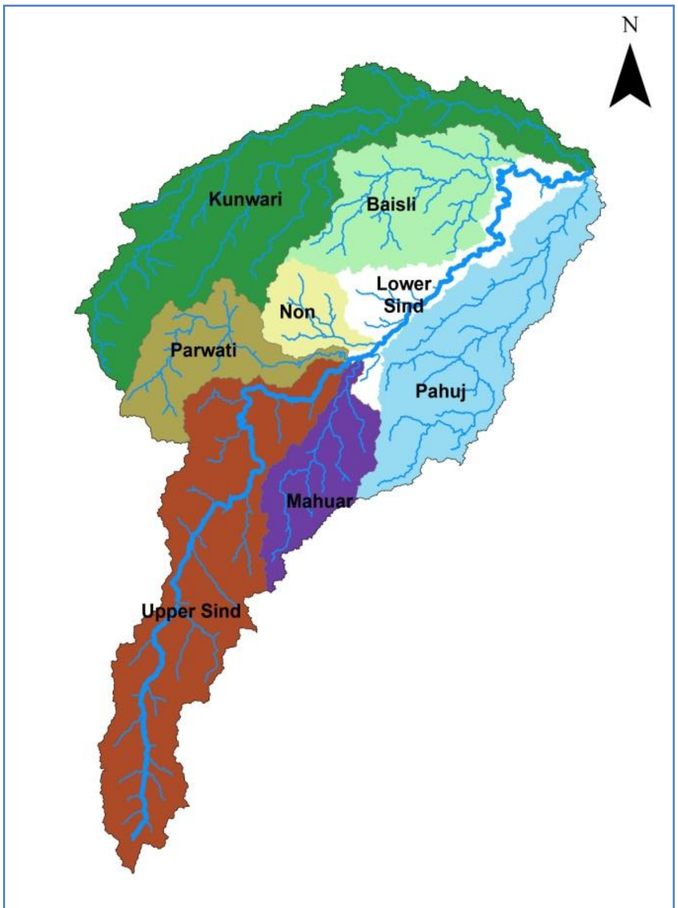


Figure 33: Sub-catchment of Sind River

Mahuar, Parwati, Pahuj, Kunwari, Non and Baisli are among the larger tributaries of Sind river. Among the tributaries, Kunwari (also called Kwari) is the longest into which Asan and Sank rivers drain. Originating from the Shivpuri plateau, it flows into Sind near Lahar in Bhind district. The drainage areas of the important tributaries are shown in Figure 33 and also in Table 6.

Table 6: Drainage areas of important sub-catchments

SNo	Sub catchment Name	Drainage area in MP (Km^2)
1	Mahuar	1818
2	Parwati	2181
3	Pahuj	2466
4	Kunwari	6770
5	Non	1019
6	Baisili	3145
7	Upper Sind	6688
8	Lower Sind	1995
	Total	26082

Water Resources Infrastructure

Much of the water related infrastructure came up initially in north of the sub-basin around Gwalior mainly because of large number of inhabitants in this area and also because Gwalior was the seat of a princely state.

A complex of water resources infrastructure for the water requirements of the town and nearby settlements was created by constructing reservoirs like Tigra, Pillowa, Kaketo, Pagara, Harsi, Chandpatha, Madhav lake and Kotwal; mainly for domestic water needs. These reservoirs are part of a complex intra-basin network system.

The green revolution in India started in the 1960s which also witnessed a number of dams and storages being created in the country. However the sub-basin gained little on that account as only 10-15 % of present gross storage of the sub-basin got created during this phase.

Other important dams in the basin are Madikheda, Upper Kaketo, Mahuar, Paronch, Pehsari, Akhajhiri and Harsi (Figure 34).

Madikheda is the largest reservoir in the basin (Figure 35) with gross storage capacity of 937 million cubic metres with the net irrigation of 53,005 hectares. It is also linked with Harsi, the second largest reservoir in basin for balancing spatial variations. Madikheda which was commissioned in 2008 also has an installed hydro-power capacity of 60 MW. Madikheda along with pre independence storages account for 75% of gross storage in basin.

Figure 34: Harsi dam

Figure 35: Madikheda dam

Most of the water resources infrastructure in the basin was developed during the pre-independence period by the erstwhile rulers and were mainly aimed at securing the domestic water needs around the Gwalior region. The location of important reservoirs water resources infrastructure in Sind sub-basin is shown in Figure 36 and the basic details is shown in Table 7.

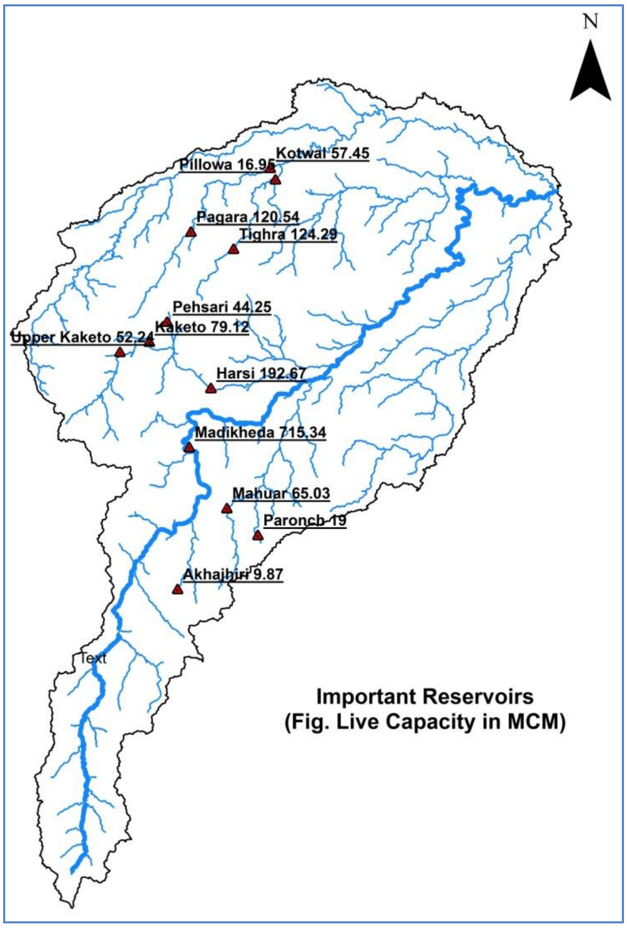


Figure 36: Water Resources Infrastructure in Sind sub-basin

Table 7: Important Water Resources Infrastructure in Sind sub-basin

Dam Name	Purpose	Live Capacity (MCM)	Irrigation (ha)	Hydropower (MW)	Year of completion
Harsi	Irrigation	192.67	62,675	-	1937
Madikheda Dam project	Multi-purpose	715.34	53,005	60	2008
Mahuar	Irrigation	65.03	13,775	-	2014
Akhajhiri	Irrigation	9.87	1,983	-	1973
Tighra	Domestic water	124.29	-	-	1917
Pagara	Irrigation-Feeder	120.54	-	-	1927
Kotwal	Irrigation-Feeder	57.45	-	-	1914
Pillowa	Irrigation-Feeder	16.95	-	-	1914
Kaketo	Irrigation - Domestic water- Feeder	79.12	2,271	-	1934
Pehsari	Irrigation-Domestic water-Feeder	44.25	831	-	1978
Upper Kaketo	Irrigation-Domestic water-Feeder	52.24	300	-	2014
Paronch	Irrigation	18.93	2,614	-	1980

Figure 37: A view of Harsi canal

Figure 38: A view of Tighra reservoir

Sind project

The Sind project was started in year 1972-73 and its subsequent phase are the most important water resources development projects in the basin.

Sind project in its first phase (Figure 39 and Figure 42) comprised of

1. Sind Diversion works- Mohini Pickup weir, Harsi Feeder canal, Remodelling of Harsi canal
2. Doab Canal
3. Kaketo Tigra Feeder Canal - Kaketo Pehsari Canal-Pehsari Dam - Pehsari Sank Canal
4. Sank Swarna Rekha Link canal - Sank Pickup weir, Sank Non canal, Non Pickup weir, Himmatgarh Tank, Jalapur weir remodelling

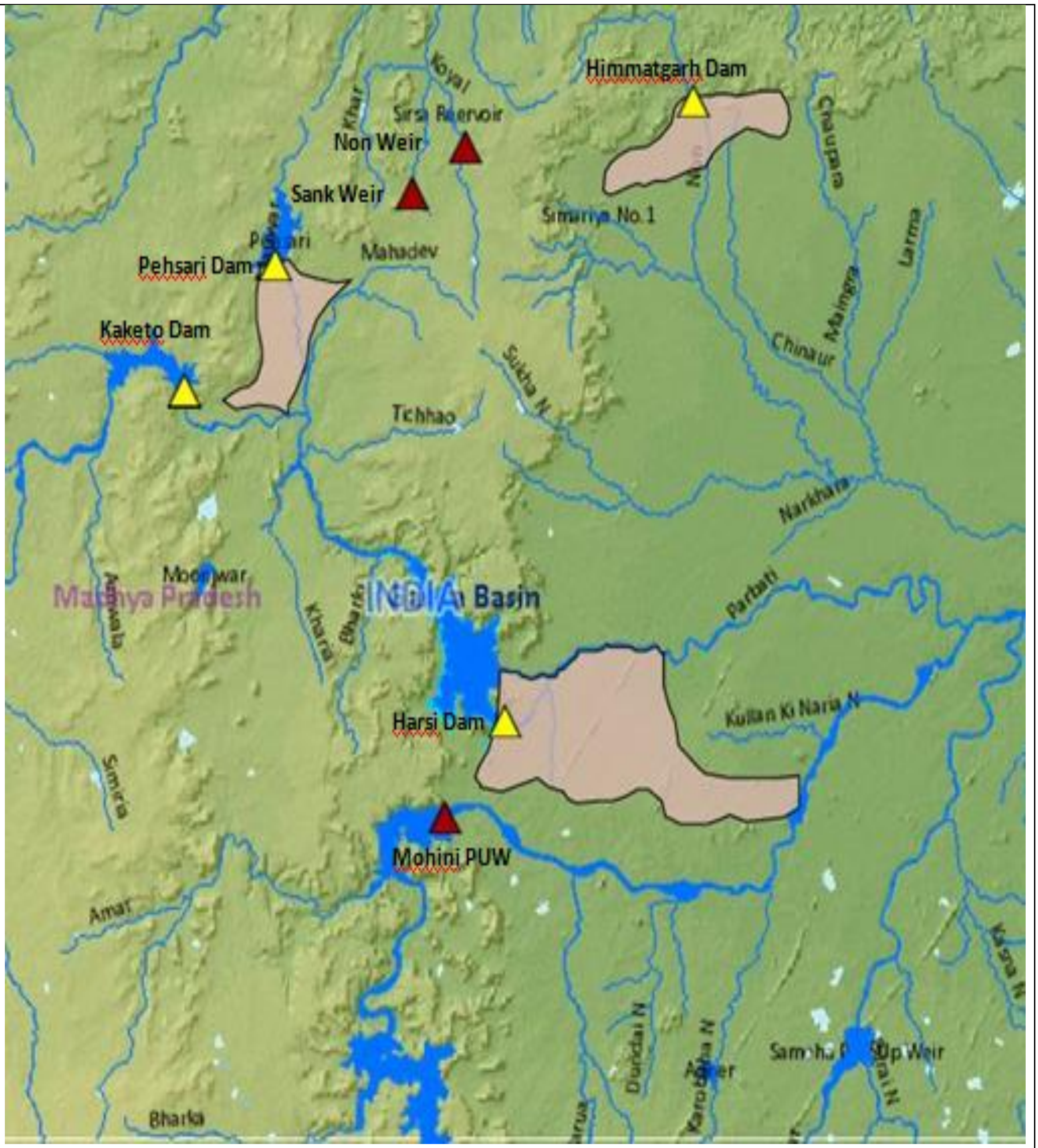


Figure 39: Map showing schemes under Sind project - Phase I

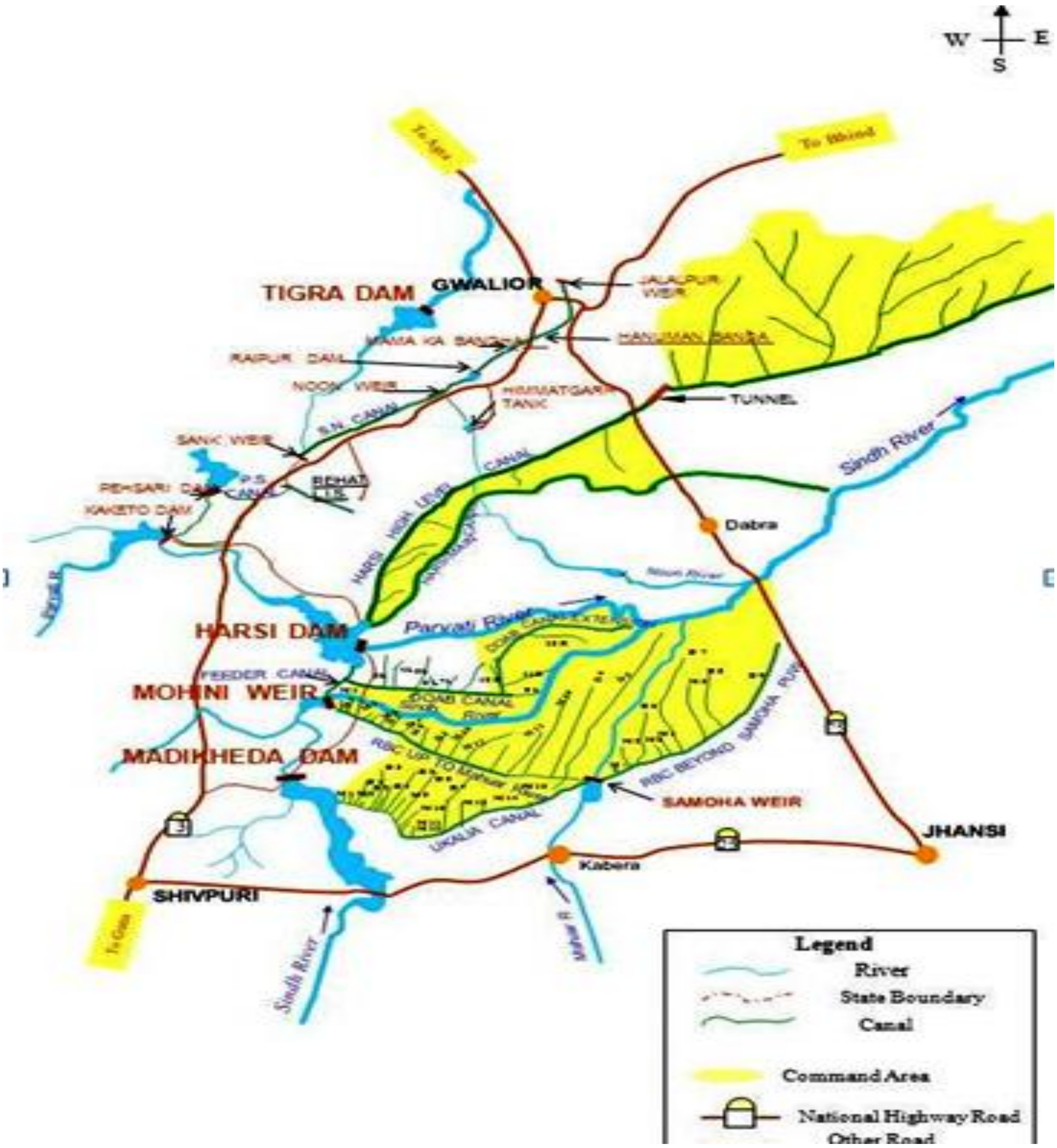


Figure 40: Line diagram - Sind Project Phase I

This project was followed up with another phase called the Sind project Phase-II (Figure 41 and Figure 42) and it comprised of:

1. Madikheda Dam (Atal Sagar dam).
2. Modernisation of Mohini Pick up Weir including installation of gates.
3. Right bank high-level Ukaila canal.
4. Right bank canal up to Mahuar River.
5. Samoha Pickup Weir & R.B.C beyond Mahuar River.
6. Extension of left bank Doab canal.
7. Harsi high-level canal.
8. Powerhouse with installed capacity of 60 MW at Madikheda Dam.

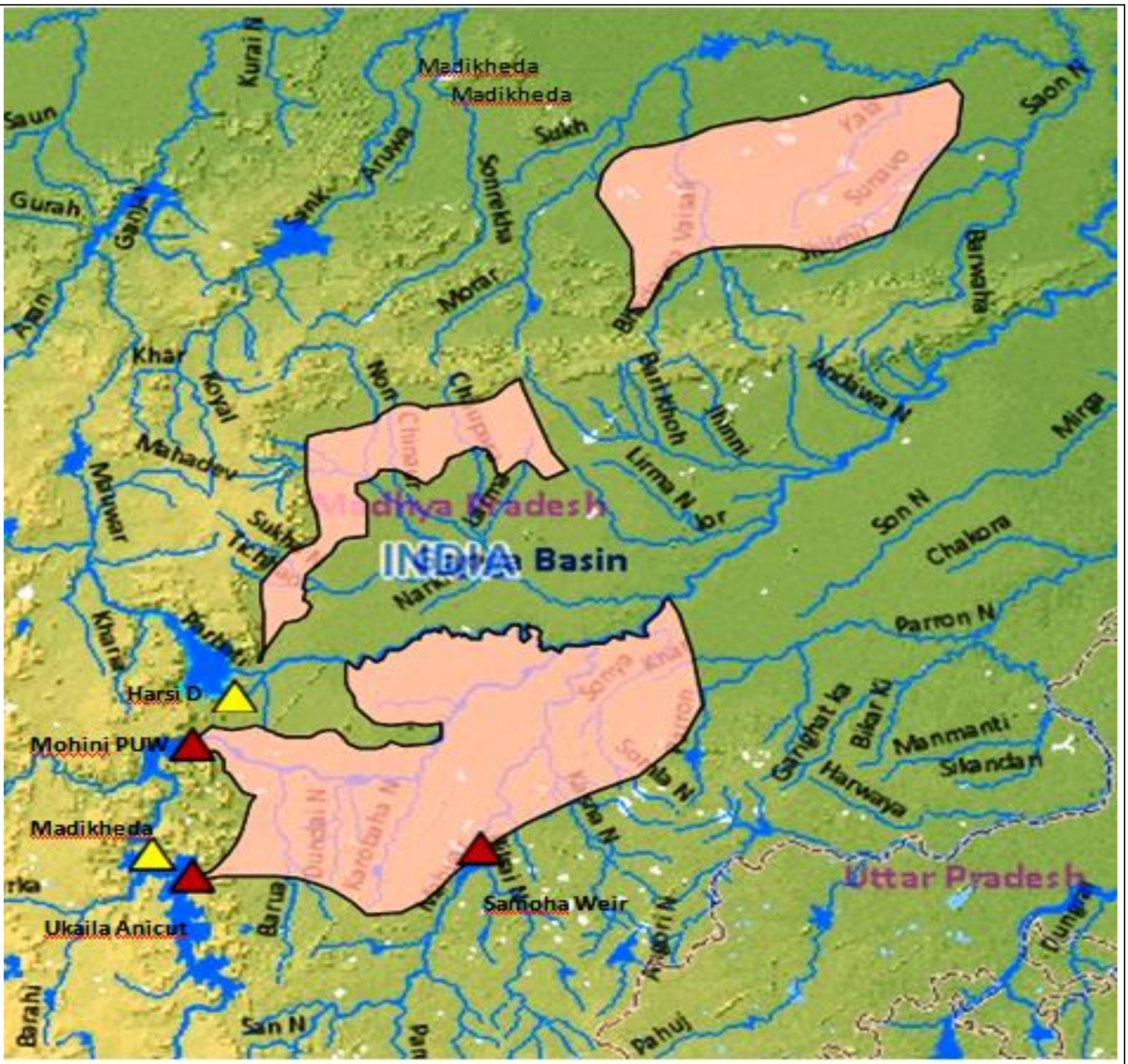


Figure 41: Map showing schemes under Sind Project Phase II

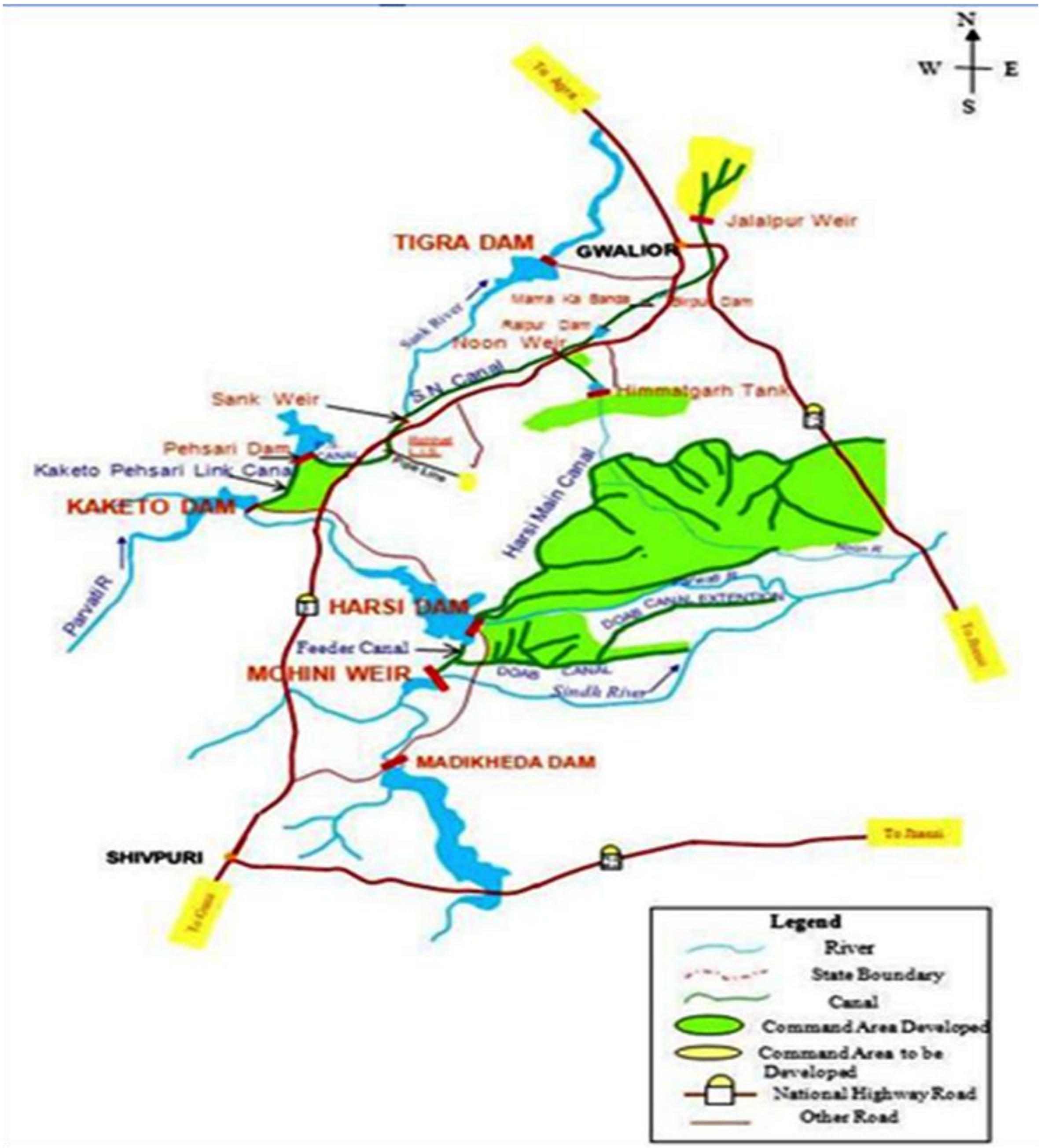


Figure 42: Line diagram - Sind Project Phase II

In the adjacent western inter-state Chambal river basin, the Chambal project was initiated during the first five year plan of independent India. The realization of this project - a complex of dams, barrage and canal system, ensured supply of irrigation water to the districts of Sheopur, Morena and Bhind in the Sind sub-basin. Based on the average water availability, the state of Rajasthan is expected to release 110.5 m^3/s (or 3900 cusecs) to Madhya Pradesh through the Chambal Right Main Canal. Approximately two-third of this water helps irrigating Sind sub-basin.

The development of the water resources through times and expressed as the storage capacity is depicted in Figure 43. Details of existing water resources infrastructure in Sind sub basin is shown in Table 8.

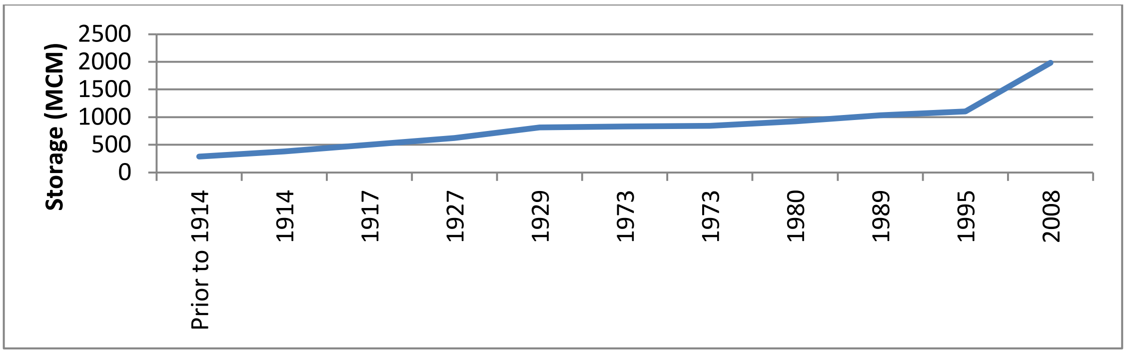


Figure 43: Water resources storage creation in Sind sub-basin

Table 8: Existing Water Resources Infrastructure in Sind sub basin

Type of scheme	No. of schemes	Culturable command area (ha)	Storage (MCM)
Major Schemes (CCA >10000 ha)	2	115,680	908
Medium Schemes (CCA >2000 <10000 ha)	8	21,774	514
Minor Schemes (CCA <2000 ha)	329	51,819	331
Total	**339**	**189,273**	**1,753**

(Source http://eims1.mpwrd.gov.in/imreport/control/main)

Water Availability - Ground Water

The nature of bedrock geology is crucial in determining groundwater availability. Topography is an expression of the geological structure and morphology. Climate and weather are largely controlled by physiographic features. Thus, soil formation, water generation, its movement and retention, all are dependent on natural features of which the base is geology. The geological setting plays a very decisive role in deciphering the ground water possibilities in the region. The hydro-geological formation in Madhya Pradesh as depicted by CGWB is illustrated in Figure 44.

In Sind sub-basin, two groups of rock formations have been identified depending on characteristically different hydraulic parameters- Porous Formation (high specific yield values) and Fissured Formation (limited to weathered, jointed and fractured rocks). Alluvium, sandstone, granite, shale and basalt are the main aquifer systems in the basin. The hydro-geological features of Sind sub-basin is shown in Table 9.

Table 9: Hydro-geological features of Sind sub-basin

District	Geological Age / Group	Rock Formation	Hydro-geological charactersistic
Bhind, Sheopur, Morena, Datia	Pleistocene to Recent Alluvial plains (older and Newer Alluvium)	Unconsolidated clays and silts, gravels and sands of different mix. Lenses of Peat and organic matter carbonate and siliceous concretions (Kankars)	Form very potential ground water reservoirs with a thick sequence of sandy aquifers down to great depths (>300 m below ground level-bgl). The aquifers are unconfined, semi-confined (leaky confined) or confined.
Guna, Ashoknagar, Vidisha	Cretaceous to Eocene Deccan Trap	Basalts	Weathered, Fractured and vesicular basaltic layers of Traps, Such unconfined hallow aquifers, leaky confined/confined deeper aquifers yield upto 5 lips, Sp.Yield 1 to 4% Hydraulic conductivity 5-15 m/day.
Gwalior, Morena, Sheopur, Shivpuri, Guna, Ashoknagar, Vidisha	Precambrian (Proteozoic) Vindhyan Super Group. Bhander, and Semri Groups. Mahakoshal (Cuddaph) Super Group Gwalior Groups.	Shales, Sandstones and limestones	Generally, devoid of any primary porosity. Weathering and denudation, structurally weak planes and fractures impart porosity and permeability in the rock mass. Solution cavities (Cavernous) in carbonate rocks, at places give rise to large groundwater storage/circulation. Sp. Yield value of unconfined aquifer is generally low (0.2% to 3%). Hydraulic conductivity varies widely depending upon fracture incidence (2 to 10 m/day.)

District	Geological Age / Group	Rock Formation	Hydro-geological charactersistic
Datia, Gwalior, Shivpuri	Archaeans Older Metamorphics Sausar, Sakoli and Chilpi Groups. & Bundelkhand Granites.	Granitoid gneisses, schists, gneisses, quartzites and granites	Do not posses primary porosity. Weathering, fracturing, jointing impart secondary porosity. Groundwater mostly occurs under phreatic conditions and at some places also under confined/semi confined conditions.

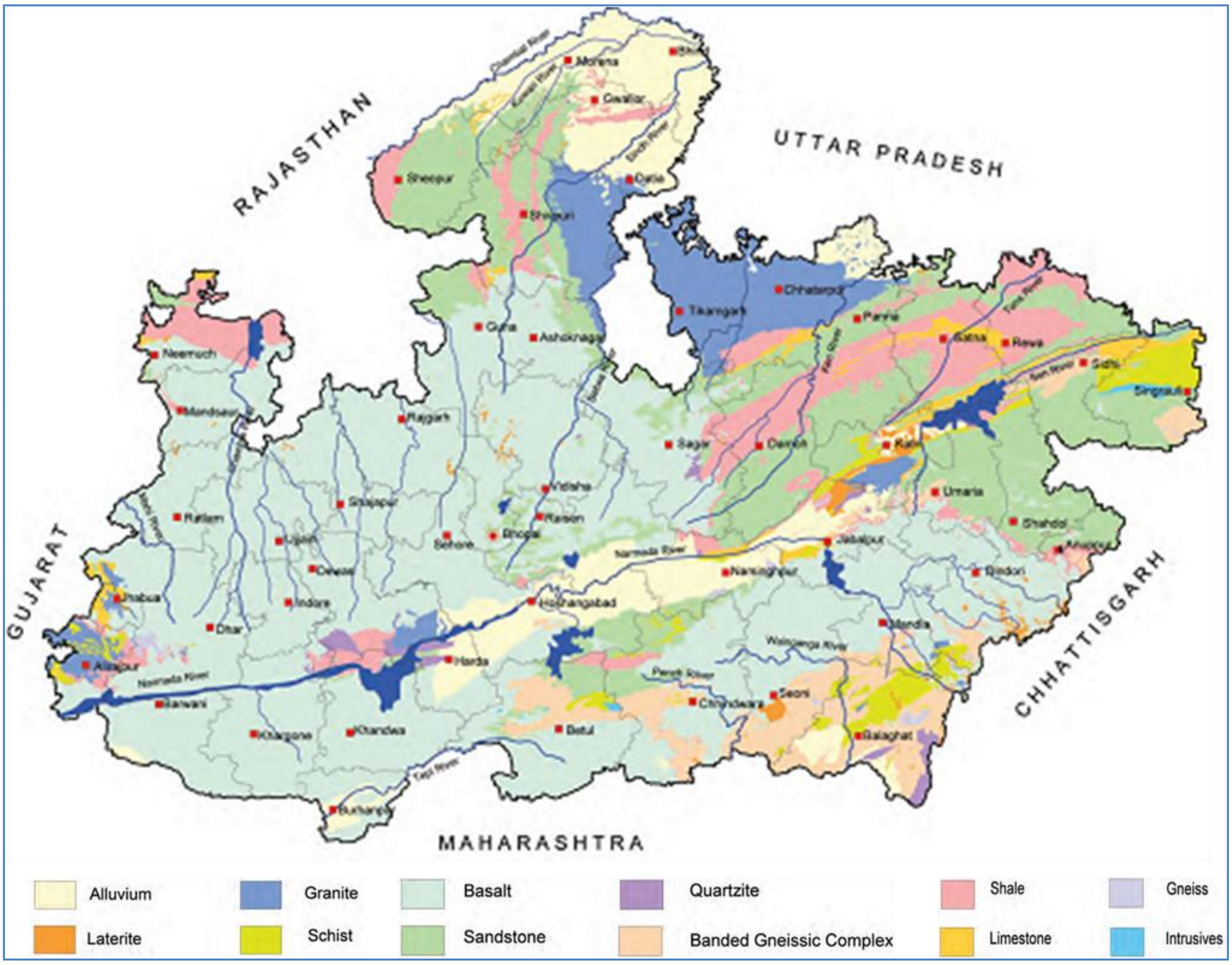


Figure 44: Map showing hydro-geological formation in Madhya Pradesh

Ground water status in the basin:

The Central Ground Water Board (CGWB) monitors ground water levels and quality in the basin. The location of groundwater monitoring wells is depicted in Figure 45.

Ground water levels before and after monsoons are monitored at the central ground water stations Figure 46 and Figure 47. The monitoring data for 2013 has been analyzed and interpolated using inverse distance weighted method to show the spatial pattern of ground water levels in the basin.

Few areas of the basin could not be covered as data for stations beyond the grid were not available. It is evident that monsoon plays an important role in recharging groundwater.

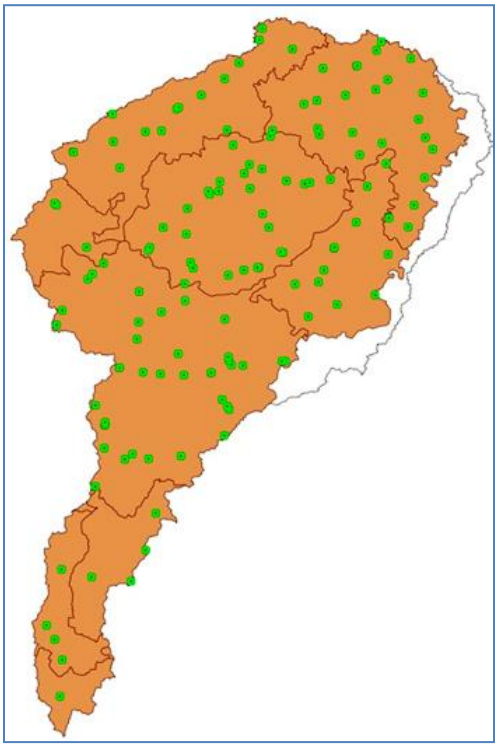


Figure 45: Locations of GW monitoring wells (Source - CGWB)

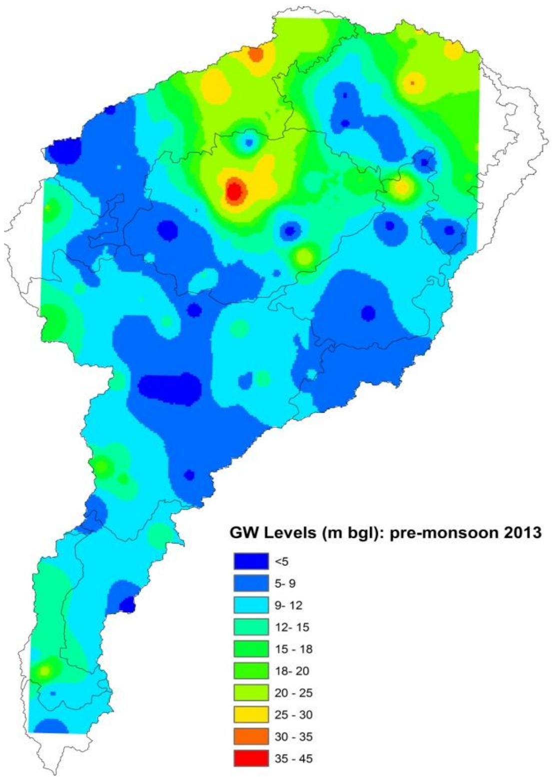


Figure 46: Pre monsoon 2013 - GW levels (source-CGWB)

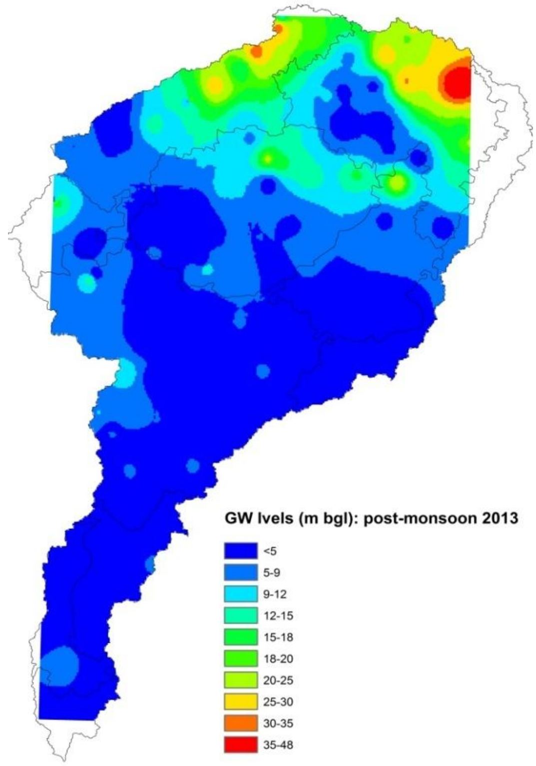


Figure 47: Post monsoon 2013 - GW levels (source-CGWB)

Spatial Variation of the Ground Water Availability

The Net ground water availability in the Basin is 2696.63 MCM with Bhind district having the highest net groundwater availability of 552.52 MCM and Vidisha with lowest of 55.73 MCM. Total recharge from rainfall in the basin is of the order of 2191.73 MCM, with Bhind district having the highest recharge of 477.51 MCM and Sheopur district has minimum recharge of the order of 50.61 MCM. Recharge from rainfall is mainly a function of geographical area of the district, normal monsoon rainfall and lithology of the area. Component of recharge from other sources is highest in Gwalior district (167.03 MCM) followed by Morena district (158.53 MCM) where maximum canal irrigation facility is available. Lowest value of recharge from other source is recorded in Vidisha (6.96 MCM) as area falls under basin is very low. GW recharge in this sub-basin is more from rainfall (2191.73 MCM) while less from other sources (646.83 MCM) Total annual recharge from all sources in the basin is of the order of 2838.57 MCM, with Bhind district having the highest recharge of 581.61 MCM and Vidisha district has minimum recharge of the order of 58.66 MCM. Total unaccounted natural discharge in the Basin is of the order of 141.93 MCM, with Bhind district having the highest discharge of 29.08 MCM and Vidisha with lowest of 2.93 MCM.

The district wise net groundwater availability is given in Table 10 and is also depicted in the map as shown in Figure 48

Table 10: Ground Water Resources Availability in Sind sub-basin

S. No	District	Annual Replenishable Ground Water Resource (MCM)					Natural Discharge During Non Monsoon Period (MCM)	Net Ground Water Availability (MCM)
		Monsoon Season		Non Monsoon Season		Total		
		Recharge from Rainfall	Recharge From Other Sources	Recharge from Rainfall	Recharge From Other Sources			
1	Ashoknagar	108.37	3.72	0.00	15.57	127.66	6.38	**121.28**
2	Bhind	477.51	6.61	0.00	97.49	581.61	29.08	**552.52**
3	Datia	295.09	7.76	0.00	48.94	351.79	17.59	**334.20**
4	Guna	104.43	4.91	0.00	17.74	127.09	6.35	**120.73**
5	Gwalior	367.57	42.15	0.00	124.88	534.60	26.74	**507.86**
6	Morena	321.59	7.23	0.00	151.29	480.12	24.01	**456.11**
7	Sheopur	50.61	0.82	0.00	19.58	71.00	3.55	**67.45**
8	Shivpuri	414.86	16.76	0.00	74.42	506.04	25.30	**480.75**
9	Vidisha	51.70	1.18	0.00	5.78	58.66	2.93	**55.73**
Total		**2191.73**	**91.15**	**0.00**	**555.69**	**2838.57**	**141.93**	**2696.63**

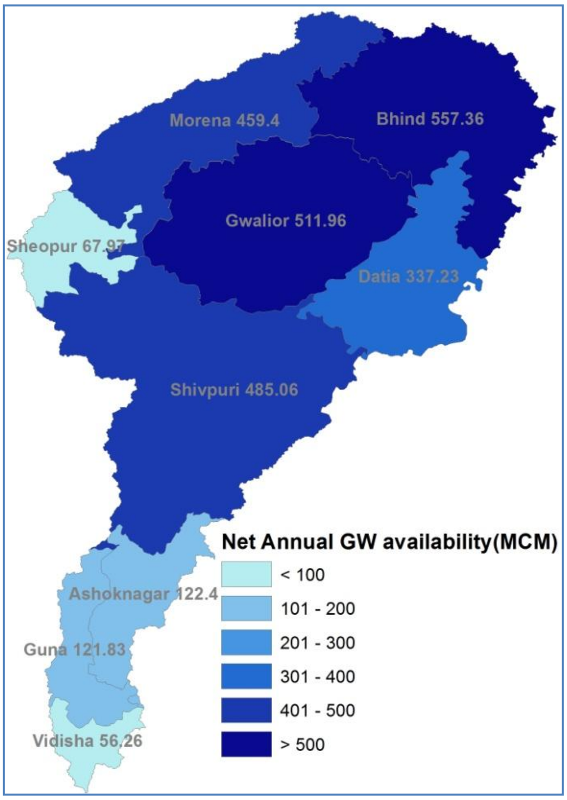


Figure 48: Net GW Availability in MCM

Water Availability - Surface Water

The assessment of available resources is a basic requirement in all resource planning. River basin planning is no exception. The purpose of assessment of water availability and its variability over the basin is to determine the extent and dependability of supply of water. Not only the total quantity available within a certain period of time, but also the distribution of the available quantity with respect to both location and time is important. In basin planning, the spatial distribution of available water often dictates the location of the various structures while seasonal distribution governs their size. Monsoon precipitation is the major source making water available in the basin- both in the form of surface flows and as groundwater recharge. The rainfall estimates based on the available gauges (Figure 49) show that the

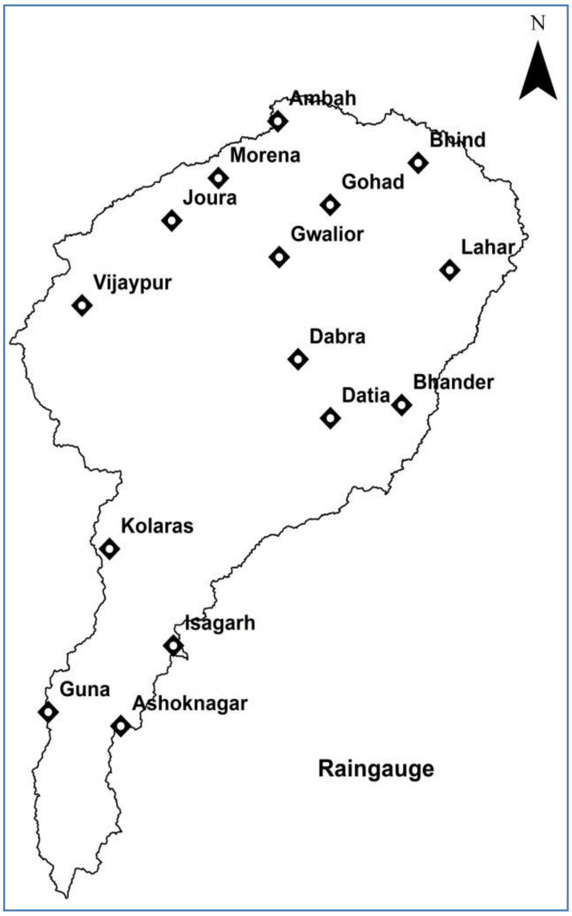


Figure 49: Location of Rain guage sites in basin

average annual rainfall over the basin area of 26,082 km^2 is 875.5 mm.

Among the important tributaries, only Kunwari and Pahuj are gauged. The main river is gauged at 4 locations (Figure 50). For other important tributaries viz. Parwati, Mahuar (limited data), Baisli and Non, regionalization methods were applied to estimate the flows.

Considering the flow data from Jun-1988 to Dec-2012, the basin has a mean annual runoff of 4.55 BCM. The runoff calculations are based on non-naturalized flows and hence include much of the abstractions. The annual pattern of the runoff over months is as shown in Figure 51. The flow duration curve (Figure 52), for flow data from calendar year 1989 to 2012, yields 75% dependable annual runoff of 3.22 BCM.

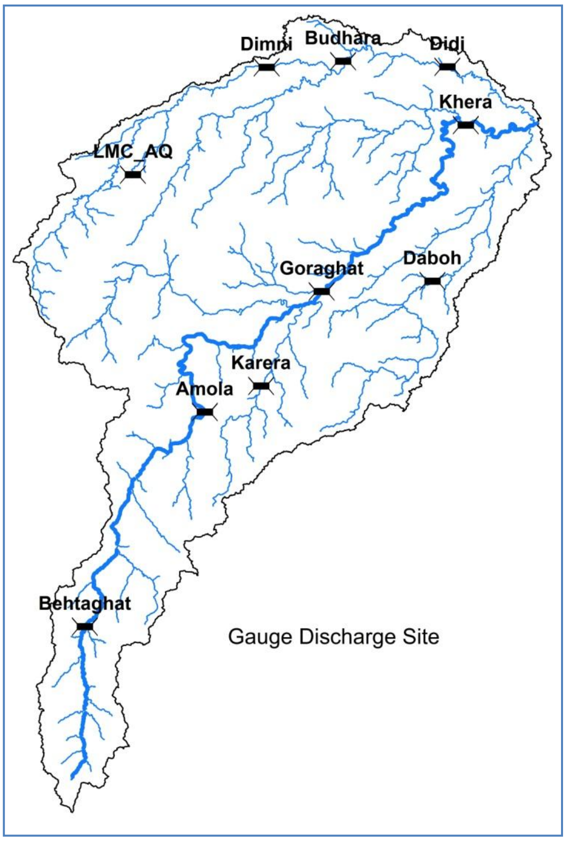


Figure 50: Location of Guage-Discharge site in basin

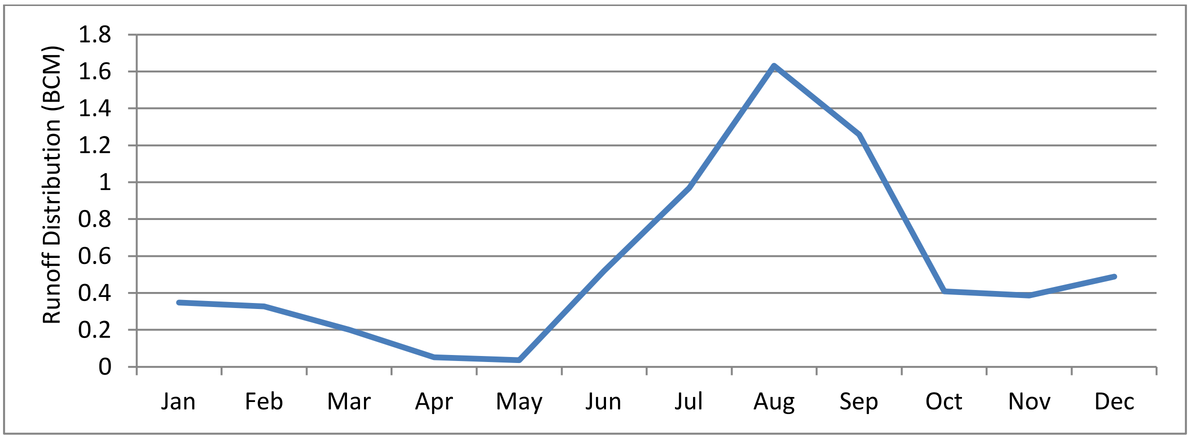


Figure 51: **Water Availability based on MAR**

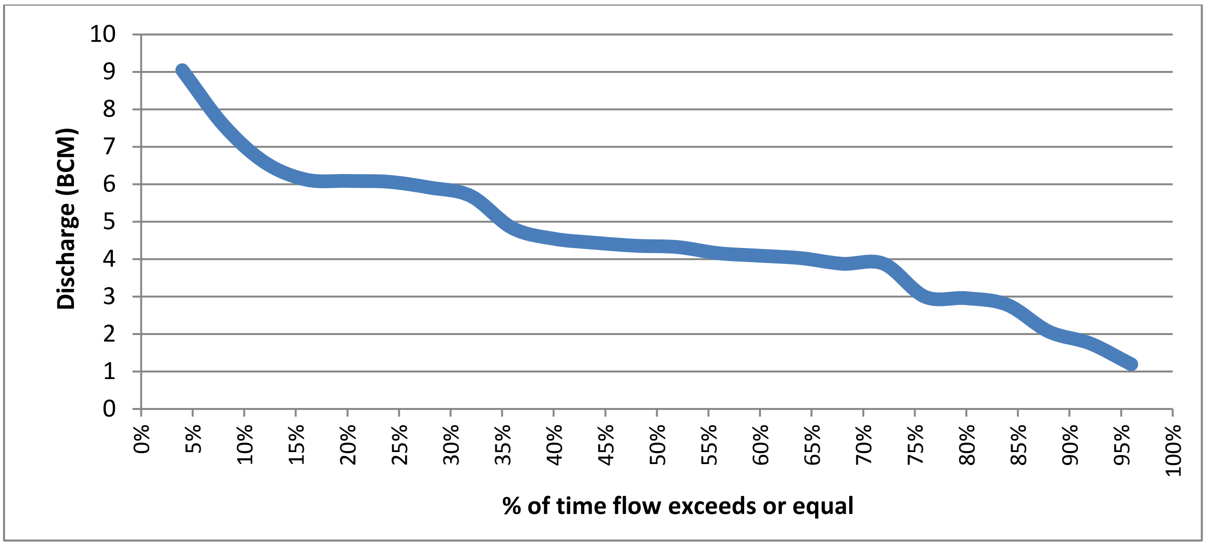


Figure 52: Flow Duration Curve

Apart from the non-naturalized flow, due to non-virgin catchment conditions the surface water availability estimates would include the surface storages. The Central Groundwater Board has calculated groundwater recharge from rainfall in the basin at 2.19 BCM and is discussed in the following section on groundwater. The sub-basin receives 24.08 BCM; from precipitation 22.83 BCM and another 1.25 BCM from Chambal canal system. The water receipts translate into surface runoff and groundwater recharge i.e. 4.55 and 2.19 BCM respectively, thus the total runoff is 6.74 BCM. The remainder is available for evapo-transpiration (inclusive of other losses like evaporation from water bodies) i.e. 17.34 BCM.

The available surface water is the difference of annual receipts and evapo-transpiration. Considering the flow data from Jun-1988 to Dec-2012, Sind sub-basin has a mean annual availability of 6.74 BCM (Table 11). More than 66% of the quantity is available during the monsoon period June to September.

Table 11: Estimated water availability in Sind sub-basin

Particulars	Quantities in BCM
Annual Rainfall	22.83
Inter basin receipt from Chambal sub-basin	1.25
Evapo-transpiration	17.34
Surface Runoff (MAR) at state outlet	4.55
Groundwater recharge from rainfall	2.19
Available water	6.74

Water balance of Sind sub-basin is depicted in simplified diagram as shown in Figure 53.

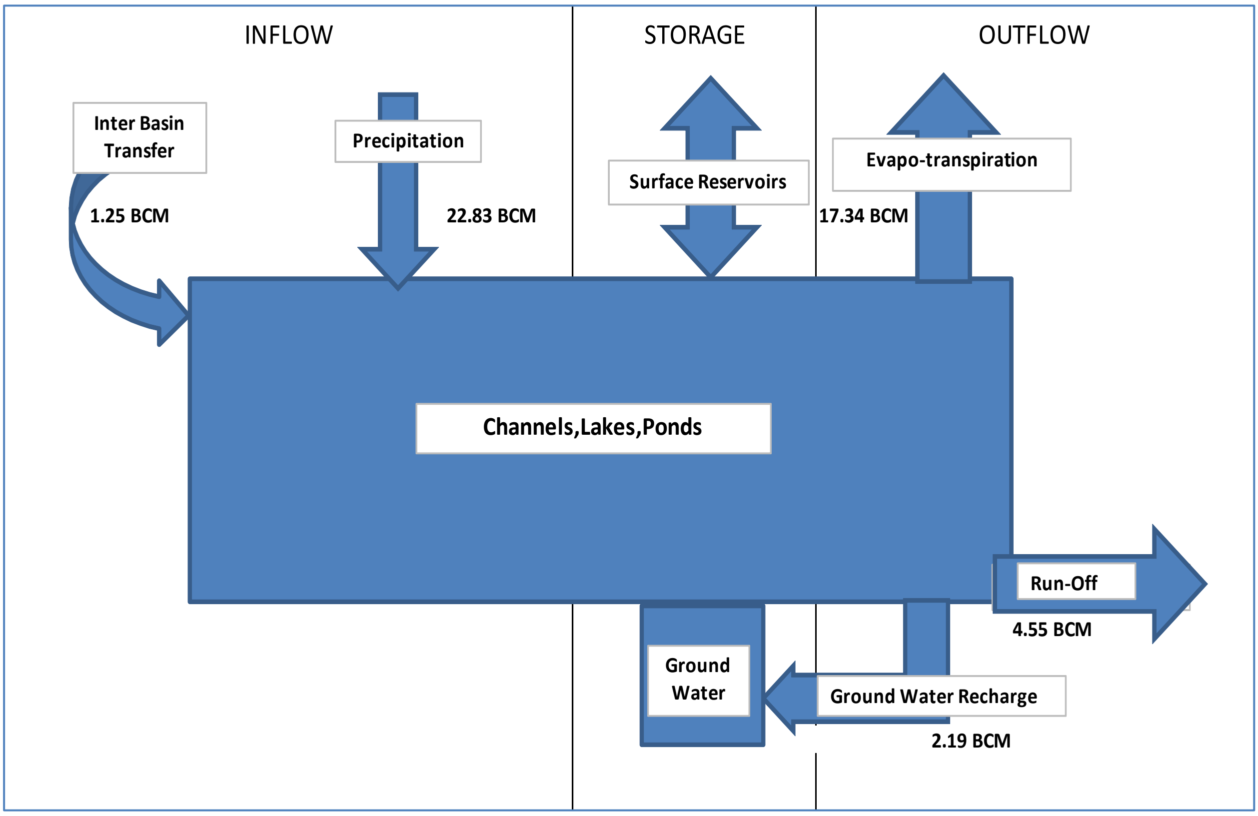


Figure 53: Simplified diagram showing water balance of Sind sub-basin

The annual surface water availability of Sind sub-basin is estimated at 6.74 BCM including inter basin Chambal canal irrigation.

The Ministry of Environment and Forests, Government of India (& DHI Water.Environment.Health) in its October 2010 report "Baseline of Yamuna River Basin" estimated the surface water availability of Sind sub-basin at 6.77 BCM based on river gauging station at Seondha.

Rainfall-runoff relation for Sind sub-basin:

As there exist many data gaps in the available river flow measurements, a numerical hydrological using HEC-HMS was set up for Amola gauge discharge site, as continuous data for years 1989 to 1998 was available for this site. This assumed outlet has a catchment area of 4934 km^2. The continuously available data for this outlet is given in Table 12.

Table 12: Data availability for Amola gauge discharge site

Type of Data	Spatial Variation	Frequency (data length)	Remark
Precipitation	7 Rain gauge Station namely Lateri, Sironj, Ashoknagar, Isagarh, Guna, Kolaras, Pichhore	Daily (30 years)	Manually Operated
Discharge	1 Gauge Discharge Site Amola	Daily (9 years)	Manually Operated

The soil-moisture accounting method (SMA) is selected in this study. SMA in HEC-HMS is a lumped bucket-type model that represents a sub-basin with well-linked storage layers/ buckets accounting for canopy interception, surface depression storage, infiltration, evapo-transpiration, as well as soil water and groundwater percolation.

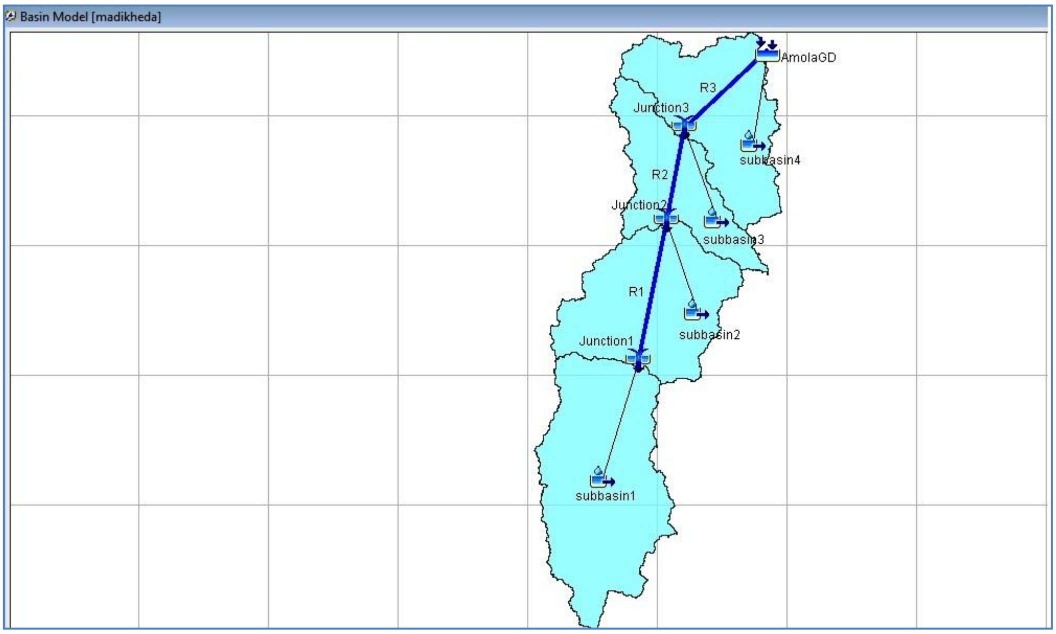


Figure 54: Basin model showing hydrological connectivity

According to the SMA method, rainfall contributes first to the canopy interception storage. Then, rain water available for infiltration, which is determined by infiltration capacity and soil storage. Any excess rainwater sequentially fills the surface depression storage and eventually contributes to surface runoff.

With the help of HEC-GeoHMS, the basin model was created. It contains all hydrologic elements and their hydrologic conductivity viz. sub-basin area, physical characteristics of streams and watersheds which are directly used in HEC-HMS. The basin model is shown in Figure 54.

In the continuous hydrologic model, the simulation time period ranged from 01January1989 to 31 January 1994 and one day time step was used. After simulation the model is calibrated for time period range from 31 January 1994 to 31 January 1999 the final parameters obtained from calibration are used on 30 years rainfall data from 1981 to 2012 to obtain the runoff data of missing period.

The continuous hydrologic model was calibrated and verified using the observed flow data at the Amola Gauge discharge site. The comparison between annual runoff of observed and simulated flow is shown in Figure 55.

The Nash Sutcliffe efficiency comes out to be 0.54 which was found satisfactory due to short data length.

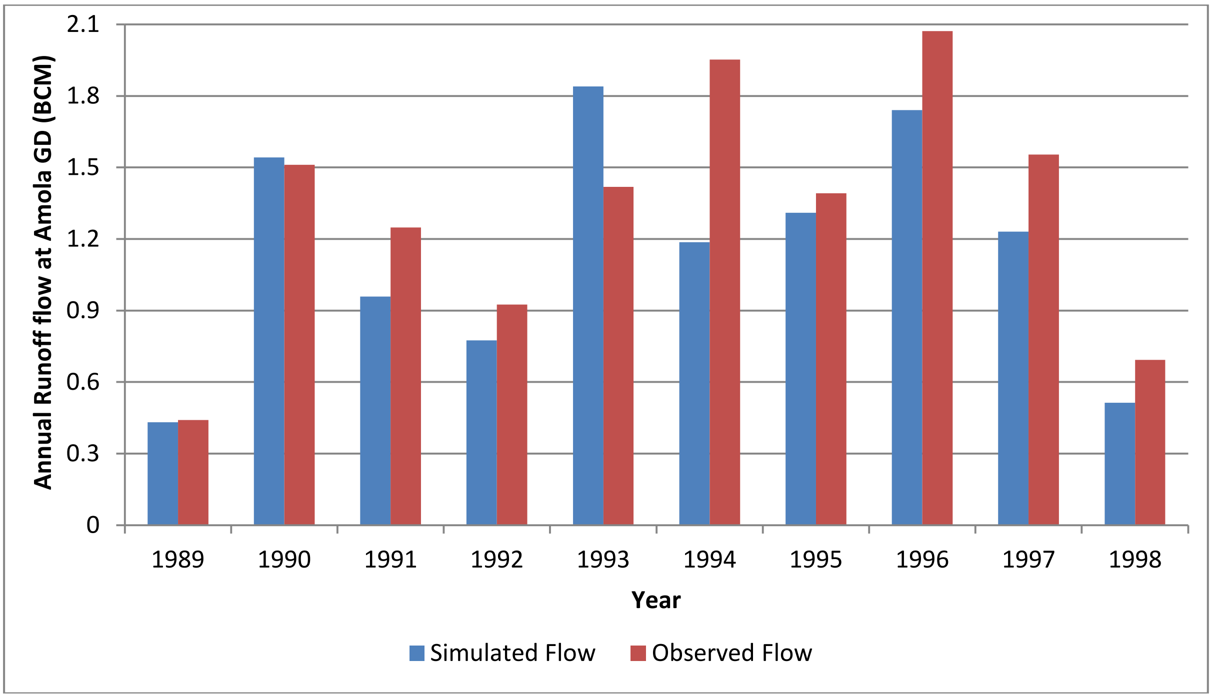


Figure 55: Comparison of Observed and Simulated Flow

The details of the model study, yearly comparison of observed and simulated flow and statistical analysis is detailed in Appendix 1.

Based on the simulated flow at Amola GD site, from 1981 to 2011, the the flow duration curve yields annual runoff 0.653 BCM/ year at 75% probability of exceedance Figure 56. The average flow at this station is 1.18 BCM/ year.

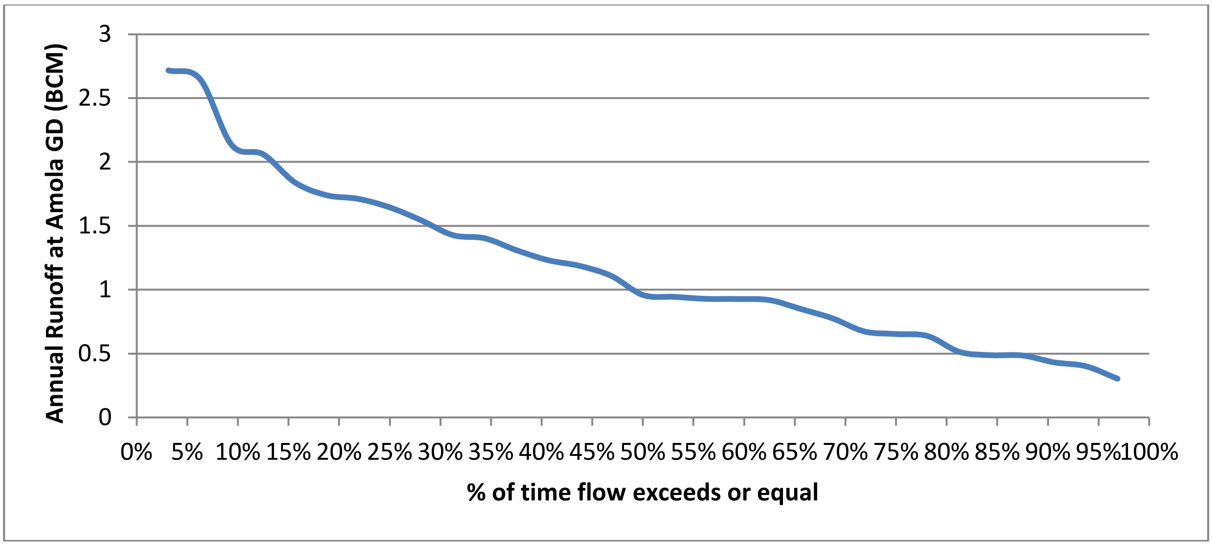


Figure 56: Flow duration curve at Amola GD station

When normalized for Madhya Pradesh catchment area of Sind sub-basin i.e. 26,082 km^2, MAR_{75} is estimated at 3.45 BCM which is lower than 4.55 BCM computed in this chapter's water balance. The average runoff volume for the entire sub-basin is estimated at 6.23 BCM/ year which is higher than 4.55 BCM computed in this chapter's water balance.

Total Water Availability

The total water availability in the basin is the summation of available surface and ground water. As discussed in the preceding section on water availability (Table 11 and Table 10), the total water availability of Sind sub-basin (in MP) is 9.44 BCM/ year (Table 13).

Table 13: Total water availability in Sind sub-basin

Surface Water Availability	6.74 BCM/ year
Ground Water Availability	2.70 BCM/ year
Total Water Availability	**9.44 BCM/ year**

Water Quality - Surface Water

Fresh water is a finite resource essential for use in agriculture, industry, propagation of wildlife & fisheries and for human existence. Madhya Pradesh is home to 10 major rivers which originate from the state. Most of the rivers being fed by monsoon rains run dry throughout the rest of the year often carrying wastewater discharges from industries or cities/towns endangering the quality of our scarce water resources.

There are many agencies, departments and organizations which monitor water pollution as per their domain and rules of business. Much of such monitoring is supplementary in nature and much more could be achieved in supplementing if the monitoring data is shared between such organizations. Central Water Commission, in its 2011 report "Water Quality Hot-Spots in Rivers of India", identifies hot-spot in Sind River due to excessive pH (>8.5) and BOD (>3 mg/l) based on its monitoring data at Seondha station. However there exists a degree of inconsistency on these parameters with CPCB data for 2011.

Apart from such sporadic reports and voluntarily disclosed field observations, monitoring by Water Resources Department itself on a periodic basis is not being done. Lack of monitoring data in suitable period leads to non-identification of the source, reason and magnitude of river pollution. The need for such monitoring is emphasized as without such monitoring, preserving and improving upon river water quality standards is very difficult.

Municipal corporations or the Public Health Engineering department (PHED) monitor water quality at their point of intake and before and after water treatment plant (i.e. before actually supplying the domestic water). The municipalities also have similar monitoring points before and after the sewage treatment plants. Similarly, the industrial water quality is being monitored by the Audyogik Kendriya Vikas Nigam (AKVNs) or Industries themselves at the intake point and at the point of discharge after effluent treatment plant. Water Resources Department too has a Water quality laboratory set up at Gwalior. However, all these agencies/organizations monitor the water quality for different parameters and their frequency of monitoring is also not same.

Sind River is considered to be one of the clean rivers of India. However its tributaries near major towns such as Gwalior are known to be polluted due to sewage disposal. Sind sub-basin is home to some important sanctuaries and national parks; Madhav national park and National Chambal sanctuary, Kuno-Palpur Wildlife sanctuary. The sanctuary houses many varieties of flora and fauna. For protection and sustainability of these rich flora and fauna, it is very important that adequate and suitable quality of water is assured.

Monitoring:

The Central Pollution Control Board (CPCB), a statutory organization, was constituted under the Water (Prevention and Control of Pollution) Act, 1974. It serves as a field office and also provides technical services to the Ministry of Environment and Forests (MoEF). Water quality monitoring is one of the mandates of CPCB. It is the responsibility of CPCB to collect, collate and disseminate technical and statistical data relating to water pollution.

Water quality criteria and classification for different uses has been laid down by the CPCB as given in Table 14.

Table 14: Water quality criteria and classification for different uses

Class of water	Criteria	Designated-Best-Use
A	Total Coliforms Organism MPN/100ml shall be 50 or less	Drinking Water Source without conventional treatment but after disinfection
	pH between 6.5 and 8.5	
	Dissolved Oxygen 6mg/l or more	
	Biochemical Oxygen Demand 5 days 20°C 2mg/l or less	
B	Total Coliforms Organism MPN/100ml shall be 500 or less	Outdoor bathing (Organized)
	pH between 6.5 and 8.5	
	Dissolved Oxygen 5mg/l or more	
	Biochemical Oxygen Demand 5 days 20°C 3mg/l or less	
C	Total Coliforms Organism MPN/100ml shall be 5000 or less	Drinking water source after conventional treatment and disinfection
	pH between 6 to 9	
	Dissolved Oxygen 4mg/l or more	
	Biochemical Oxygen Demand 5 days 20°C 3mg/l or less	
D	pH between 6.5 to 8.5	Propagation of Wild life and Fisheries
	Dissolved Oxygen 4mg/l or more	
	Free Ammonia (as N) 1.2 mg/l or less	
E	pH between 6.0 to 8.5	Irrigation, Industrial Cooling, Controlled Waste disposal
	Electrical Conductivity at 25°C micro mhos/cm Max.2250	
	Sodium Adsorption Ratio Max. 26	
	Boron Max. 2mg/l	

CPCB has set up 2 monitoring stations on river Sind and its tributaries within Madhya Pradesh. The location of these monitoring stations can be seen in the map of Sind Sub basin shown in Figure 57. The water quality (WQ) data at these stations for the year 2011, 2012 and 2013 is available (Source: CPCB website) and analysis is presented in Table 15.

Table 15: Water quality status (Source: CPCB website)

S.No	WQ Station	River	Year	BOD (mg/l)	COD (mg/l)	Conductivity (µmhos/cm)	DO (mg/l)	Nitrate (mg/l)	pH	SAR	TDS (mg/l)	CLASS (as per CPCB)
1	Tighra Reservoir	Sank	2011	1.9	NA	693	7.7	0.4	8	NA	NA	A
			2012	1.9	44.6	585	8.2	0.7	7.6	0	204	A
			2013	2.3	58.7	567	7.7	0.5	7.9	0	370	B
2	Dabra	Sind	2011	2	NA	897	8	0.3	7.6	NA	NA	A
			2012	2.2	48.6	450	8	0.7	7.6	0	306	B
			2013	2.2	74	652	8.3	0.5	7.6	0	399	B

The above data has been analyzed and results are discussed below:

a. The water quality parameters being monitored are: Temperature, pH, Conductivity, Dissolved Oxygen, BOD, COD, Nitrate and Sodium Adsorption Ratio (SAR).
b. It is observed that there is slight increase in the BOD value in the year 2013 at both Tighra and Dabra stations (Figure 58). Due to this the class of water at both stations changed from A to class B in 2013.
c. However, DO levels at both these stations are observed to be above 6mg/l for all three years (Figure 59).
d. pH values are within the acceptable range at both stations for all years. Electrical conductivity and nitrate levels are also within the acceptable limits at both the stations.
e. Data gaps are found during 2011 in both stations with respect to parameters such as COD, TDS and SAR.

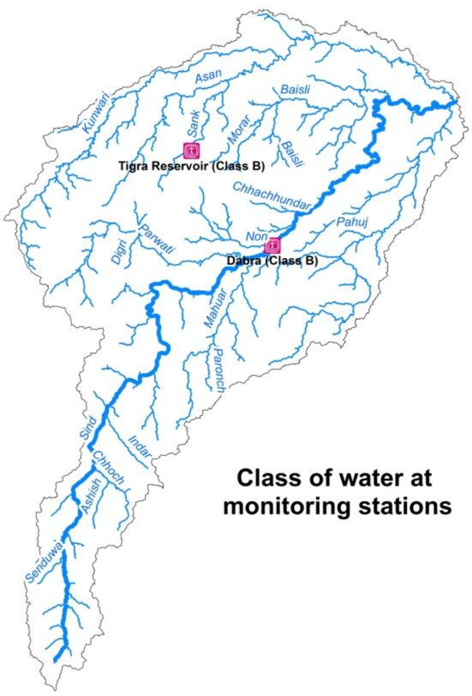


Figure 57: Class of Water at WQ Monitoring Stations

There is also an increase in the total dissolved solids from 2012 to the year 2013. The TDS however is still less than permissible limit of 500 mg/l.

Conclusion:

The water quality monitoring results from 2011 to 2013 are analyzed with respect to indicator of oxygen consuming substances (Bio-chemical Oxygen Demand). They indicate that there is a little organic and bacterial contamination in water bodies which may be due to discharge of partially treated domestic wastewater from nearby towns. However, due to absence of any major town and industry near these stations, the situation is not alarming. The water from Tighra reservoir is used to meet drinking water needs of Gwalior city. Hence, deterioration in quality from Class A in 2011 to Class B in 2013 is a matter of concern. It is important to control further deterioration and restore the water at Tighra to Class A, so that it is fit for drinking purposes.

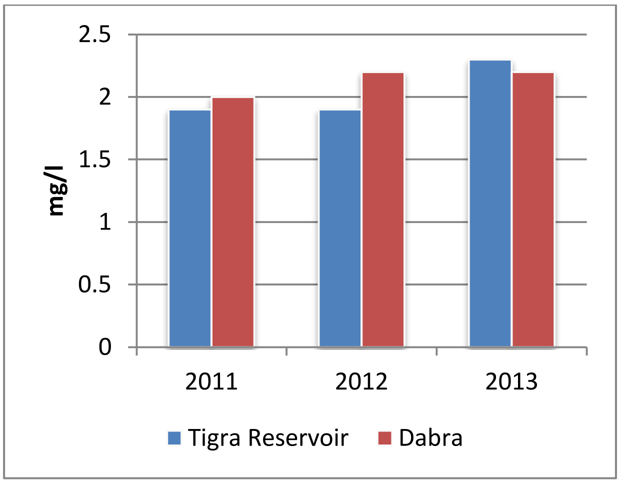


Figure 58: Variation in BOD from 2011 to 2013

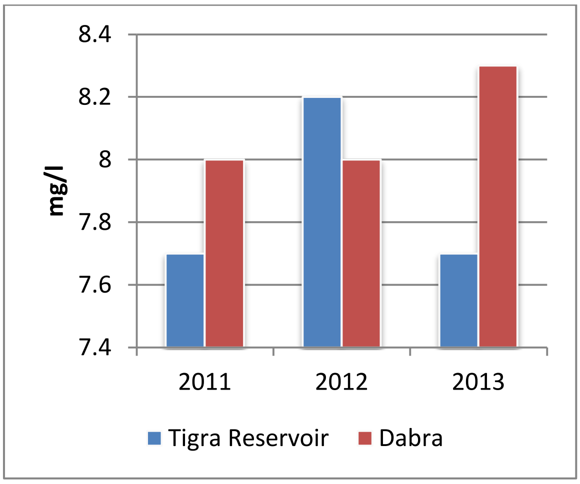


Figure 59: Variation in DO from 2011 to 2013

There are not enough monitoring stations on Sind River and its tributaries to give idea of water quality of the entire sub basin. Gwalior is a major city within the Sind sub basin but there is no monitoring station at or near this town. The quality of water does not vary much between the two stations implying there is no major polluting industry or town between these two stations.

Only limited basic parameters are being measured at these stations. Some other important parameters like Fecal and Total Coliform, Chlorides, Phosphates, etc. also need to be monitored. The data available shows only mean annual values of the water quality parameters. The seasonal variation in these parameters needs to be studied. The frequency of monitoring at both the stations is not consistent.

Water Quality - Ground Water

Ground water is the main source of irrigation and drinking water supply in most part of the Sind sub-basin. About 56% of the total irrigation is either through dug well or tube wells. Most of the population within the basin does not have access to piped water supply and is therefore dependent on ground water for their drinking and other domestic needs. The population uses ground water directly without any pre treatment. Contamination of ground water can prove to be hazardous to the human health. Hence it is very essential to have a effective groundwater quality monitoring system. The Bureau of Indian Standards has prescribed desirable and permissible limits of various parameters for drinking water are shown in Table 16.

Table 16: Water quality standards for drinking water ***As per Bureau of India Standards***

S.No.	Characteristic	Requirement (Acceptable Limit)	Permissible limit in the absence of Alternate source
1	Colour (Hazen Units, Max)	5	15
2	Odour	Agreeable	Agreeable
3	pH Value	6.5-8.5	No relaxation
4	Taste	Agreeable	Agreeable
5	Turbidity (NTU,Max)	1	5
6	Total Dissolved Solids (mg/l, Max)	500	2000
7	Calcium as Ca (mg/l, Max)	75	200
8	Choride as Cl (mg/l, Max)	250	1000
9	Fluoride as F (mg/l, Max)	1	1.5
10	Iron as Fe (mg/l, Max)	0.3	No relaxation
11	Magnesium as Mg (mg/l, Max)	30	100
12	Nitrate as NO_3 (mg/l, Max)	45	No relaxation
13	Total Hardness as $CaCO_3$ (mg/l, Max)	200	600
14	Sulphate as SO_4 (mg/l, Max)	200	400
15	Total Alkalinity (mg/l, Max)	200	600
16	Electrical Conductivity (micromhos/cm at 25^0 C)	100-250	750
17	BOD 5 days at 20^0C (mg/l, max)	2	2
18	COD (mg/l, max)	10	10
19	Dissolved Oxygen (mg/l, min)	6	6
20	Sodium (mg/l, max)	60	120
21	Boron (mg/l, max)	1	5

Central Ground Water Board (CGWB) under Ministry of Water Resources is the national agency entrusted with the responsibilities of providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of ground water resources in India. In Madhya Pradesh, the periodic monitoring of ground water quality from wells aquifers in different blocks done by CGWB in association with the State Water Resources Department and ground water board.

Monitoring:

Currently, ground water quality data for all districts within the Sind sub-basin is available from year 2007 to 2013[19]. The data has been analyzed with respect to the permissible limits for drinking water as per and following are the observations:

a. There are adequate numbers of GW quality monitoring stations within a district and they succinctly represent the characteristics of entire aquifer within that district.
b. Major water quality parameters being measured are pH, Nitrate, total hardness, chloride, fluoride, calcium, alkalinity, potassium, magnesium, carbonates, bicarbonates, Electrical conductivity and Sodium Adsorption ratio.
c. The most common parameters used for determining the irrigation water quality, in relation with its salinity, are EC and TDS. The parameter used to determine the sodium hazard is SAR - Sodium Adsorption Ratio.
d. Monitoring is being done bi-annually at all locations mostly in pre monsoon and post monsoon period.

The variation in different water quality parameters across different districts of the Sind sub basin is shown in Figure 60 to Figure 65.

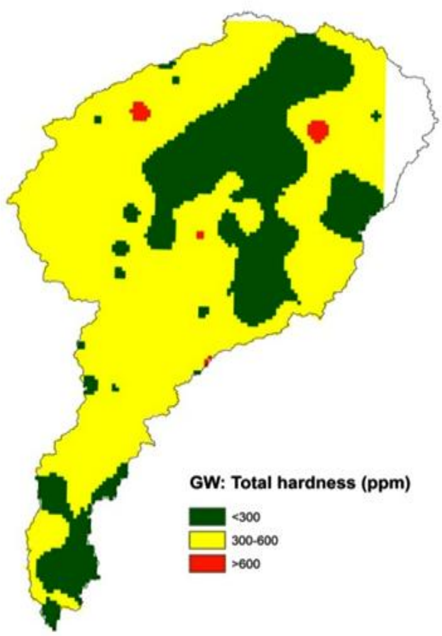


Figure 60: Groundwater Quality-Total hardness (PPM)

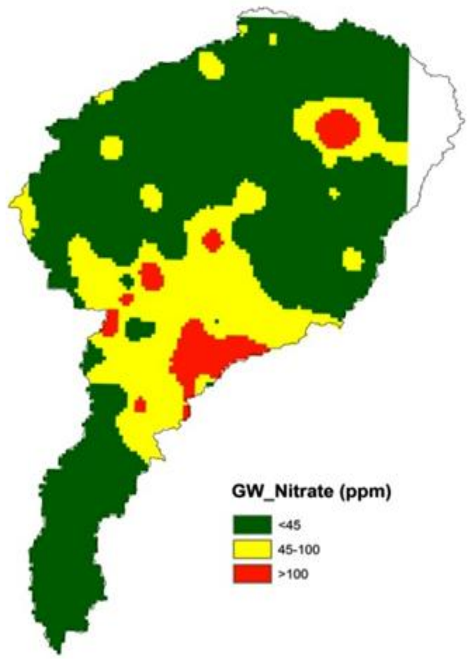


Figure 61: Groundwater Quality - Nitrates (ppm)

[19] Central Ground Water Board

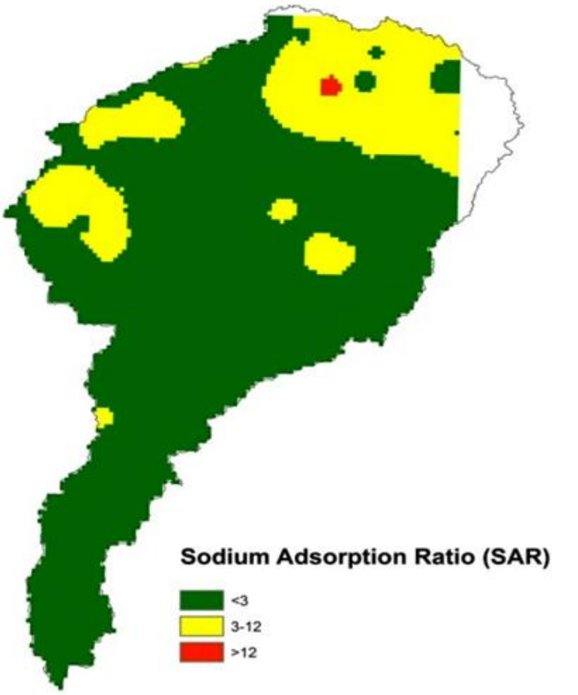


Figure 62: Ground water quality - Sodium Adsorption Ratio (SAR)

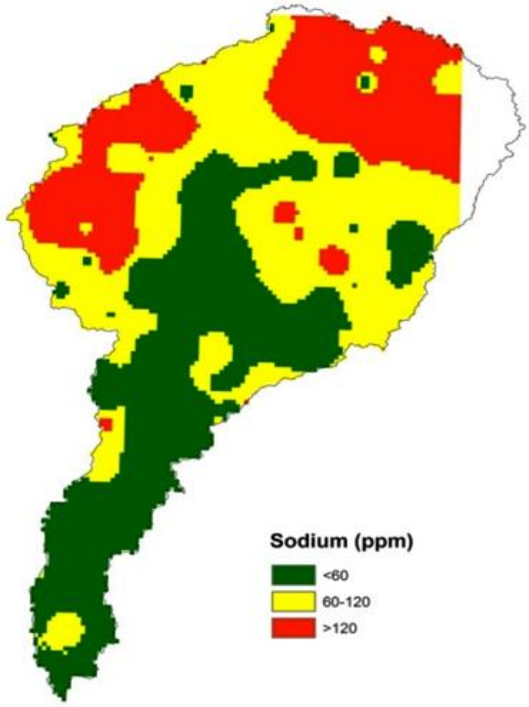


Figure 63: Ground water quality- Sodium in ppm

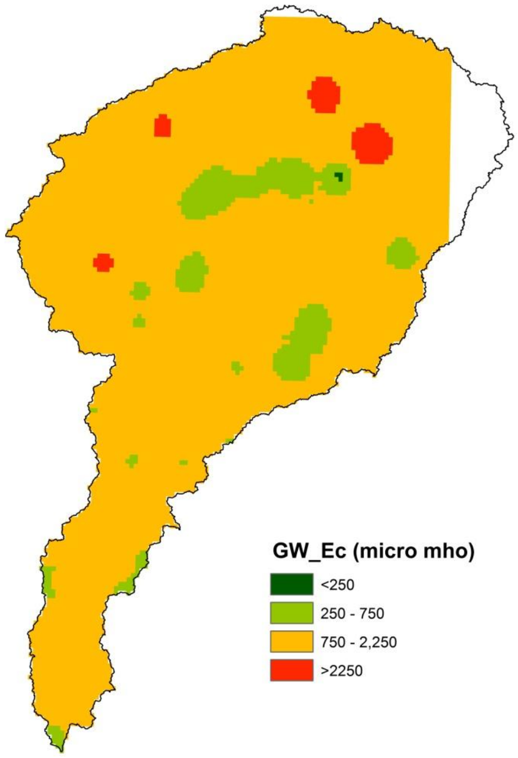


Figure 64: Ground water quality - Ec in micro mho

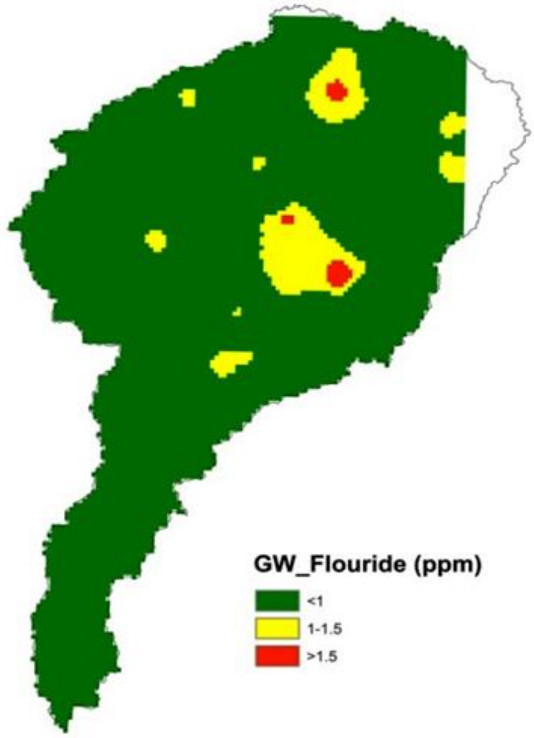


Figure 65: Ground water quality - Fluoride in ppm

Areas marked in red represents the block where a particular parameter has exceeded permissible limits for drinking water as set by Bureau of India Standards (BIS).

a. It is observed that pH is within the permissible range of 6.5-8.5 in entire basin except in Pohri block of Shivpuri district and Guna block of Guna district. The pH value at these two places is below 6.5.
b. Total hardness is observed to be more than 600 ppm in Gohad block of Bhind and Joura block of Morena district. It is within acceptable limits in remaining basin.
c. Calcium and Magnesium ion concentration is within the permissible limits set by BIS in almost entire Sind sub-basin except a few patches in Morena district and Gohad block of Bhind district.
d. Shivpuri, Bhind and Gwalior districts have nitrate concentration of more than 45 mg/l in their ground water. Though, the major concern is exceedingly high values (more than 100 mg/l) in certain blocks such as Pichhore, Shivpuri, Gohad and Dabra.
e. Fluoride content in excess of 1.5 mg/l is observed in Narwar and Karera blocks of Shivpuri district, Gohad block of Bhind and Dabra of Gwalior district thus making it unsuitable for drinking.
f. Electrical conductivity as high as 3000 micromhos/cm is observed in Bhind, Sheopur and Guna districts. Water with such high EC values is unsuitable for irrigation purposes.
g. Sodium Adsorption Ratio (SAR) is in excess of acceptable limit of 12 in Gohad block of Bhind district.

Conclusion:

Analysis of ground water quality data within the Sind sub-basin reveals that overall quality of ground water is within the permissible limits set up by BIS, except in some pockets of the Sind sub-basin. The major areas of concern are:

4. Gohad block of Bhind district where most of the parameters such as hardness, calcium, magnesium, nitrate, EC and SAR are outside permissible limits.
5. Parts of Shivpuri where fluoride and nitrate concentration is high.
6. Hard water with high concentration of calcium and magnesium ions is found in parts of Gohad block of Bhind district and Joura block of Morena district.

Socio Economic System (SES)

The integrated water resources management and water use efficiency planning is an essential element of IWRM. The success of IWRM planning depends on the institutional and human resources capacity and awareness.

According to Loucks et al (2005) conceptualization the SES mainly includes water-using and water-related human activities. The main consumptive uses in Sind sub-basin are domestic, agriculture and industries, whereas the fisheries and hydropower are non-consumptive users.

Demography:

Demography data is important for basin level studies and planning. Census data represents one of the most important components of the information system and serve as the basis for many other statistical activities related to food, agriculture, education and infrastructure. Census data is also important for agriculture & infrastructural development planning and formulation of policies. Census data 2011 has been used for analyzing the demography, socio-economic system of Sind sub-basin.

Population:

As per Census 2011, total population of the Madhya Pradesh is 72 million (in 2011). The decadal population trend of Madhya Pradesh from 1901 is shown in Figure 66. The total population of Sind sub-basin is 7,687,394. The district wise share of population is shown in Figure 67. The population density of Sind sub-basin is 295 per km^2.

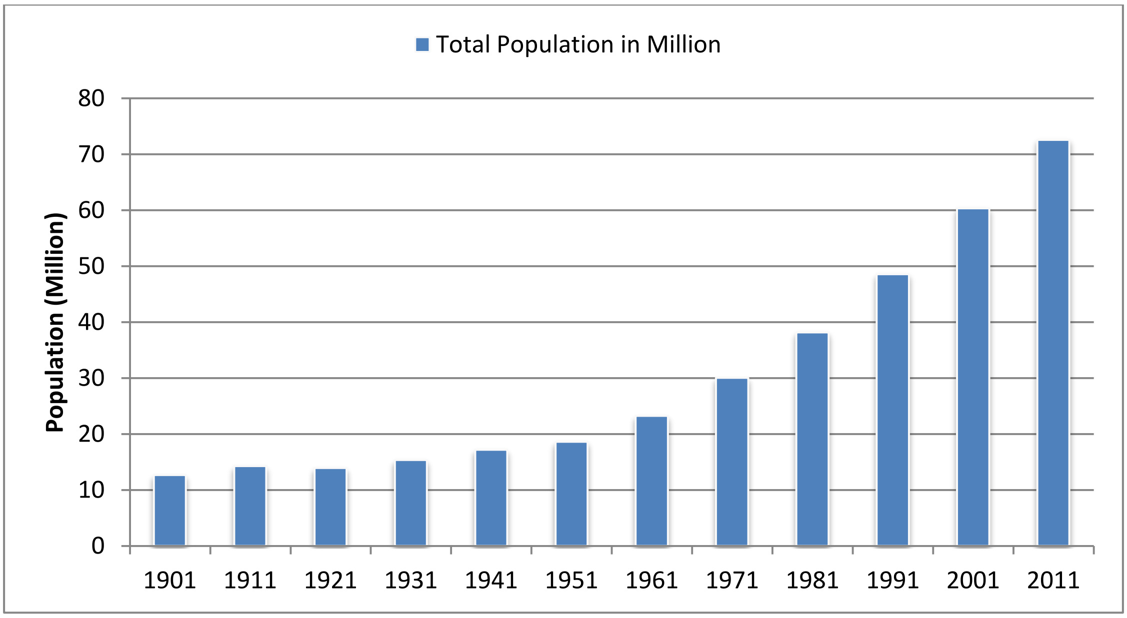


Figure 66 : Population Trend in Madhya Pradesh (Source: Census of India)

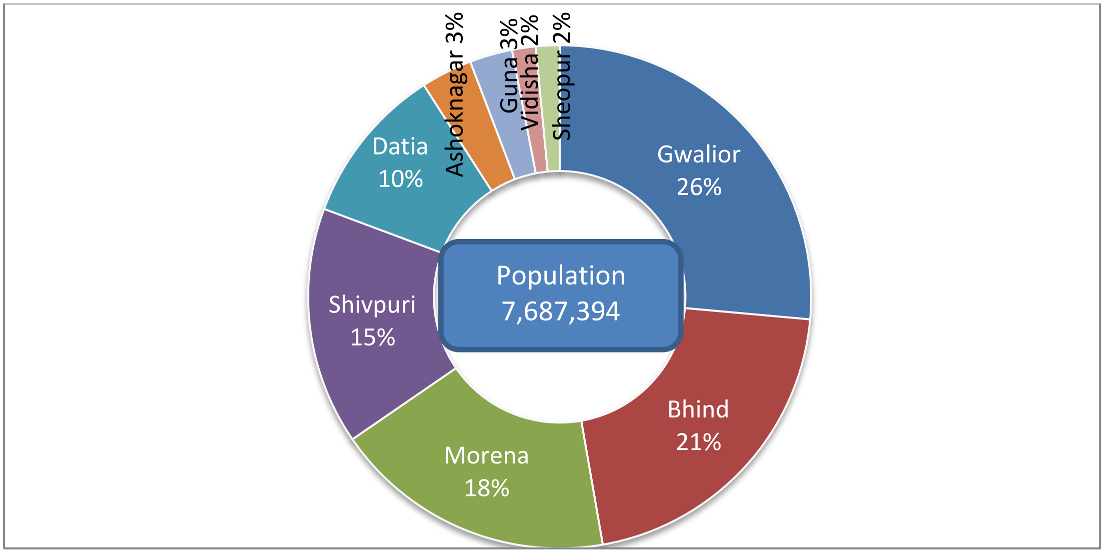


Figure 67 : **District wise share of Population in Sind sub-basin**

Population density is represented as person per square kilometer. Most densely populated city or district shares relatively small area with population of the area drawing also on rural resources outside the area. In Sind sub-basin, Gwalior district has the highest population density whereas the Sheopur district has lowest density (Figure 68).

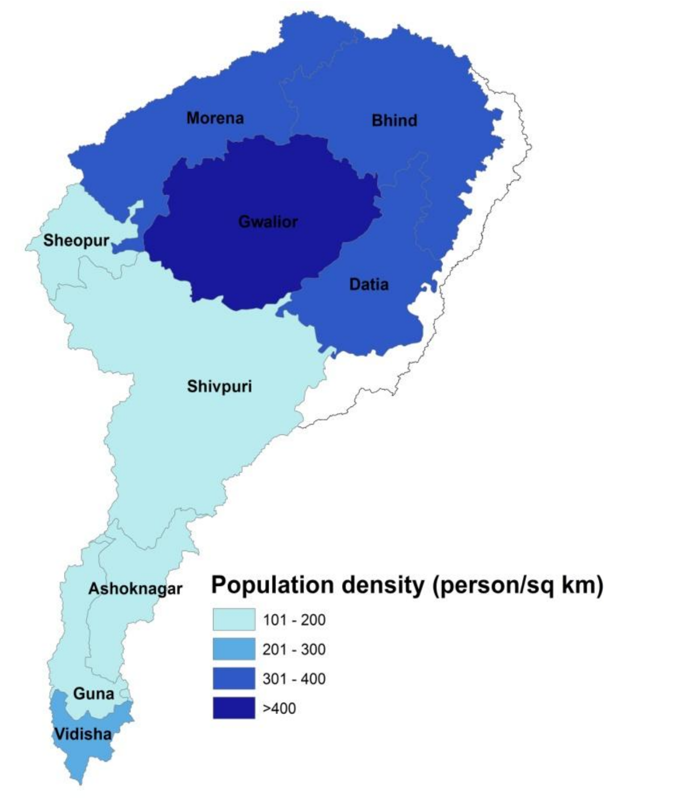


Figure 68: District wise population density of Sind sub-basin

Urban and rural population:

As per census 2011, the majority of the population (72.37%) of Madhya Pradesh state live in rural areas. Rural areas are dominant of agricultural activity. In Sind sub-basin, the percentage of rural population is 66.93%. The analysis of census data from 1901 to 2011 of Madhya Pradesh shows a rapid increase in urban population and decrease in rural population (Figure 69). This is mainly due to migration for better living standard in urban areas.

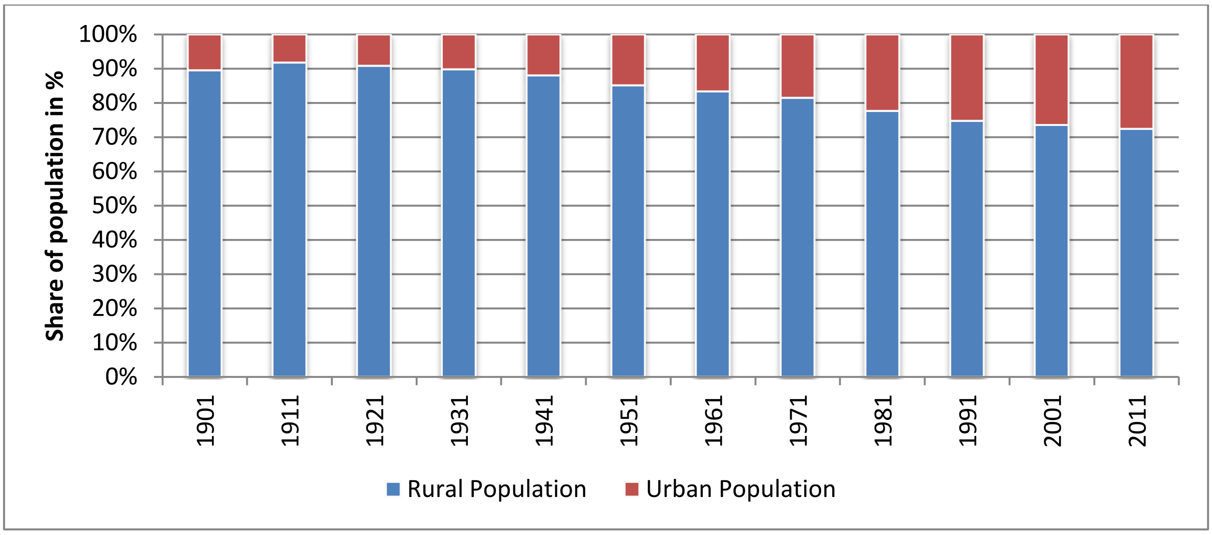


Figure 69 : **Trend of Urban and Rural Population in Madhya Pradesh**

The Population growth in urban area is mainly due to infrastructure development. Lack of development and insecurity in agriculture returns is responsible for migration from rural areas to urban areas. In rural areas, often small family does farming. It is quite difficult to improve living standard. Farming is dependent on unpredictable environmental conditions.

With the improvement in opportunities for jobs, education, housing and transportation; urbanization occurs naturally. Living in urban area gives advantage of the opportunities of diversity and competition of market. There are more and variety of job opportunities, better health facilities. Due to increased mechanization in farming, many labourers become out of work and results in migration to urban areas.

Apart from this, migration from smaller cities to bigger cities is continuing along with the migration from rural to urban areas besides an increasing natural population pressure. This is leading to serious shortages of power, water, sewerage, housing, transportation and communication along with the increase in pollution, poor public health, unemployment and poverty.

The understanding of the past and current urbanization process leads to prediction of future requirement, preparedness and hence for urban planning.

Approximately 33% of population lives in urban area and 67% in rural area in Sind sub-basin in the Year 2011. District wise urban and rural population as per Census 2011 is shown in

Table 17. The distribution of Urban population in Sind sub-basin is shown in Figure 70 which shows that the urban population is concentrated in Gwalior, Bhind and Morena district. On the other hand, the rural population is well distributed over Gwalior, Bhind, Morena, Shivpuri and Datia district of Sind sub-basin (Figure 71).

Table 17: District wise population in Sind sub-basin (Census 2011)

S.No.	District	Population in basin	Population in basin	
			Urban	Rural
1	**Ashoknagar**	253,521	46,105	207,416
2	**Bhind**	1,600,825	406,947	1,193,878
3	**Datia**	786,754	181,982	604,772
4	**Guna**	211,058	53,155	157,903
5	**Gwalior**	2,032,036	1,273,792	758,244
6	**Morena**	1,395,839	334,028	1,061,811
7	**Sheopur**	116,936	18,250	98,687
8	**Shivpuri**	1,173,714	200,888	972,826
9	**Vidisha**	116,710	27,169	89,541
	Total	**7,687,394**	**2,542,316**	**5,145,078**

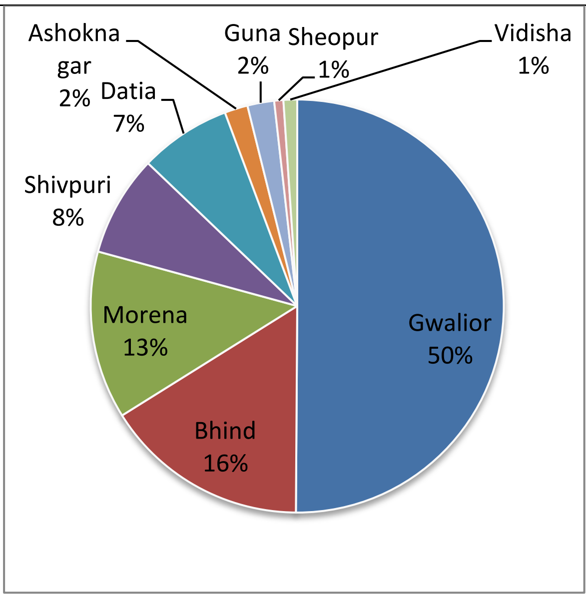


Figure 70: Distribution of Urban Population

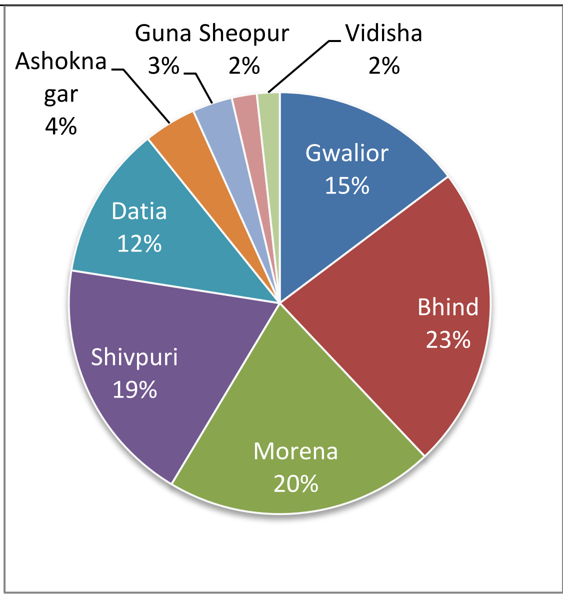


Figure 71: Distribution of Rural Population

Agglomerations & Cities

An urban agglomeration is a continuous urban spread constituting a town and its adjoining outgrowths (OGs), or two or more physically contiguous towns together with or without outgrowths of such towns[20]. An Urban Agglomeration must consist of at least a statutory town and its total population (i.e. all the constituents put together) should not be less than 20,000 as per the 2001 Census. In varying local conditions,

[20] http://www.citypopulation.de/India-MadhyaPradesh.html

there were similar other combinations which have been treated as urban agglomerations satisfying the basic condition of contiguity.

There are 8 urban agglomerations in Sind sub-basin. Population of these urban agglomerations is given in Table 18. The agglomeration rate in last decade is shown in Figure 72. Gwalior has the highest agglomeration, as compare to other districts but rate of increase of agglomeration from Year 2001 to 2011 is highest in Ashoknagar i.e. 42 % in comparison to other districts. The lowest agglomeration is observed in Sheopur of 71,951 and lowest rate of agglomeration from year 2001 to 2011 is in Datia i.e. 21 %. There are 3 Districts in Sind sub-basin which shows an increase in rate of agglomeration from last two decades namely Morena highest 30% than Gwalior and Ashoknagar while other shows negative trend from last two decades. The average rate of increase of agglomeration from 2001 to 2011 of Basin is 28% which is higher than that of MP i.e. 24% and the contribution of basin in total agglomeration of MP is 13.36% in Year 2011 and which is almost constant from last two decades.

In context to Sind sub-basin plan, increase in agglomeration means increase in water demand as urban water requirement is more than rural water requirement and already water requirement increases day by day with increase in population. The rapid growth of urban centers will place tremendous stress on the environment and pose formidable problems of social and institutional change, infrastructure development, and pollution control. Water will be one of the key resources for sustainable urban development. It is needed for virtually every human endeavor – for household use, agriculture, industry, leisure – and water also has an important ecosystem function. Provision of sufficient water and preventing pollution, however, are formidable tasks.

Table 18: Urban agglomeration population

Urban Agglomeration	Urban agglomeration population		
	Year 1991	Year 2001	Year 2011
Bhind	109,755	153,752	197,585
Datia	64,477	82,755	100,284
Guna	100,490	137,175	180,935
Gwalior	717,780	865,548	1,117,740
Morena	147,124	150,959	200,482
Sheopur	39,047	58,342	71,951
Shivpuri	108,277	146,892	179,977
Vidisha	92,922	125,453	155,951
TOTAL	**1,422,010**	**1,778,581**	**2,286,733**

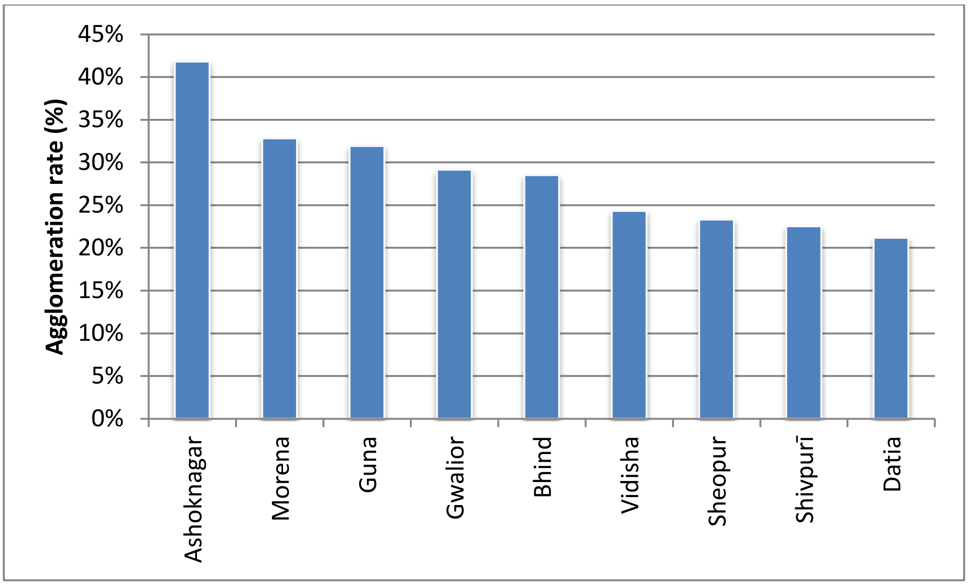


Figure 72: District wise agglomeration rate in last decade (2001-2011)

Sex Ratio:

The sex ratio is defined as the number of females per 1000 males. According to the Census 2011, the sex ratio of Madhya Pradesh is 931. This is quite an improvement from the 2001 Census, which recorded 920 females per 1000 males. In Sind sub-basin also, sex ratio has increased from census year 2001 to 2011. The sex ratio of Sind sub-basin is 878 in comparison to 931 of the state. District wise sex ratio in Sind sub-basin is shown in Figure 73.

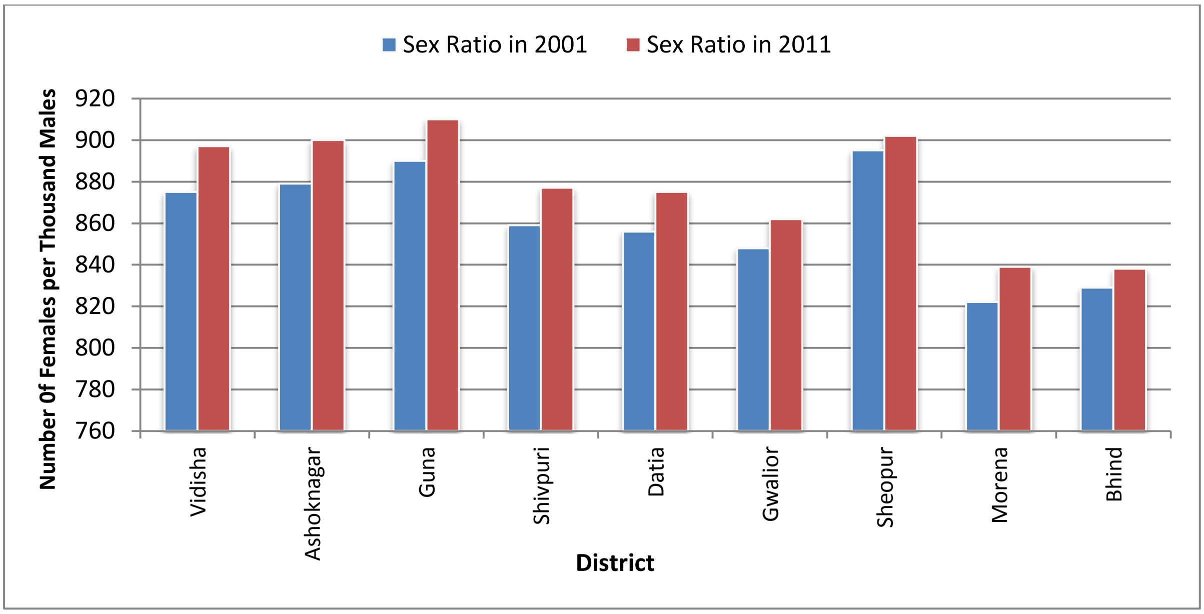


Figure 73: **Sex Ratio in Sind sub-basin**

Growth rate:

Population decadal growth helps in planning for infrastructure development and also scenario generation for population estimation. The decadal growth rate in Madhya Pradesh state is shown in Figure 74. District wise comparison of growth rate in the year 2001 and 2011 is shown in Figure 75. Gwalior, Morena and Bhind districts shows increase in decadal growth from 2001 to 2011.

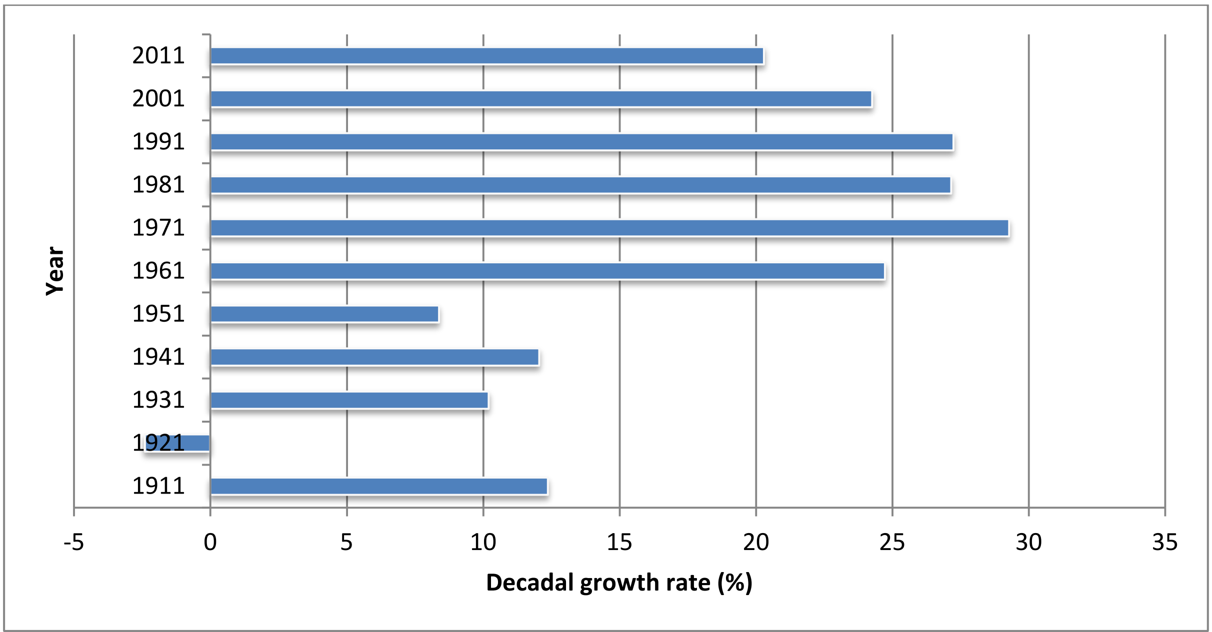


Figure 74 : **Decadal Growth Rate of Madhya Pradesh**

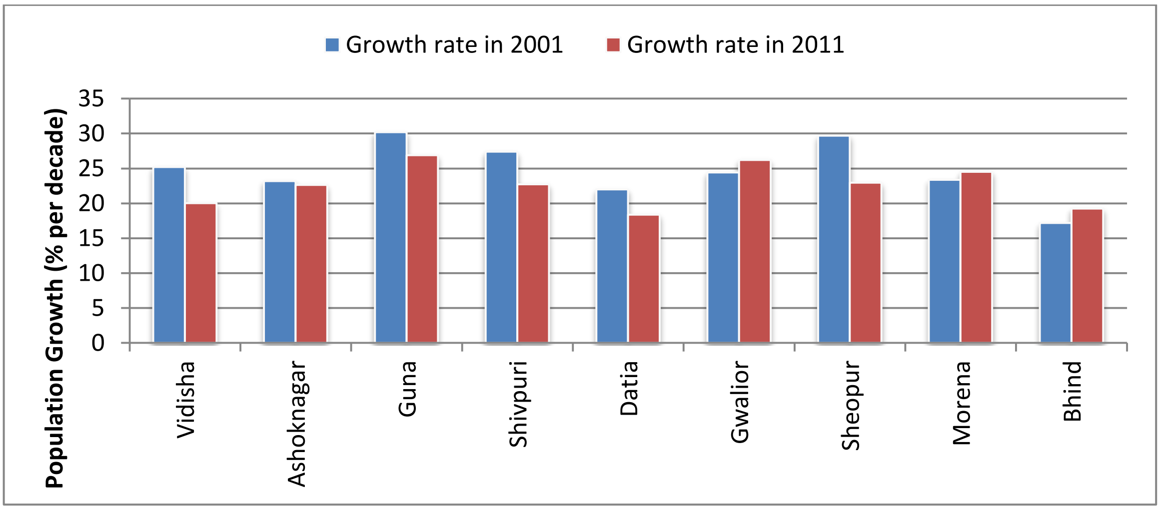


Figure 75 : District-wise Growth Rate in Sind sub-basin

Literacy rate:

Literacy rate in the Sind sub-basin has increased in last decade. District wise literacy rate is shown Figure 76. The literacy rate of MP is 59% whereas literacy rate of basin is 70% which is quite good than state percentage.

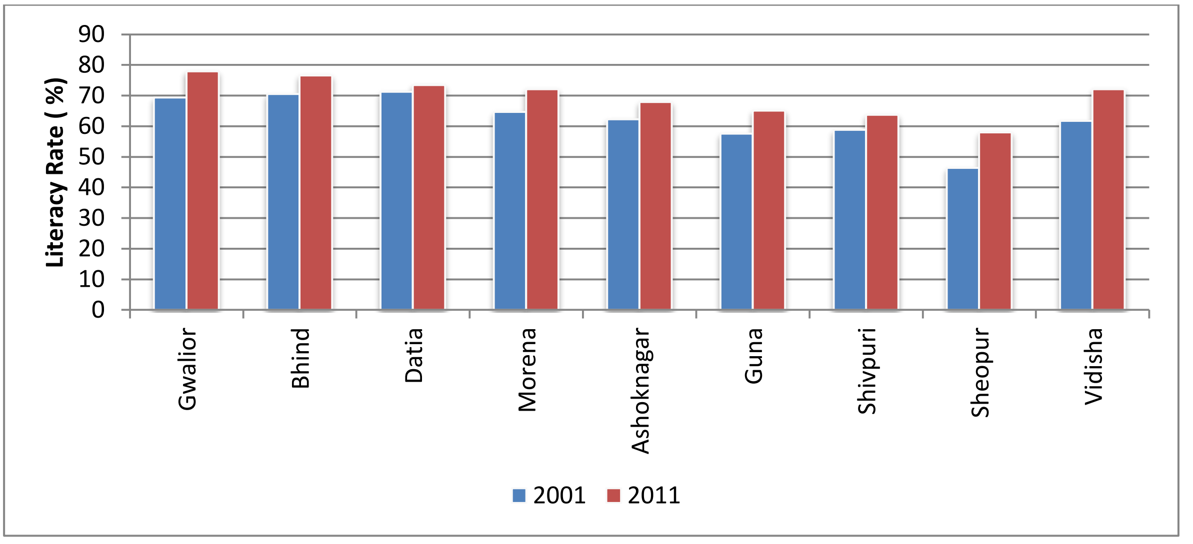


Figure 76 : **Literacy Rate in Sind sub-basin**

Main and Marginal Workers:

Participation in any economically productive activity can be termed as 'Work' and the persons engaged in 'work' are called workers. As per Census of India, workers who had worked for 6 months or more of the 'reference period' are termed as Main Workers and who had not worked for the major part of referenced period, but have worked are termed as Marginal Workers. For determining a person as main worker or marginal worker, the reference period is taken as one year. As per Census 2011, in Sind sub-basin there are 27,65,572 workers, out of which 23,30,894 Main worker, 4,34,678 Marginal workers. District wise distribution of workers in Sind sub-basin is shown in Figure 77.

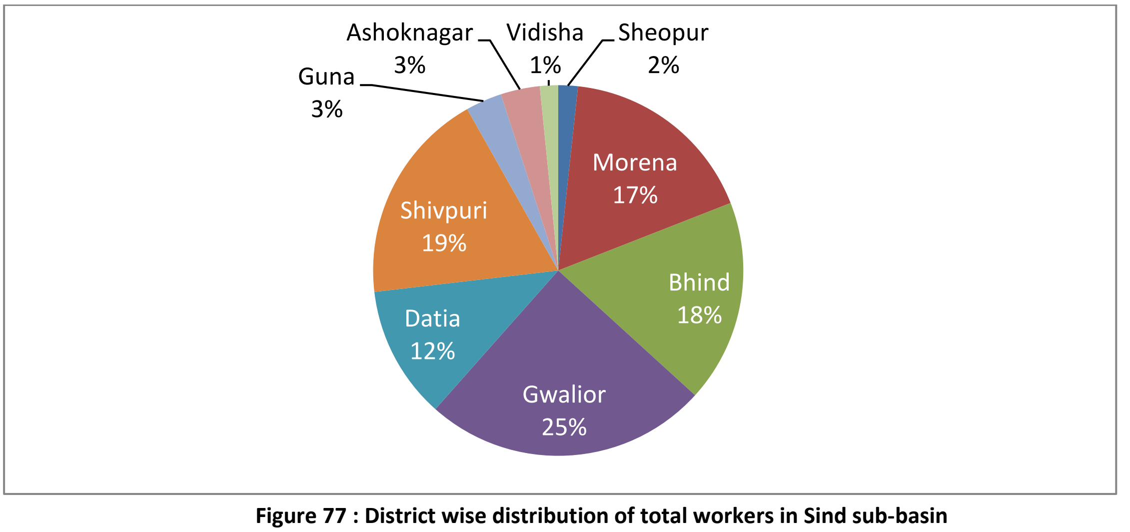


Figure 77 : District wise distribution of total workers in Sind sub-basin

Cultivator and Agricultural Labourer:

A cultivator is a person who is engaged in cultivation of owned/shared/rented land and the person who works on land of the cultivator is termed as Agricultural labourer. As per Census 2011 the distribution of cultivators and agricultural labour in the basin are shown in Figure 78 & Figure 79.

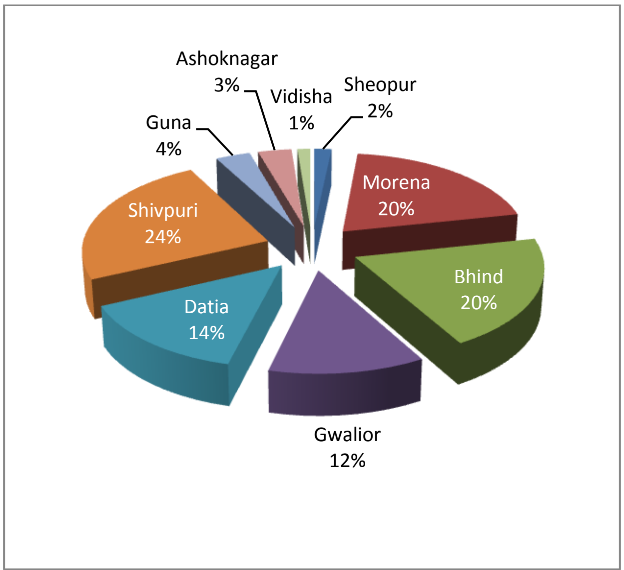


Figure 78 : **Distribution of Cultivators in Sind sub-basin**

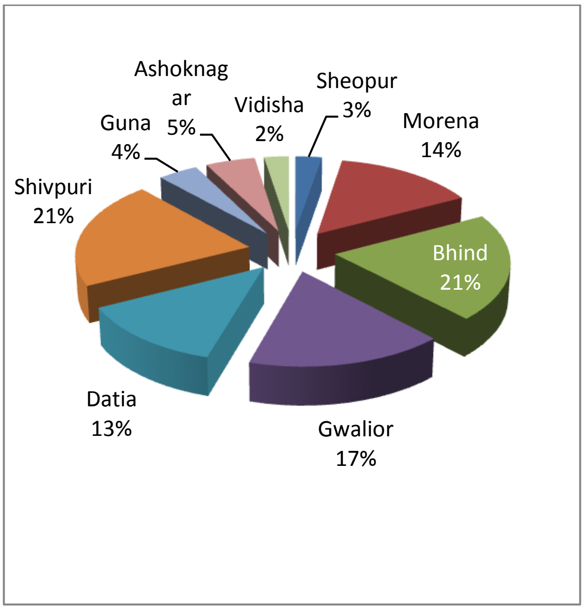


Figure 79 : **Distribution of Agricultural Labourer**

Land Holding Pattern:

As per the Agriculture Census 2001 of Madhya Pradesh published by Department of Land Records, approximately 59% agriculture area in Sind sub-basin are having 2 to 10 ha field size and 29% area are with less than 2 ha field size (Figure 80). In terms of number of fields, approximately 68% number of fields have size less than 2 ha (Figure 81). District wise land holding pattern is given in Table 19.

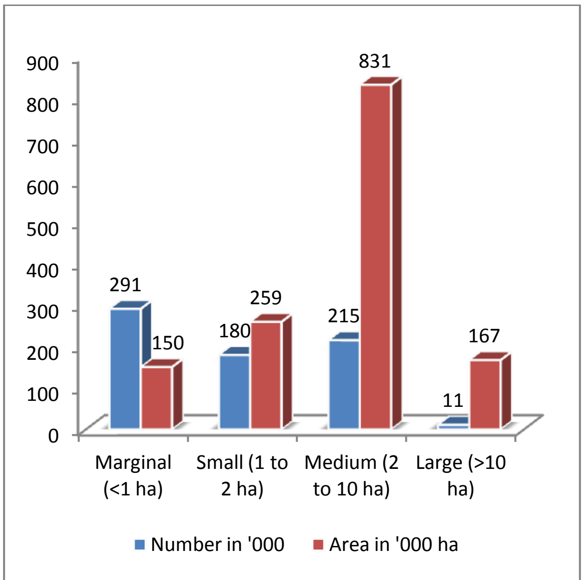


Figure 80 : Land Holding Pattern of basin in numbers

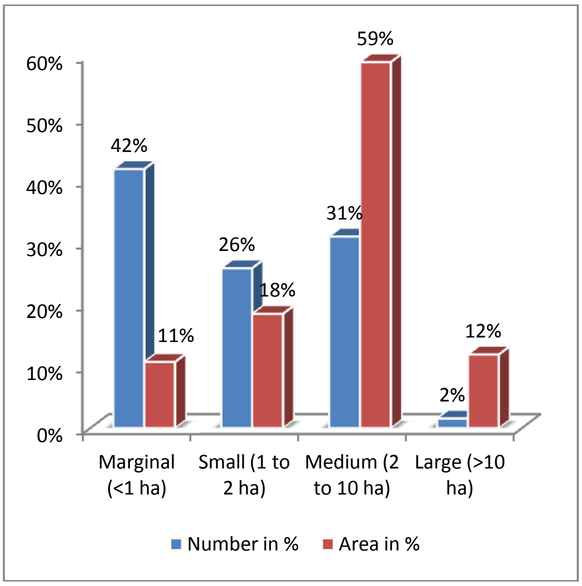


Figure 81: Land Holding Pattern of basin in %

Table 19: Land Holding Pattern in Sind sub-basin

Sno	District	Marginal		Small		Medium		Large	
		(below 1 hect.)		(1 to 2 ha)		(2 to 10 ha)		(10 ha. & Above	
		Number	Area	Number	Area	Number	Area	Number	Area
1	Bhind	74,383	37,772	39,260	57,704	51,772	204,802	1,941	26,781
2	Datia	41,309	20,749	25,804	37,522	33,839	130,542	1,662	23,940
3	Guna	12,541	6,799	11,645	17,022	15,743	62,088	1,223	19,904
4	Gwalior	47,831	23,843	28,434	40,948	31,698	123,337	1,867	30,957
5	Morena	65,409	33,834	30,486	43,767	28,846	103,551	725	11,136
6	Sheopur	4,591	2,615	4,846	6,743	4,481	15,999	104	1,488
7	Shivpuri	42,121	23,348	36,260	51,787	43,653	168,581	2,368	37,261
8	Vidisha	2,562	1,287	2,775	3,921	5,008	22,455	883	15,542
	Total	**290,747**	**150,247**	**179,510**	**259,415**	**215,041**	**831,355**	**10,773**	**167,009**

Livestock Population:

Livestock refers to domestic animals raised in an agricultural setting to produce commodities such as food and work. Livestock census is done by Department of Animal Husbandry, Ministry of Agriculture. District wise Livestock population in basin is shown in Figure 82.

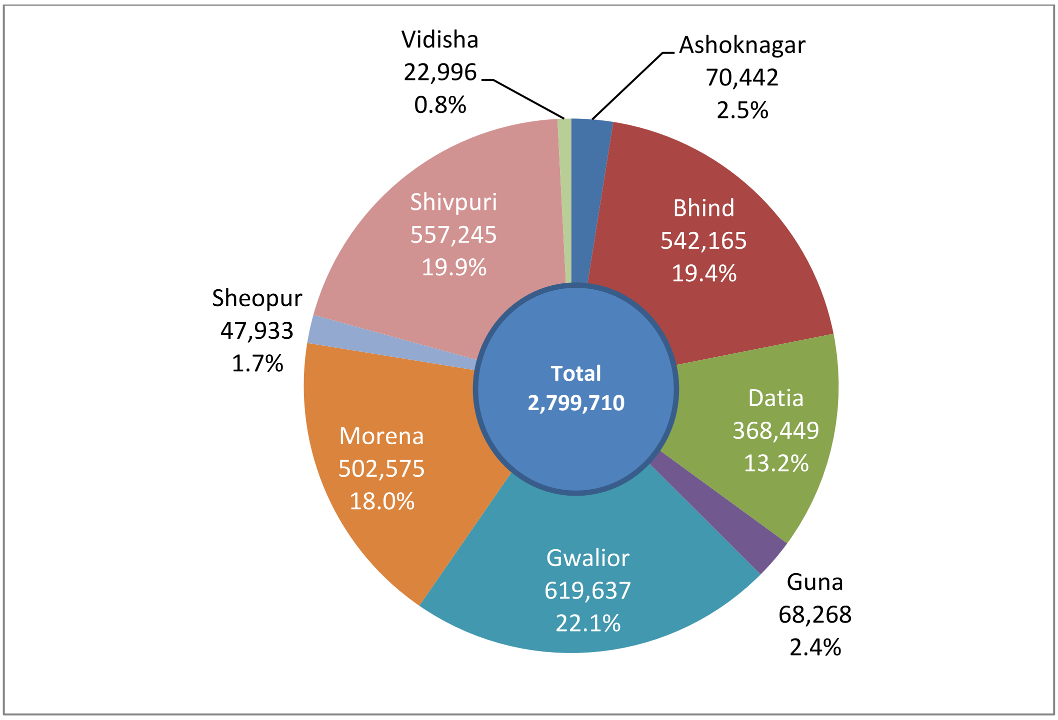


Figure 82 : **District wise Livestock Population in Sind sub-basin**

Domestic Water & Sanitation:

Domestic Water

Sind sub-basin comprises of 9 districts out of which 5 lie almost entirely within the basin. Total population in the basin is 7,687,393 out of which 5,145,078 is rural and 2,542,316 is urban. The major towns within Sind sub-basin are Gwalior, Datia, Shivpuri, Bhind and Morena comprising of a population of 1,877,896.

There are 51,533 villages with 127,559 habitations in the state[21]. Domestic water supply of these villages is looked after by the Gram Panchayat and Public Health Engineering Department. Presently the domestic water need in most of the urban and rural area is met from ground water sources. In most of the cities and towns, the water is supplied intermittently to the houses through pipes from overhead water storage, which is provided on flat monthly charge basis. There are public taps which provide free of charge water to economically weak section of the society. In most of the rural area, domestic need of water is met by means of hand pumps. The present domestic use in rural area is estimated to be 45 lpcd.

In April 2009 Government of India has launched National Rural Drinking Water Programme (NRDWP) with specific goal to ensure every rural person has enough safe water for drinking, cooking and other domestic needs as well as livestock throughout the year including during natural disasters, by the year 2022[22].

There are 5 major cities/ towns in Sind sub-basin. The City Development Plan (CDP) of these districts has been prepared by the Urban Development Department of Madhya Pradesh. The present domestic water supply of these cities/ towns has been used for estimating the future domestic water demand. The present domestic water supply in these cities ranges from 40 lpcd to 76 lpcd.

The future water demand for domestic use has been estimated on the basis of the projected population. The per capita demand in 2021 is considered as 100 lpcd and for the year 2031 is 135 lpcd. The CDPs also have mentioned target to provide 135 lpcd in the year 2031.

On the basis of population, present domestic water demand for urban and rural area of Sind sub-basin is estimated to be 199 MCM/year.

[21] http://indiawater.gov.in/IMISReports/NRDWPDistrictMain.aspx?APP=IMIS&IState=017&StName=MADHYA%C2%A0PRADESH
[22] *NRDWP guideline 2013*

Extracts from City Development Plans[23] (Urban Areas only):

***Gwalior**: Gwalior is the biggest and most populated city of the Sind sub-basin. The main source of water for the city is Tighra dam located on Sank River. The water supply is further supplemented by supply from reservoir of the Kaketo dam on Parwati River. The total water available from these two reservoirs is 146 MLD. The city also uses significant amount of ground water extracted through bore wells and hand pumps.*

There are two water treatment plants each of capacity 77 MLD and 68 MLD at Motijheel (Gwalior). The treated water is then supplied to city through a distribution system by Municipal Corporation. Out of about 145000 household in the city, only 61% households have domestic water supply connections. These connections are un-metered. The condition of distribution network is also poor and a loss as high as 45% has been reported. The actual amount of water reaching households is only 79MLD out of total supplied quantity of 145 MLD. The city development plan proposes repairs in the old network and 100% coverage within the city by the year 2021.

***Shivpuri:** Shivpuri is an important tourist destination in Sind sub-basin. The famous Madhav National park lies within Shivpuri district. Madhav Sagar lake is the main source of water supply for the city. Water from the lake is directly pumped into the water treatment plant. Capacity of WTP is 5MLD, whereas total water supply is 9MLD. The remaining 4MLD is supplied from ground water through tube wells and hand pumps. The distribution network covers only 50% of the total population of the town and per capita supply is about 47LPCD. Total number of connections are 12885 including domestic, commercial and industrial connections. A new water supply scheme is under construction wherein 100% coverage is proposed.*

***Datia:** Datia is a prominent religious centre and heritage city in the Sind sub-basin. 18% of the total population lives in slums. The primary source of water supply is Ram Sagar Lake and Anguri barrage. Approximately 6.2MLd water is supplied against a current demand of 10 MLD. Rest is met through wells and hand pumps. The per capita water supply is about 65LPCD as against the standard minimum of 135 LPCD. There is a water treatment plant of 5MLD capacity which treats water pumped from Ram Sagar Lake and Anguri barrage. However water from tubewells is not treated. There are 8436 household connections in Datia city.*

***Bhind:** Bhind town has nearly 24000 households. Out of which 78% houses have tap water connection. Ground water is the only source of water supply in Bhind. Water pumped from tube wells is chlorinated and then supplied to the town. There is no water treatment plant. The total water supplied by Municipality is 18.9 MLD which is almost at 106 LPCD.*

***Morena:** Morena city is very close to Gwalior. The water supply here is entirely dependent on ground water. Water is supplied through 65 bore wells and 495 hand pumps. The water is not treated before distribution. In all, 9884 households and 102 commercial connections are there. The connections are unmetered and tariff is minimum flat rate of INR 40.*

[23] http://www.e-mpcdp.com/CDPSynopsis.aspx

Sanitation:

In Sind sub-basin there are 9 districts namely:- Ashoknagar, Guna, Vidisha, Shivpuri, Datia, Gwalior, Bhind, Morena and Sheopur. As per the City Development Plan of urban areas, the details of treatment Capacity and sewage disposal are given in Table 20.

Table 20: Details of Treatment Capacity and Sewage Disposal

S.no	Districts	Treatment Capacity (MLD)	Area Connected to Sewer	Treated Sewage Disposal(River)
1	Vidisha	9	25%	Betwa
2	Sheopur	-----	62%	Seep-River
3	Gwalior	50	80%	Swarn-rekha and Morar River
4	Bhind	--------	61%	Local Nalla(Drain)
5	Morena	------	0%	Local Nalla(Drain)
6	Guna	--------	0%	Negri River
7.	Datia	-------	0%	Lakes
8.	Shivpuri	---------	10%	Jadhav-Sagar Lake
9.	Ashok Nagar	------	60%	Local- nalla

As per Central Pollution Control Board report "status of water supply, wastewater generation and treatment in class-I cities & class-II towns of India" the average sewage production is at the rate of 80% of domestic water supply .As per Census of India, the class of cities and towns has been classified[24] on the basis of population as follow:

Class I: 100,000 and above;
Class II: 50,000 to 99,999;
Class III: 20,000 to 49,999;
Class IV: 10,000 to 19,999;
Class V: 5,000 to 9,999 and
Class VI: Less than 5,000 persons.

The current and future gaps in the treatment capacities and sewage production are being met by the Urban Development Department under the Jawaharlal Nehru National Urban Renewal Mission.

[24] http://censusindia.gov.in/towns/ap_towns.pdf

Extracts from City Development Plans (Urban Areas only):

Gwalior: *Gwalior city has coverage of underground networked sewer and about 62 % toilets in the city are connected with underground sewerage system. The trunk sewers ultimately discharge into outfall sewers which are connected to the Sewage treatment plant (STP). There are 2 STPs: one of 50 MLD capacity and another of 90 MLD capacity which is under construction. The STPs discharge treated wastewater into Swarnarekha River.*

The city generates about 149 MLD of waste water and the collective installed capacity of the two treatment plants is about 140 MLD; which indicates adequacy of the treatment facilities upto 98%. However, only 60% of the generated waste water is carried through the sewer system to the STPs. This is because of old sewer lines are ruptured at different places causing siltation which restricts the free flow of sewage; Lack of proper maintenance of existing sewerage system especially main sewer lines; At certain points the sewer lines are not functioning properly because of siltation in main sewer lines. This sewage gets directly discharged into Morar River without any treatment.

City Development Plan of Gwalior envisages many infrastructural interventions to minimize pollution in Swarnarekha and Morar river. All the nallas joining Morar River are proposed to be intercepted with sewer line so that the sewage coming from the households can be trapped and diverted into the sewerage system. It is also proposed to cover 100 percent households with sewerage network and replacing old damaged pipelines with new ones.

Shivpuri: *The sewerage system in Shivpuri is very old (constructed in 1940). The entire system is in very dilapidated condition, network pipes are choked and hence not functional. The entire sewage of the city is therefore discharged directly into the Jadav Lake. Only 50% household have septic tanks from which the wastewater flows into the lake downstream. There is no sewage treatment plant at present. The CDP has proposed construction of new sewer lines and STP in the city.*

Datia: *Currently, there is no underground sewerage system in the city. Sewage flows in open drains and is discharged into lakes. Slums do not have access to toilets and hence open defecation is rampant in slum areas. Approximately 3.25 MLD of wastewater is generated and the entire amount goes untreated into lake. It is proposed to a lay new sewerage network and constructing Sewage treatment plant of 11 MLD capacities in the City development plan.*

Bhind: *The sewerage system in the city is very old and is not useful anymore. Most houses have septic tank where sewage is disposed which then flows into open drains. Others resort to open defecation in absence of sanitation facilities. There is no sewage treatment facility and drainage and sewerage flows in open drains and is eventually disposed off onto the fields.*

Morena: *Currently, there is no underground sewerage system in Morena. Sewage flows from septic tanks into open drains/local nallahs. Only 60% households have sanitation facilities whereas rests are forced to practice open defecation. The current sewage generation is about 24 MLD. City development plan proposes construction of sewer network as well as a sewage treatment plant by 2020.*

For rural areas, the mandate of sewage treatment and disposal is with Public Health Engineering Department and Madhya Pradesh Jal Nigam Maryadit. Therefore, this plan does not address water supply and sewage treatment issues of the basin. However the quality of sewage- whether treated or not, whether treated to acceptable standards and effect of its mixing with water bodies- need to be monitored. The coverage of sanitation facilities in the villages has still to go a long way for 100% coverage.

Fisheries

Nearly 0.39 million hectares of reservoirs and ponds are under fisheries activities in the State of which 0.21 million hectares is supported by the Fisheries Federation, 0.02 million hectares by the Fisheries department and 0.10 million hectares have been transferred to the Village, Janpad and Zilla Panchayats. The annual state demand of standard fry is 850 million.

In Sind sub-basin, fisheries activities in large reservoirs are taken up in Madikheda, Harsi (both under Fisheries Federation), Pehsari and Paronch dams. The water spread area of these reservoirs at full tank level is 9300 hectares while the average water spread area is nearly 5521 hecatres.

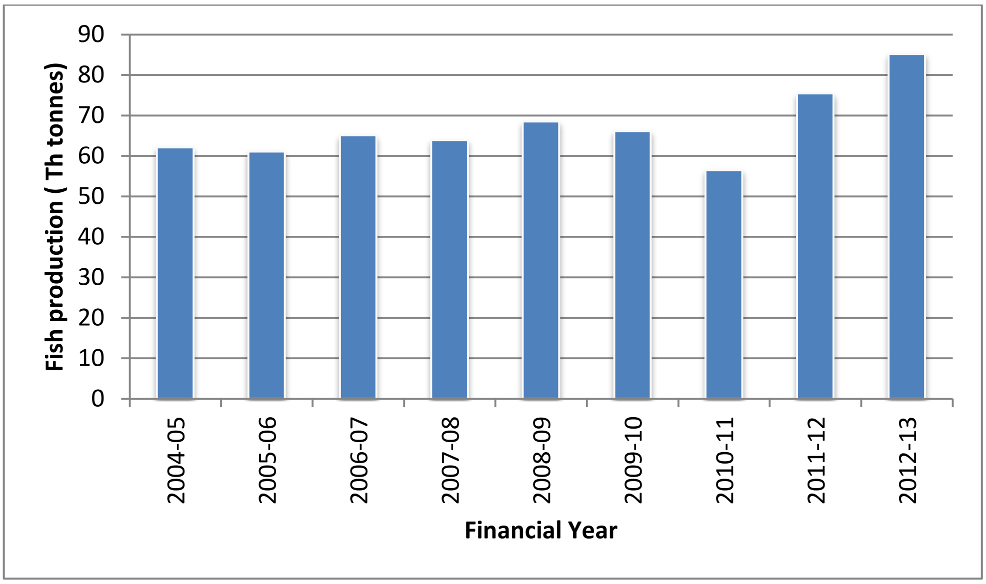


Figure 83 : **Inland Fish Production**

The Fisheries Department has a Chinese-type hatchery with 24 nurseries and over a water spread area of 2.4 hectares at Bhagora hatchery in Shivpuri district in the basin. There is another hatchery at Gwalior with 12 nurseries and 0.53 hectares water spread.

In all the reservoirs, fishing activities are done by fish farmers under the fisheries cooperative societies.

Energy

India is among the 10 leading hydro-electric power generating countries of the world. The current installed hydro-electric generation capacity is more than 39,000 MW of which 3346 MW is the share of Madhya Pradesh out of various projects as listed in Table 21. Many of these hydro-electric power generation schemes in the state are inter-state.

Table 21: Hydro power in Madhya Pradesh

Hydro-Electric Power Station	Basin	MP Share in generation (MW)
Gandhi Sagar	Chambal	58
Rana Pratap sagar & Jawahar Sagar	Chambal	136
Indira Sagar Project (ISP)	Narmada	1015
Sardar sarovar	Narmada	827
Bargi	Narmada	100
Bansagar	Son	425
Madikheda	Sind	60
Omkareshwar	Narmada	520
Rajghat & Matatila	Betwa	78
Pench	Wainganga	107
Birsinghpur	Son	20
Total		**3346**

Among the leading hydro-electric power generation schemes in the above table, one scheme in Sind sub-basin Madikheda (Sind project) has an installed capacity of 60 MW. Madikheda is a multi-purpose dam; however, irrigation service to northern part of the state is the primary purpose. The power generation in GWh during years 2011 and 2012 is depicted in Figure 84.

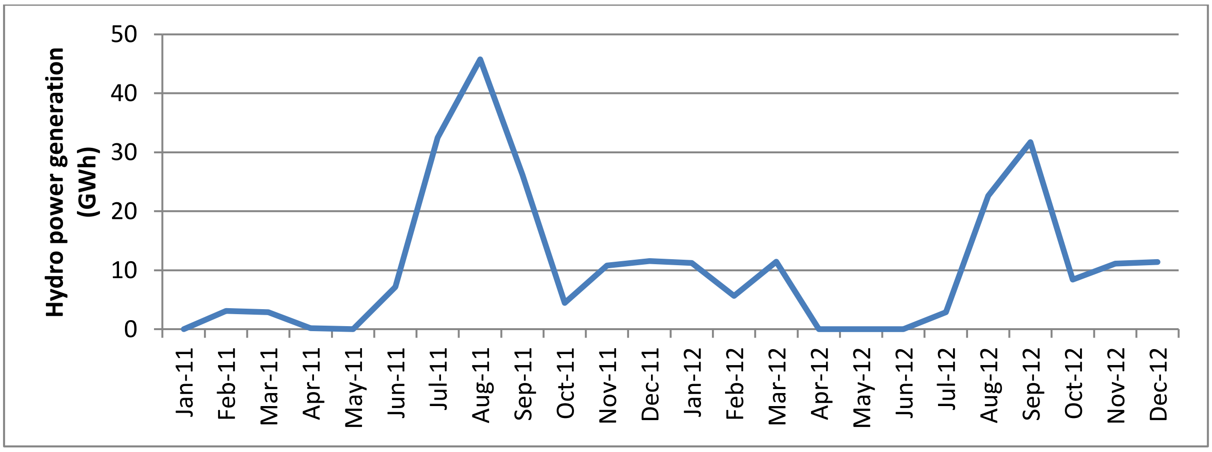


Figure 84 : Power Generation from Madikheda Dam **(Source: CEA, India)**

Tourism

Gwalior, Shivpuri and Kuno-Palpur Wildlife Sanctuary (Sheopur) are important areas from tourism point of view. Kuno-Palpur sanctuary is yet to match its potential for attracting tourism because Madhya Pradesh's Bhandhavgarh, Kanha and Pench National Parks as well as nearby Ranthambore in Rajasthan gain more attention of the tourists.

Figure 85: Kuno-Palpur Sanctuary, Sheopur

Figure 86: Madhav National Park, Shivpuri

Gwalior and Shivpuri come under often frequented Gwalior- Shivpuri- Orchha - Khajuraho travel circuit of Madhya Pradesh.

The annual average number of visitors to Gwalior and Shivpuri according to the study on tourist statistics[25] is shown in Figure 87. Considering total number of visits of all tourists i.e. domestic and foreign, Gwalior (491,783) is second highest in the State after Bhopal (1,086,679).[26]

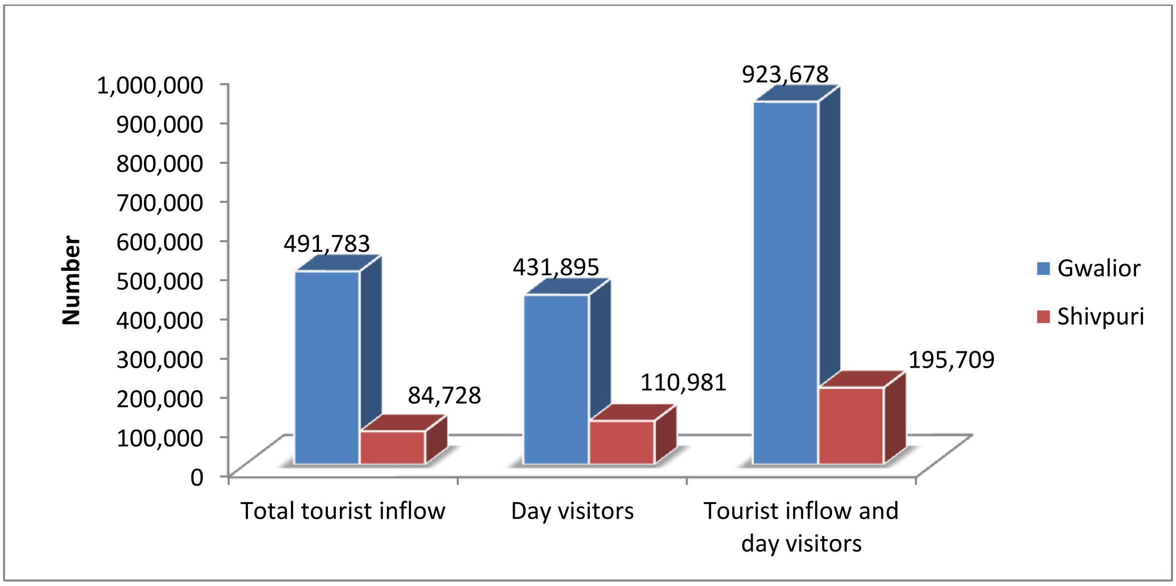


Figure 87: Tourist Inflow (n°/ year)

[25] Collection of Domestic Tourist Statistics for the State of Madhya Pradesh- JPS Associate's Report to Market Research Division, Department of Tourism, Government of India

[26] Collection of Domestic Tourist Statistics for the State of Madhya Pradesh- JPS Associate's Report to Market Research Division, Department of Tourism, Government of India

Agriculture:

Madhya Pradesh has about 72% rural population, which largely depends on agriculture. Approximately 66% of total geographical area is under cultivation. Out of the total cropped area in the state, the share of cereals is 40%, pulses 24%, oilseed 33% and the remaining area is covered by other crops like vegetables, fruits, fodder etc (Figure 88).

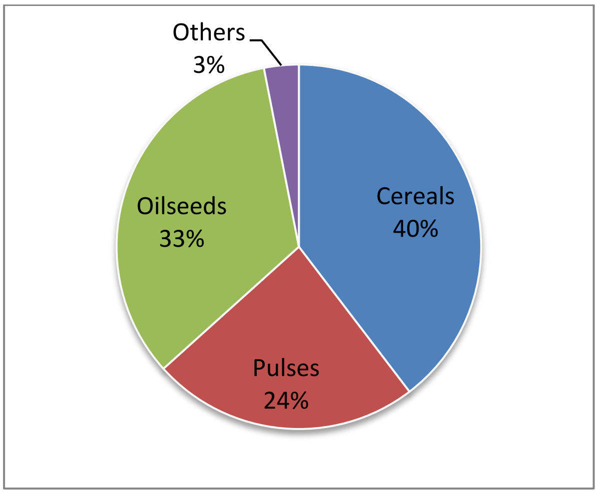


Figure 88: Area under different Crops in Madhya Pradesh

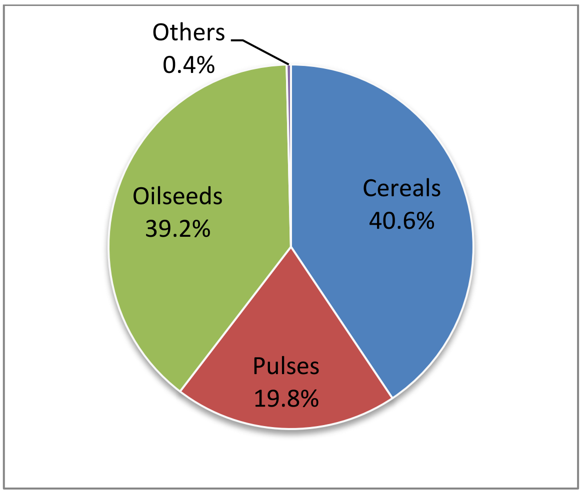


Figure 89: Area under different Crops in Sind sub-basin

In the Sind sub-basin, approximately 52% of the total geographical area is under cultivation. Out of the total cropped area in the sub-basin, cereals cover 40.5%, pulses 20% and oilseed 39% and the remaining are under other crops like vegetables, fruits, fodder etc (Figure 89).

Figure 90: Mustard crop in the sub-basin (Morena district)

Rabi crop (winter crop), which is sown in November and harvested in March, is the main crop in Sind sub-basin. Kharif crop, which is a rainfed crop, is sown in July and harvested in October. Major crops grown in Kharif season in the sub-basin are Paddy, Soyabean and in Rabi season are Pulses, wheat, mustard, and gram.

Figure 91: Paddy field in Shivpuri district

Table 22: Area in '000 ha under Rabi & Kharif Crops in Year 2012-13 (Source- MP CLR)

	Total Area	Rabi	% Area of Rabi	Kharif	% Area of Kharif
In Madhya Pradesh	30,825	10,554	34%	11,923	39%
In Sind Sub-Basin	2,608	1,277	49%	684	26%

.

49 % of the basin area is under Rabi crop and 26% basin area is under Kharif crop. In Madhya Pradesh Rabi crop area is 34% which is less than Kharif (rain-fed) crop area (39%). It shows that sources of irrigation in Sind sub-basin are comparatively better than sources of irrigation in the State, because Rabi crop depend mainly on irrigation, so while kharif crop is a rain fed crop.

Agriculture Growth Trend:

Sown area of the Rabi crop in Sind sub-basin has increased from 1139 Th. ha are in the year 2006 to 1277 Th. ha in the year 2013, which is 12% increase (Figure 92). Similarly, production has also increased from 1722 Th. ton to 3002 Th. ton in these years, which is 74% increase (Figure 93). In the last 3 years production has increased very rapidly. About 50% increase could be attributed to expansion of irrigation services and timely availability of other farm inputs.

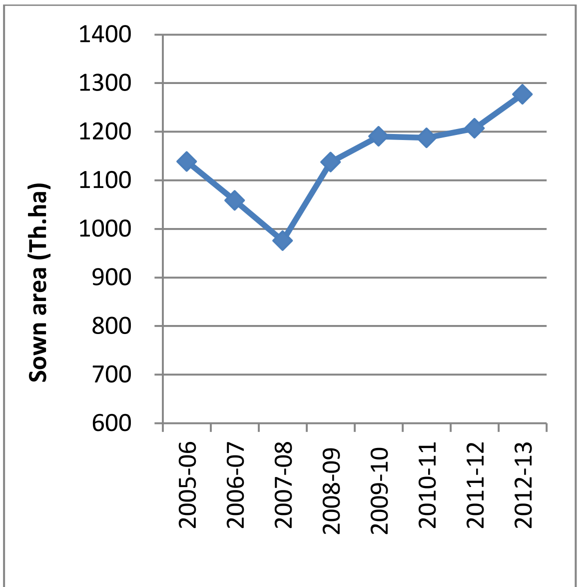


Figure 92: Rabi Sown area

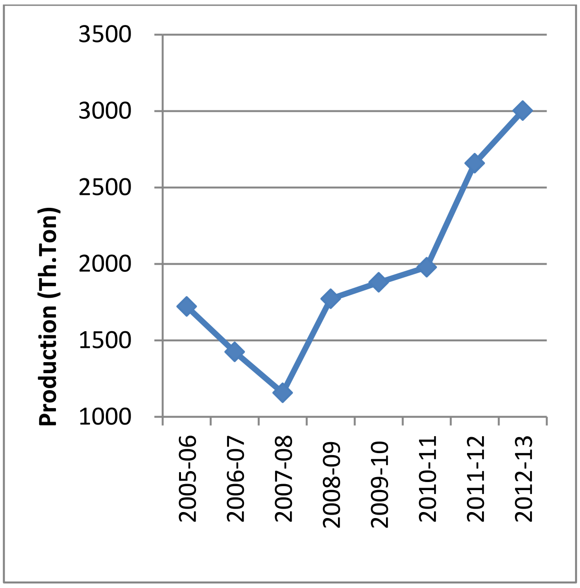


Figure 93: Rabi Production

Sown area of Kharif crops in the basin has increased from 483 Th. ha in the year 2006 to 684 Th. ha in the year 2013, which is 42% increase (Figure 94). Kharif production has also increased from 610 Th. ha to 896 Th. ton in these year, which is 47% increase (Figure 95). Still much of the farmers take only Rabi crops and leave the land uncultivated during Kharif season. It is mainly because of uncertainty of rains, lack of awareness and poor communication to the farmers about the weather condition. Production can be further improved if farmers take up cropping in Kharif season as well.

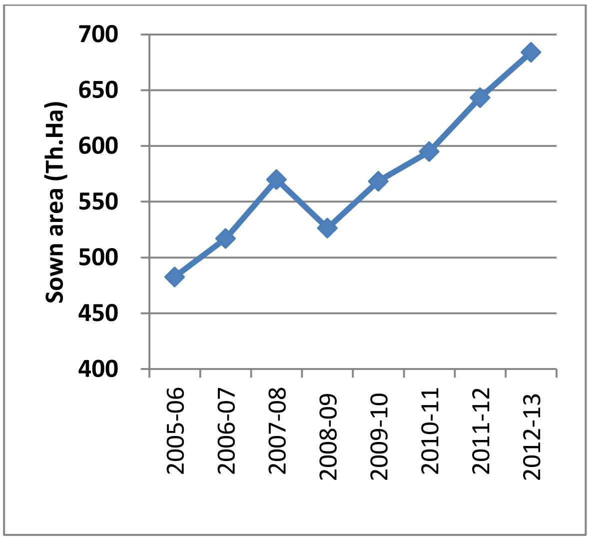


Figure 94: Kharif Sown Area

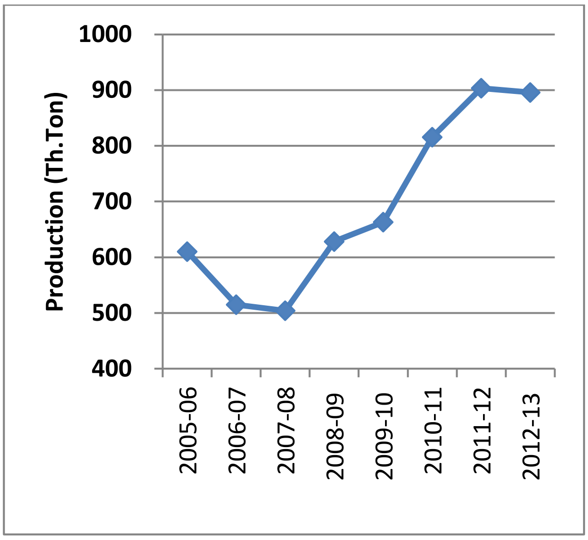


Figure 95: Kharif Production

Total area under cultivation in Sind sub-basin is approximately 1356 Th. ha out of which Rabi crops are sown in 1277 Th. ha and Kharif crops in 684 Th. ha. Sown area of Kharif crop is nearly half of Rabi crop. District wise Rabi and Kharif crop sown area for year 2012-2013 in Sind sub-basin is shown in Table 23.

Table 23: District wise Rabi and Kharif Crop Sown area in **'000 ha** -year 2012-13

S.No.	District Name	Crop Area	
		Rabi	Kharif
1	Ashoknagar	84.5	55.1
2	Bhind	300.0	63.0
3	Datia	228.5	99.0
4	Guna	32.0	42.5
5	Gwalior	196.5	91.0
6	Morena	183.6	72.5
7	Sheopur	23.0	17.9
8	Shivpuri	189.9	215.0
9	Vidisha	39.0	28.0
	Total	**1276.9**	**684.0**

Crop Yield:

In the basin, yield of major crops is improving over the years. The trend for the last 8 years is shown in the Figure 96.

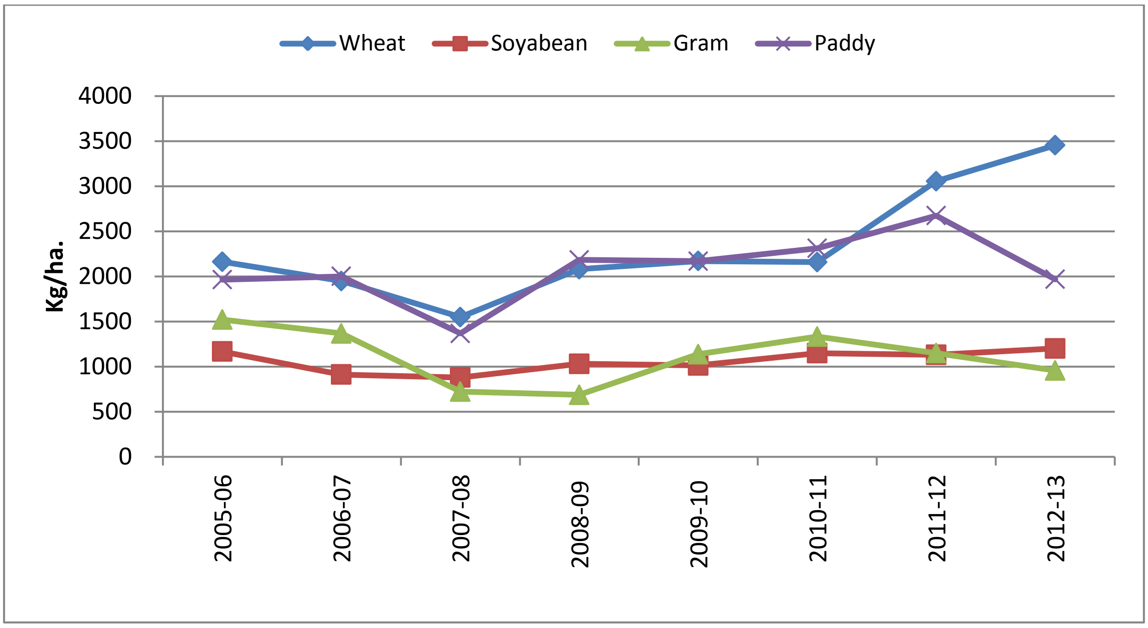


Figure 96 : **Major crops Yield in Sind sub-basin**

Yield of gram is low since it is purely depend on rain. Comparison of basin yield with state yield in 2013 is given in Table 24.

Table 24: Comparison of Yield (kg/ha) of major crops in the state and sub basin

Crop	Average yield in Kg/ ha	
	Sind sub-basin	Madhya Pradesh
Wheat	3456	2959
Soyabean	1202	1365
Paddy	1970	1807
Gram	958	1220

Wheat and paddy crop yield is better than state average yield, but soyabean and gram need more improvement to come up with the state average.

Cropping Pattern:

Wheat is the main food crop of the sub-basin and sown area of wheat crop is 44 % of the total sown area (Figure 97). State government gives minimum support price to motivate the farmers to grow more wheat for food security of the state. Approximately two third area of Rabi crop is Wheat & Mustard only. It shows the dominancy of Wheat, Mustard and Gram over the other crops in the sub-basin. District wise sown area under different crops in Rabi season for the year 2012-13 is shown in Table 25.

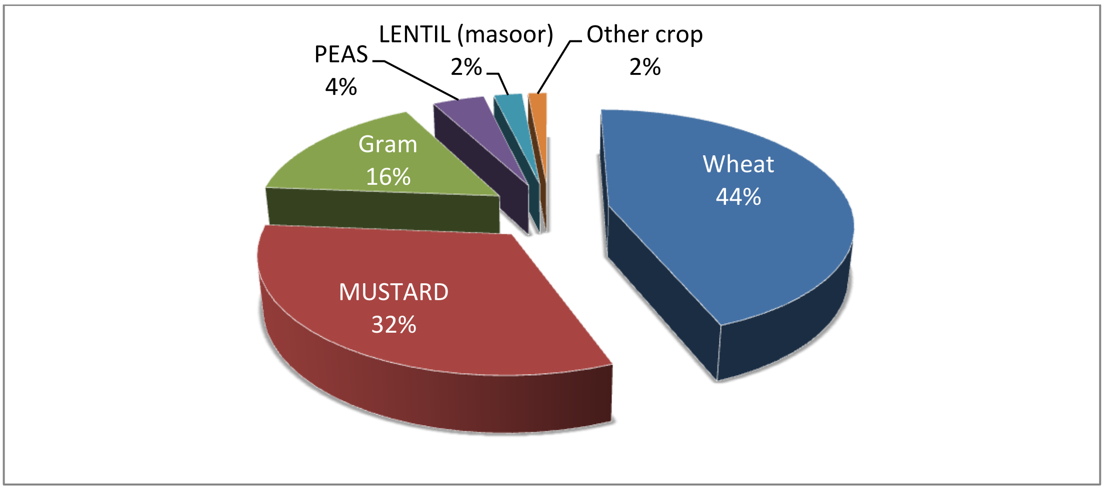


Figure 97 : **Cropping Pattern - Major crops of Rabi 2012-13**

Table 25: District wise sown area in Th. ha under different crops in Rabi season -Year 2012-2013

S.No	DISTRICT	Wheat	MUSTARD	Gram	PEAS	LENTIL (*masoor*)	Other crop	Total
1	Askhonagar	36.9	1.1	38.3	0.7	7.0	0.5	**84.5**
2	Bhind	93.5	169.2	20.7	2.8	7.5	6.2	**299.9**
3	Datia	117.0	19.5	40.0	44.0	3.6	4.4	**228.5**
4	Guna	18.9	0.4	12.0	0.1	0.2	0.4	**32.0**
5	Gwalior	111.9	54.0	22.9	2.3	1.3	4.1	**196.5**
6	Morena	63.7	110.8	5.1	0.5	0.9	2.6	**183.6**
7	Sheopur	13.1	8.4	1.4	0.0	0.0	0.1	**23.0**
8	Shivpuri	86.2	47.3	49.6	1.1	3.9	1.8	**189.9**
9	Vidisha	20.0	0.1	13.6	0.4	4.0	0.9	**39.0**
	GRAND TOTAL	561.3	410.8	203.6	51.8	28.4	21.0	1276.9

Soyabean is the major crop sown in Kharif and other crops are Bajra, urad, and paddy as shown in Figure 98. In future sown area of paddy may increase after assured water availability for irrigation and also due to state government providing minimum support price for paddy production to farmers. District wise detail of different crops in Kharif crop for the year 2012-2013 is shown in Table 26.

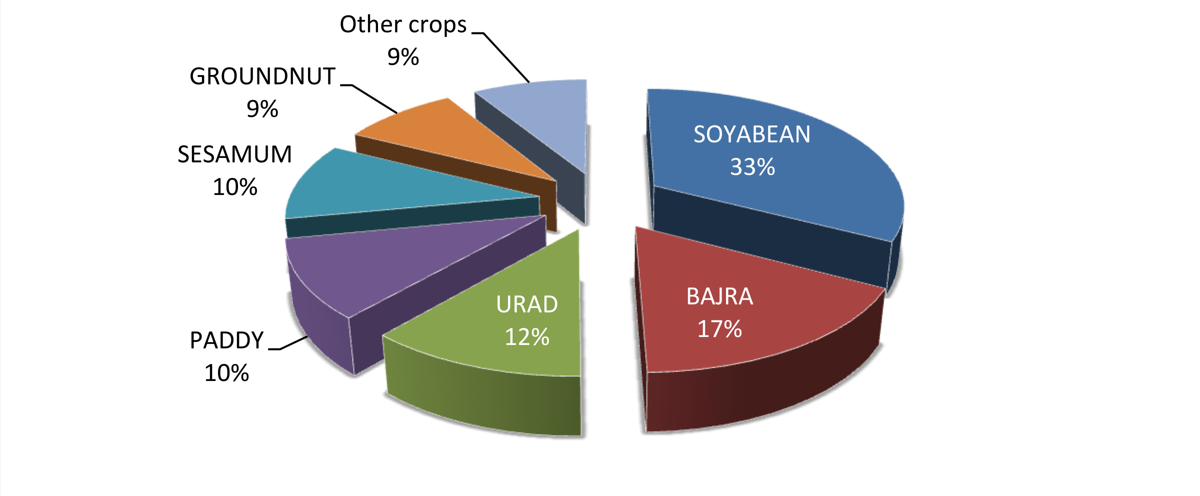


Figure 98 : **Kharif Cropping Pattern 2012-13**

Table 26: District wise sown area in Th. ha. under different crops in Kharif season -Year 2012-2013

S.No	DISTRICT	SOYABEAN	BAJRA	URAD	PADDY	SESAMUM	GROUNDNUT	Other crops	Total area
1	Ashoknagar	34.1	0.0	17.6	0.3	0.1	0.2	2.8	55.1
2	Bhind	0.0	37.6	2.1	4.9	4.9	0.0	13.5	63.0
3	Datia	6.2	1.0	30.6	7.4	33.8	12.0	8.0	99.0
4	Guna	37.6	0.0	0.9	0.1	0.1	0.1	3.7	42.5
5	Gwalior	8.2	6.1	6.2	49.1	16.4	0.3	4.7	91.0
6	Morena	0.3	64.1	0.7	0.3	3.3	0.1	3.7	72.5
7	Sheopur	6.9	2.7	0.2	2.3	4.6	0.1	1.1	17.9
8	Shivpuri	108.1	4.2	17.5	8.0	9.0	47.3	20.9	215.0
9	Vidisha	22.8	0.0	3.9	0.1	0.0	0.0	1.2	28.0
GRAND TOTAL		**224.1**	**115.8**	**79.8**	**72.5**	**72.1**	**60.0**	**59.6**	**684.0**

Agriculture Water

Major water users in the Sind sub-basin are Agriculture, Domestic and Industries of which the agriculture is the dominant user.

Estimation of 'Crop Water Requirement': Amount of water required at root zone of a plant from sowing of the seed up to the time of harvest for healthy growth and optimum yield is termed as 'Crop Water Requirement' (CWR). 'Net Irrigation Requirement' (NIR) is calculated by subtracting effective rainfall from 'Crop Water Requirement'.

For calculating water demand fortnightly rainfall has been taken as the average rainfall of different rain gauge stations of district for last 30 years.

Present water requirement for agriculture

Crop water requirement is estimated on field as per design Technical Circular no. 25 "Estimation of crop water requirement and irrigation water requirement" issued by Madhya Pradesh Water Resources Department which is mainly based on FAO irrigation and drainage paper No. 24 and 56.

The present water requirement for Rabi and Kharif crops is shown in Table 27 and Table 28.

Table 27: Present water requirement for Rabi and Kharif Crops

S.No	District	Area		Crop Water Requirement in field (MCM)			Net Irrigation Requirement in field (MCM)		
		Rabi	Kharif	Rabi	Kharif	Total	Rabi	Kharif	Total
		(Th.ha)	(Th.ha)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1	Ashoknagar	85	55	319	257	**576**	319	54	**374**
2	Bhind	300	63	1063	360	**1423**	1063	133	**1196**
3	Datia	229	99	855	497	**1352**	855	130	**985**
4	Guna	32	43	126	204	**330**	126	36	**161**
5	Gwalior	197	91	724	724	**1449**	724	299	**1024**
6	Morena	184	73	656	342	**998**	656	90	**746**
7	Sheopur	23	18	92	100	**192**	92	43	**136**
8	Shivpuri	190	215	737	1110	**1846**	737	301	**1038**
9	Vidisha	39	28	131	127	**259**	131	27	**159**
Total		**1277**	**684**	**4704**	**3721**	**8426**	**4704**	**1114**	**5819**

Table 28: Monthly Crop Water Requirement in MCM

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	Total
CWR	877	980	1108	756	556	976	1217	1309	647	0	0	0	8426
NIR	578	188	77	271	556	976	1217	1309	647	0	0	0	5819

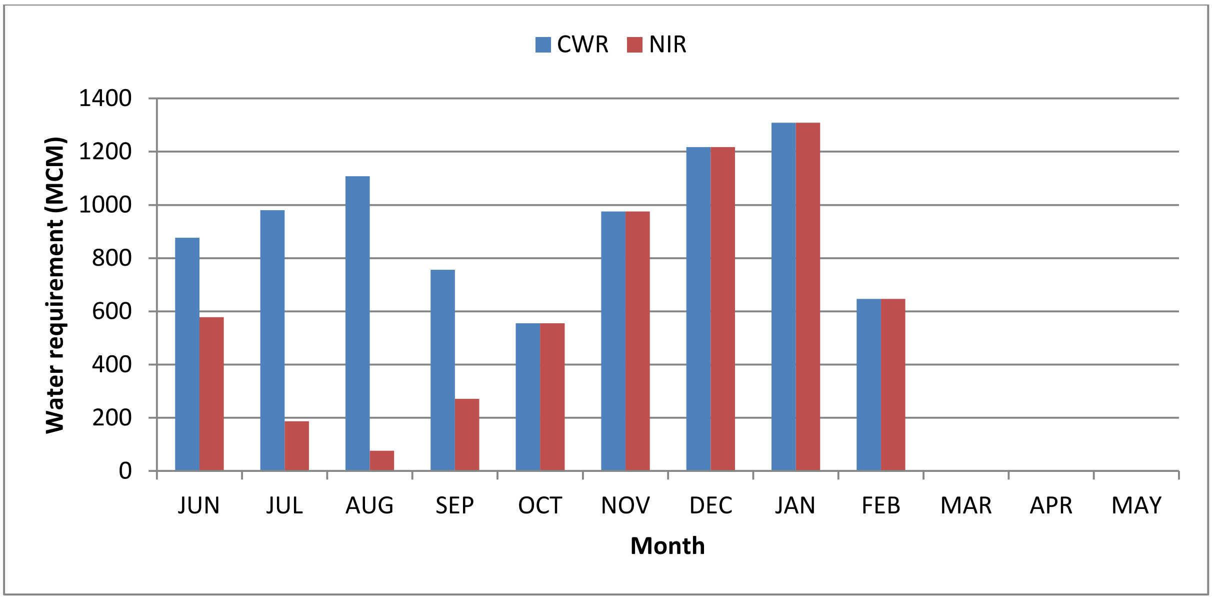


Figure 99 : **Monthly Crop Water Requirement**

The Figure 99 shows that Crop water requirement and net irrigation water requirement for Rabi crop is same, it indicates that effective rainfall during Rabi season is nil, i.e. very little or nil rain fall occurs during winter season. So the water requirement for Rabi crops is met out by irrigation either by surface or ground water. For Kharif crops net water requirement is about 1/3 of Crop water requirement, which means major requirement of crop, is fulfilled from precipitation directly, and the rest of the requirement is fulfilled by surface or ground water.

Source wise Irrigation:

As per the data made available from Department of Land Record website the total area under cultivation in Sind sub-basin is approximately 1356 Th. ha out of this area irrigated with different sources is approximately 717 Th. ha. Source-wise irrigated area in the basin is shown in Table 29 and Figure 100.

Table 29: District wise, Source wise Irrigation in Sind sub-basin in Th. ha

District	Canals	Tanks	Wells	Tube Wells	Other Sources (direct from river)	Total Irrigated Area
Morena	41	0	53	29	2	124
Sheopur	10	0	2	7	1	20
Bhind	17	0	63	17	2	99
Gwalior	77	0	12	43	5	137
Shivpuri	18	3	45	32	15	113
Guna	3	1	7	10	5	25
Ashoknagar	3	1	5	13	11	35
Datia	84	0	56	2	1	143
Vidisha	3	0	3	9	5	20
Total	**257**	**6**	**246**	**161**	**47**	**717**

Area irrigated by surface water source through tanks, canals and other sources (by lift directly from rivers) is 310 Th. ha which constitute nearly 43% of total irrigation by all means, whereas area irrigated by ground water source is 407 Th. ha which is nearly 57% of total irrigation by all means as shown in Figure 100.

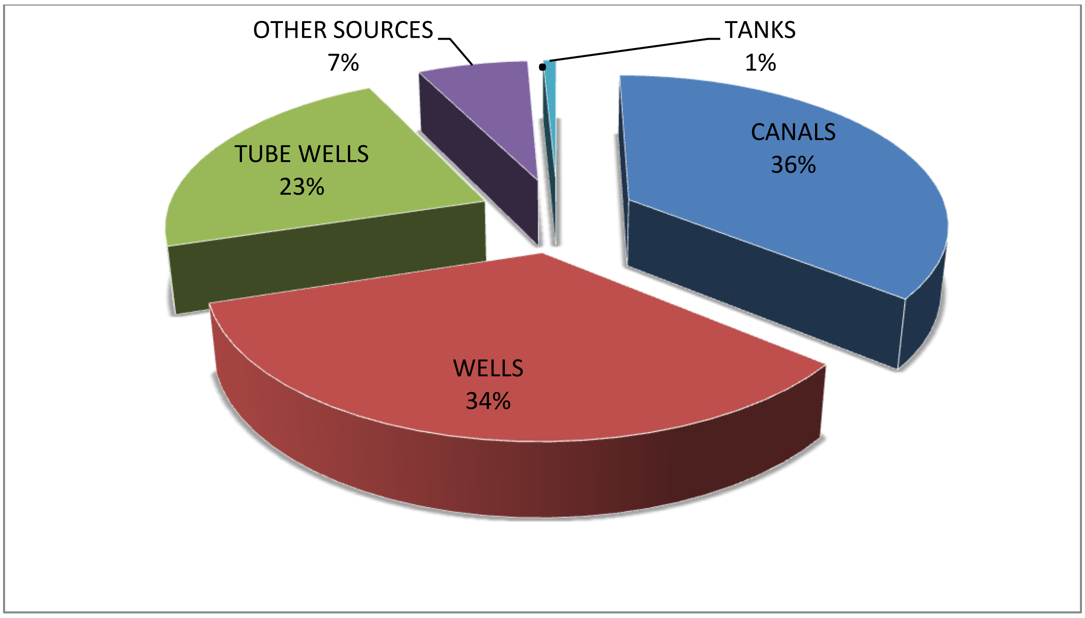


Figure 100 : **Source wise Share and Irrigation in %**

Water Use Efficiency:

Canals and irrigation distribution systems are designed on the basis of duty and intensities (Culturable Command Area). In classical irrigation engineering parlance, duty represents the irrigating capacity of a unit of water (hectares/ m^3/s). In the absence of water use efficiency monitoring, the efficacy of an irrigation project is indicated by the area serviced by the project over the volume of water released by the dam for irrigation (in hectares/ MCM).

Based on the information available from MPWRD website, the indicators for 3 irrigation schemes are given in Table 30.

Table 30: Measured Duty of Irrigation Schemes

Irrigation Project	Volume of water released for irrigation (MCM)	Irrigation area recorded (ha)	Duty of storage (MCM/ha)
Paronch	13.02	2150	165
Akhajhiri	9.87	1670	169
Mahuar	22.27	5010	225

Though it is a very convenient measure for evaluating irrigation project performance, it varies for different types of dams- earthen/ masonry/ RCC/ rockfill, size of dam- large/ small, type of channel- lined/ unlined, type of soil, age of the scheme, O&M investments, number of irrigation watering, crop types etc.

The Central Water Commission of India (CWC) in its guidelines of Feb 2014 has standardized Water Use Efficiency for a project as a product of reservoir filling efficiency, conveyance efficiency, on-farm application efficiency and drainage efficiency.

$$E_p = E_r * E_c * E_f * E_d$$

It further lays down practically achievable limits for each of the efficiencies (Table 31).

Table 31: Limits of Achievable Water Use Efficiency

Type of Efficiency		Achievable Limits of Water Use Efficiency
Reservoir Efficiency **- E_r**		95-98%
Conveyance Efficiency **-E_c**	Fully lined system	70-75%
	Partially lined system	65%
	Unlined system	60%
On Farm Field Application Efficiency **-E_f**	Sprinkler/ Drip Irrigation	85%
	Basin/ Furrow Irrigation	65%
Drainage Efficiency **-E_d**		80%
Irrigation Potential Utilized (IPU)/ Irrigation Potential Created (IPC) **- IPU/IPC**		85%

In addition to the above, CWC also recommends the ratio of Irrigation Potential Utilized (IPU) and Irrigation Potential Created (IPC) as indicator of optimal or sub-optimal water use.

In the absence of any on-field measurement of water use efficiency in Sind sub-basin, an attempt to recursively translate the measured volume of release from dam, depth of water required by crop, cropping pattern (wheat: mustard: gram 2:1:1) and actual area irrigated has been made to measure the performance of some schemes (Table 32).

Table 32: Test cases for measuring performance of schemes

Irrigation Project	Volume of water released for irrigation (MCM)	Irrigation area recorded (ha)	Volume of water at field in MCM (depth 250 mm)	E_p (%) Col 4/ Col 2	Remarks
Paronch	13.02	2150	5.38	41%	1980
Akhajhiri	9.87	1670	4.18	42%	1973
Mahuar	22.27	5010	12.53	56%	New project

These calculations are certainly not based on actual measurement of different components of efficiencies and require validation.

CWC estimates average water use efficiency in India at 38-40% for canal irrigation. From the achievable limits in water use efficiencies, it is clear that major improvements can be achieved by a combination of infrastructural measures and on-farm interventions.

GoMP envisions bringing 10% of command area in new irrigation projects under micro-irrigation to increase the water use efficiency in agriculture. The short term goal by the state government in vision document 2018 also says that water use efficiency be improved by 10%.

Economic growth:

As per 'Economic Survey 2013-14'[27] the Gross Domestic Product (GDP) of Madhya Pradesh during the financial year 2012-13 has been estimated to be INR 21,47,410 Million (at constant price of 2004-05). It is 9.89% more than the previous year 2011-12. The Gross Domestic Product in Sind sub-basin during 2004-05 to 2009-10 has shown 9.50% increase (**Figure 101**). The Net Domestic Product of Sind sub-basin at Constant price 2004-05 also shows rise from 2007-08 to 2009-10 (**Figure 102**).

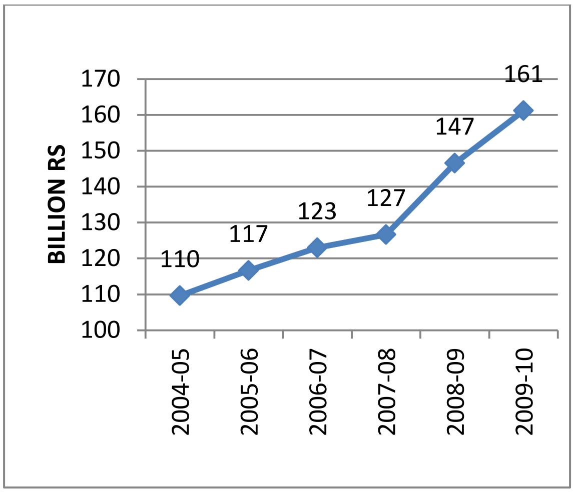


Figure 101 : Gross Domestic Product of Sind sub-basin
(at Constant price 2004-05)

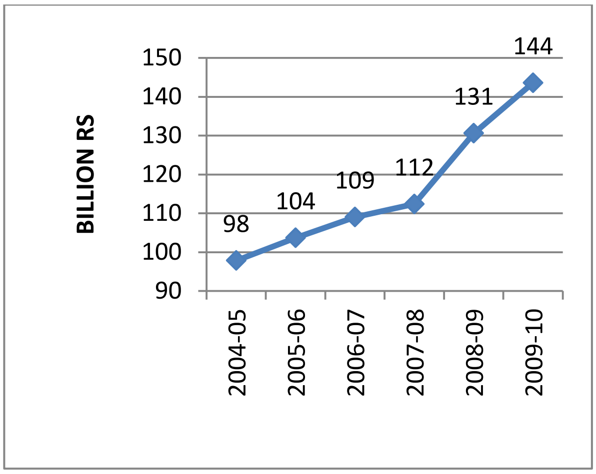


Figure 102 : Net Domestic Product of Sind sub-basin
(at Constant price 2004-05)

Year wise Per Capita Income of Sind sub-basin from 2004-05 to 2009-10, at constant price 2004-05 is shown in Figure 103. It shows a 35% increase from 2004-05 to 2009-10.

[27] *Economic and Statistical Directorate, GOMP*

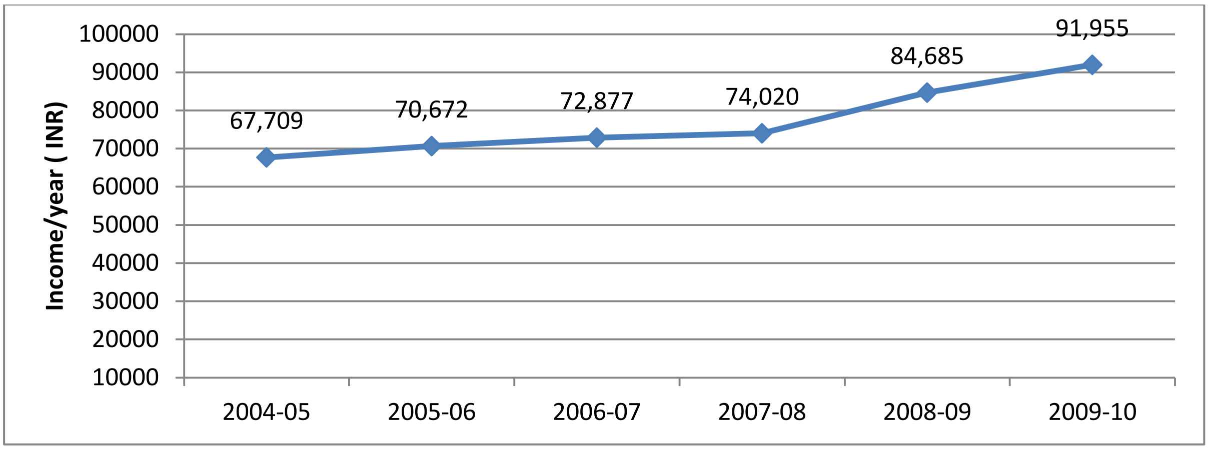


Figure 103 : Per Capita Income of Sind sub-basin (at Constant price 2004-05)

Water Pricing

With consideration of GoMP of water as invaluable and as a public good, its contribution in the economy of the State is immense, especially for public health, agriculture- food security and for industrial and services sector.

The pricing mechanisms of water for domestic and agriculture sectors are based on welfare considerations of the State. The direct pricing is low to ensure and provide coverage of the most disadvantaged sections of the society, while receiving indirect benefit in the form of increased agriculture output and reduced health spending. The pricing of water for industrial use is competitive and based on economic factors.

While the municipalities and local self governing bodies decide upon the cess on water for domestic use, the current water rates for different purposes in the sub-basin and the State are as given in Table 33.

Table 33: Current Water Rates for Different uses (Source-WRD)

Purpose	Water cess in Rs per ha	Remarks
Agriculture:		
Paddy-Kharif	85	Each watering
Other Kharif	50	Each watering
Cotton	70	Each watering
Paddy-Rabi	155	
Wheat-Rabi	125	First watering
	75	Each consequent watering
Other Rabi	75	Each watering
Vegetables	630	
Fodder crops	480	
Sugarcane, rubber, banana, horticulture crops	960	
	Water cess in Rs per m^3	
Industrial:		
From public sources	5	

Purpose	Water cess in Rs per ha	Remarks
From natural sources	1.35	
Hydropower:	**Water cess in Rs per kWh**	
From public sources	0.20	Annual increment of 0.02
From natural sources	0.05	Annual increment of 0.01

Central Water Commission's report "Pricing of Water in Public System in India 2010" assesses the performance of states during 2000-01 to 2007-08 for percentage of revenue realization against revenue assessed where Madhya Pradesh is the second best at 84.02%. But when assessed on financial aspect on percentage revenue realized Gross Revenue (GR) to working expenses (WE) (non-plan) for major and medium irrigation projects, the average for the period during 1992-93 to 2006-07 is 16.17% (Figure 104). Though the State fares much better than most of the other States, the declining trend till 2006-07 reveals rapid increase in WE as compared to GR.

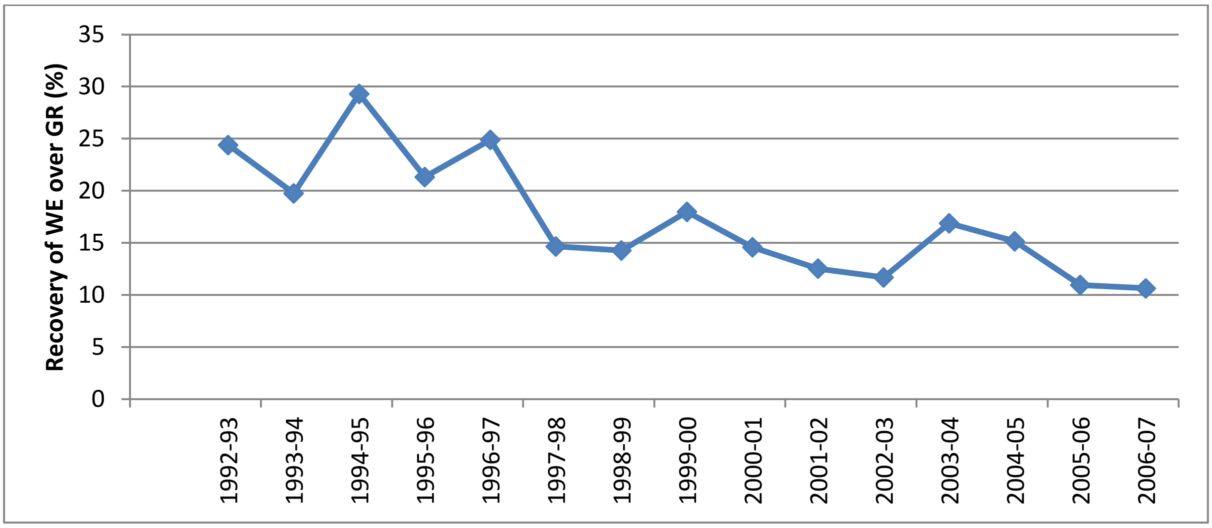


Figure 104: Recovery of WE through GR in %

Industry:

Madhya Pradesh is one of the lesser industrialized state of India and similar is true for Sind sub-basin. According to the State Economic Survey of 2013-14, whilst the growth in agriculture and service sector stood at 22.43% and 9.54% respectively, the industrial sector growth was 2.15% on Year on Year basis.

Due to rural agro based economy, the state has been more conducive for micro, small and medium industries. Handlooms, cottage industries and sericulture of the state are also unique due to its tribal art and agro-forestry.

In Sind sub-basin, most of the industries are near Gwalior-Morena-Bhind belt (Figure 105). Industrial areas of Malanpur, Sitholi and Banmore are located near Gwalior. Electronic engineering, chemical & chemical product, food processing, mechanical engineering, rubber & plastic, textile, basic metal, leather based, agro based are main production in the basin. Dairy, chemical, manufacturing and textiles are among the more important types of industries in the basin.

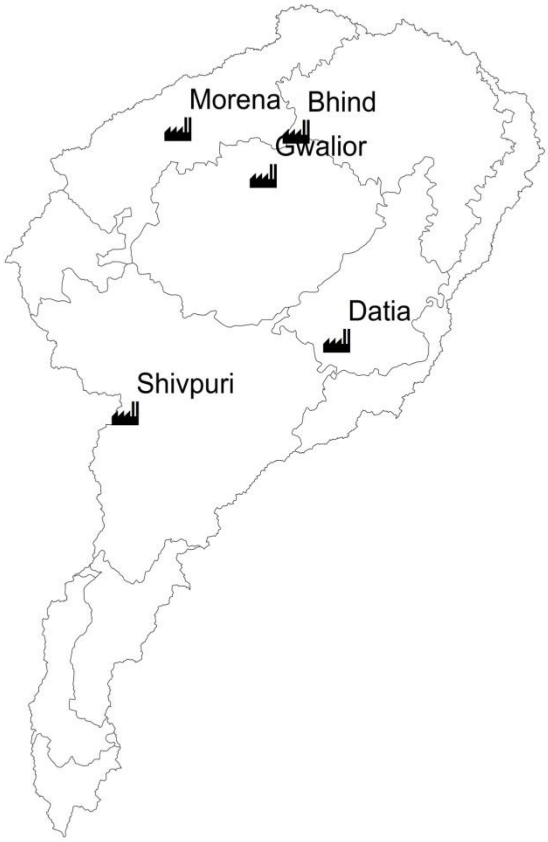


Figure 105: Industrial area in Sind sub-basin

The basin would be benefited by regional developments like the Delhi Mumbai Industrial Corridor (DMIC) and Dedicated Freight Corridor (DFC).

Figure 106: Industries in Sind sub-basin

With the limited data available, the total industrial water demand in the basin is estimated at 22.34 MCM per year. Currently, most of demand is being met from groundwater abstractions. District wise breakup of estimated industrial water demand in Sind sub-basin is shown in Table 34.

Table 34: District wise Estimated Industrial Water Demand

S.No.	District	Industrial Water Demand MCM/ year
1	Ashoknagar	0.60
2	Guna	0.60
3	Shivpuri	4.50
4	Datia	0.60
5	Gwalior	6.90
6	Morena	4.70
7	Bhind	4.44
	Total	**22.34**

Administrative and Institutional System (AIS)

Legal Framework:

The Constitution of India recognizes water resources as a state subject except for trans-boundary disputes (both intra- and inter-national) and major river valley development. In general, water law in India has largely been state based due to the constitutional scheme.

The judiciary has on different occasions upheld the citizen's right to safe drinking water under Article 21 of the Constitution of India. Also Article 47 of the Constitution of India stipulates it as a duty of the state to provide safe drinking water.

Philippe Cullet[28] states "In terms of statutory development, irrigation laws constitute historically the most developed part of water law. This is in large part due to the fact the colonial government saw the promotion of large irrigation works as central to its mission. This also included the need to introduce a regulatory framework in this area. As a result, some of the basic principles of water law applicable today in India derive from irrigation acts. The early Northern India Canal and Drainage Act, 1873 sought, for instance, to regulate irrigation, navigation and drainage in Northern India. One of the long-term implications of this act was the introduction of the right of the Government to 'use and control for public purposes the water of all rivers and streams flowing in natural channels, and of all lakes'. The 1873 act refrained from asserting state ownership over surface waters. Nevertheless, this act is a milestone since it asserted the right of the Government to control water use for the benefit of the broader public. This was progressively strengthened. Thus, the Madhya Pradesh Irrigation Act, 1931 went much further and asserted direct state control over water: 'All rights in the water of any river, natural stream or natural drainage channel, natural lake or other natural collection of water shall vest in the Government'."

The important laws and legislations which govern the water sector, water utilization and environment are:

1. Madhya Pradesh Irrigation Act, 1931: Construction, operation, maintenance of canals, compensation, roles and responsibilities of canal officers
2. Interstate River Water Disputes Act, 1956: applicable to interstate rivers/ river valleys disputes and its resolution mechanism- downstream state affecting the interests of upstream state or vice-versa
3. River Boards Act, 1956: to provide for the establishment of River Boards for the regulation and development of inter- State rivers and river valleys
4. Wildlife (Protection) Act, 1972: to provide for protection wild animals, birds and plants
5. Water (Prevention and Control of Water Pollution) Act, 1974: prevention and control of water pollution and maintaining or restoring of wholesomeness of water, for the establishment of Boards to achieve the purposes

[28] IELRC Working Paper: Water Law in India

6. Forest (Conservation) Act, 1980: Restriction on use of forest land for non-forest use
7. Environment (Protection) Act, 1986: Prevention, control and abatement of environmental pollution
8. Madhya Pradesh Participatory Irrigation Management Act, 1999: Establishment of Water Users' Association, Farmers' Organization and its election process
9. Biological Diversity Act, 2002: for protection of bio-diversity and to provide mechanisms for sharing of benefits arising from traditional bio-diversity knowledge
10. National Green Tribunal Act, 2010: for establishment of National Green Tribunal for effective & expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property
11. Madhya Pradesh Water Users' Association Charter: explains the PIM Act, powers and duties of WUAs in simple and local language
12. Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013
13. Madhya Pradesh Water Regulatory Commission Act, 2013: water tariff determination and advise to government

Administrative Setup:

At the national level, the Union Ministry of Water Resources is responsible agency. The Planning Commission of India and other ministries like Environment & Forest, Agriculture etc. influence water management.

The Central Pollution Control Board was created under the Union Ministry of Environment and Forests in 1974 after the enactment of Water (Prevention and Control of Pollution) Act. Its objective in the sphere of water is to maintain and protect water in healthy and usable condition. It also coordinates with the State Pollution Control Boards including the Madhya Pradesh Pollution Control Board.

The administration and institutional set up generally applicable to the state conditions including the Sind sub-basin is given in Figure 107. The structure of the government in the focus basin of Sind is multi-layered.

At the state level, the State Water Resources Departments and its ministry is primarily responsible for water resources development and management. Water Resources Department started as an Irrigation Wing in the Public Works Department of Government of Madhya Pradesh. In the year 1972, office of the Engineer in Chief was created and later, in 1973 the Irrigation Department was re-organized on the basis of basins. In May 1990, the mandate of the Irrigation Department was enhanced, and the department was renamed as the Water Resources Department. The additional mandate included:

a. Assessment of water resources in the State and formulation of policy for making comprehensive plan for whole of the Water Sector and to issue guidelines for affecting coordinated use of water.
b. To bring about uniformity in the development of available water resources and to plan use of water resources with the aid of Technology and Research.
c. To play the role of formulating policy and issuing resources plans in regard to irrigation and drainage of works for development of irrigation and command areas.
d. To formulate policy for optimum integrated use of water resources for irrigation by planned development of ground water resources and its irrigation with development of surface water.

A number of state-level public departments viz. Agriculture, Urban Development, Rural Development, Forests, Public Health Engineering have a stake in the way water is managed.

Rural and urban local self governing institutions called *Panchayati Raj* institutions (PRIs) play important role in the supply of domestic water. More than 2000 Water Users Associations (WUAs) are in existence in all irrigated command areas of state. WUAs are a major stakeholder as its members are directly affected by the way irrigation is delivered and managed. Their own role in managing irrigation distribution is immense and has been encouraging.

The Water Resources Department does not have a basin-level delegation based on hydrological boundary but has regional/ zonal Chief Engineer offices based on administrative or project extent. In fact, the department has migrated to this system to align itself with the general administrative structure for better coordination. Sind river basin is majorly covered by the Chief Engineer-Yamuna Basin formation based in Gwalior and some portion of the basin is catered to by the Chief Engineer-Rajghat Canal project in Datia and Chief Engineer-Chambal Betwa basin in Bhopal.

The Chief Engineer offices are supported by circle offices (headed by Superintending Engineers) and divisions (Executive Engineers). The division offices largely have a district presence where it also interacts with the district level administration and governance led by the District Collectors. At this level there exists a district level utilization committee which is accessed by water users for demands and allocations. For agricultural users, the Water Users Associations directly voice their demands to the Water Resources Department sub-divisions and divisions.

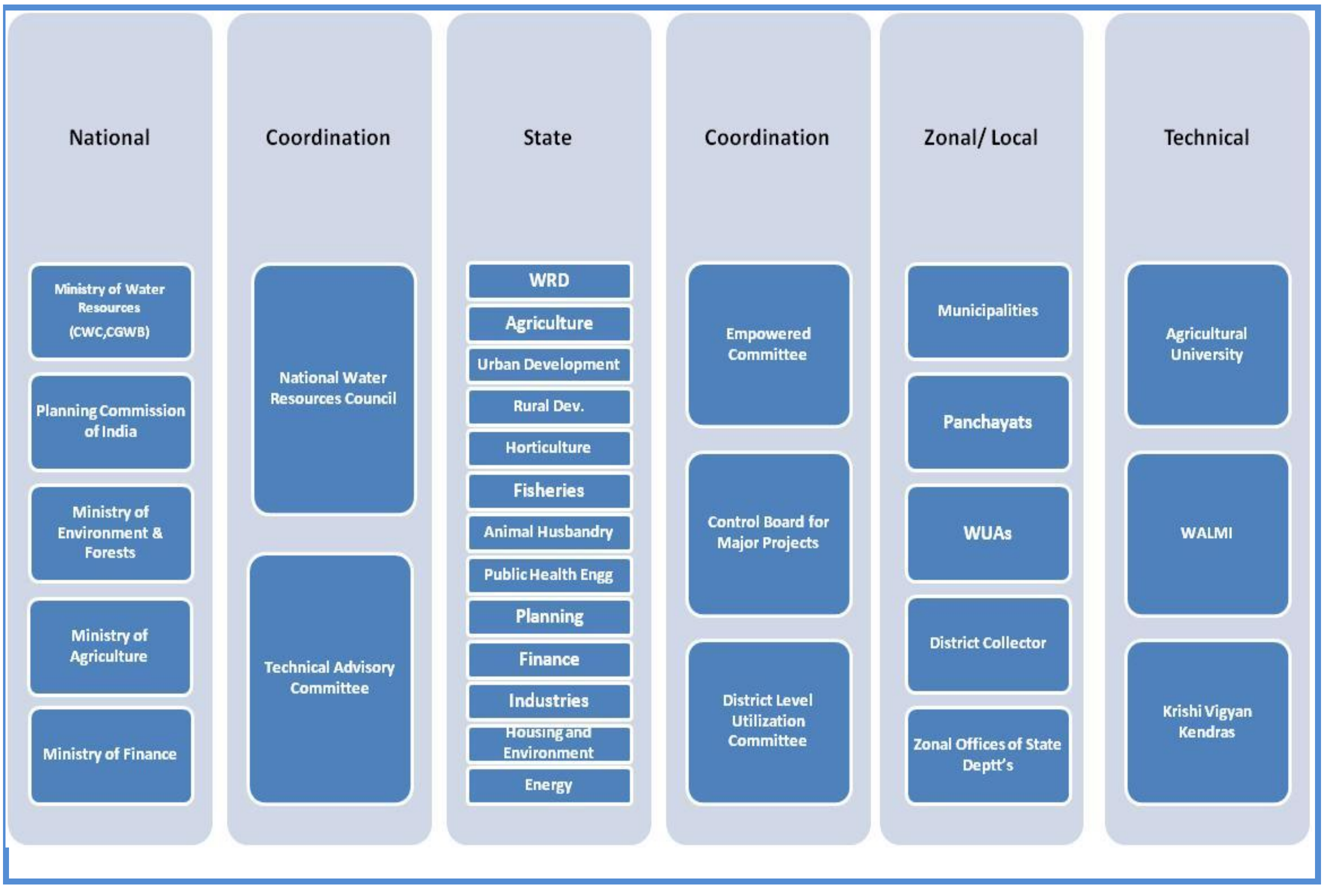


Figure 107 : Administrative and Institutional Setup

The departments of Agriculture, Horticulture, Fisheries, Veterinary (Animal Husbandry) are the key stakeholders for water resources.

The Department of Farmers Welfare and Agriculture Development or the Agriculture Department is mainly involved with agriculture extension services to farmers. It also extends help to farmers through training, soil testing, seed production, farm mechanization and agro-marketing. It also undertakes soil conservations measures at field level.

Initiated as a directorate in 1982 under the Agriculture Department, the Horticulture & Food Processing Department came into being in 2005 as a separate department. It provides extension service for horticulture crops, demonstrations for setting up controlled environment (greenhouse) production, farm mechanization and marketing.

Urban water supply is the domain of municipal (local) bodies while the Public Health Engineering Department and Madhya Pradesh Jal Nigam cater to the domestic water and sewerage disposal needs in rural areas. Two very important programmes in the water supply and sanitation sector are the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the Chief Minister Drinking Water Supply Scheme. Another important scheme taken up by Madhya Pradesh Jal Nigam is rural & industrial water supply and sewerage treatment & disposal scheme.

Institutional Role in Water Management

Among the directorates of the State Rural Development Department, the following have important role in water management:

1. Rajiv Gandhi Mission for Watershed Management,
2. Rural Engineering Services,
3. Mahatma Gandhi National Rural Employment Guarantee Scheme and
4. MP Water and Land Management Institute.

For sustainable livelihood of an individual or a household, employment is a crucial and essential need. There are several schemes and program running at present for livelihood and employment. Many of the programmes and schemes for livelihood and employment also have component of soil and water conservation works. Some of them are:

1. MNREGS: Mahatma Gandhi National Rural Employment Guarantee Scheme
2. IWDP: Integrated Watershed Development Programme
3. IRDP: Integrated Rural Development Programme
4. NREP: National Rural Employment Programme
5. TRYSEM: Training of Rural Youth for Self Employment

At district level, coordination amongst various stakeholder departments, WUA, municipal bodies etc. are exercised through the District Level Water Utilization Committee headed by the District Collector.

All State government departments which are stakeholders in the water sector are coordinated at the level of Chief Minister, Chief Secretary and Agriculture Production Commissioner depending upon the level of coordination. Thus among these ministries/ departments, there exists a high level of coordination in decision making process.

The Government of Madhya Pradesh constituted the State Water Resources Utilization Committee in 1973 to evolve an integrated approach to projects and for optimum utilization of water resources considering the schemes of the various departments where they impinge on a common source of supply. The committee comprises the Chief Secretary, Secretaries of Agriculture, Public Health Engineering, Industry, Water Resources, Chief Engineer of the concerned river basin and the Secretary of the Control Board for Major projects who is also the Additional Secretary to Government. Substantive issues related to water allocation, planning, and management based on recommendations of the District Level Water Utilization Committee is decided upon by the State Level Committee.

Vision 2018 of Madhya Pradesh State

Government of Madhya Pradesh has in its Vision Document 2018 enlisted the short term goals which are shown in Table 35.

Table 35: Short Term Goals of Government of Madhya Pradesh

Department	Goals
Irrigation	- Expand irrigation facilities by adding an additional 0.2 million ha area every year. - Comprehensive command area development projects shall be taken up to achieve effective interdepartmental co-ordination. - Provide water for irrigation to Malwa region by establishing Narmada – Malwa water link
Agriculture	- Enhance production & productivity levels to sustain high growth rates. - Expand access and use of quality inputs by all farmers. - Introduce all farmers to modern technical interventions to increase productivity. - Soil Health Management shall be made central to the modernization strategy. - Fallow and ravine lands shall be developed for cultivation and fodder production; on-farm interventions for land improvement shall be taken up. - Ensure efficient and timely access of credit to all farmers.
Horticulture & Food Processing	- Horticulture corridors and hubs &clusters shall be developed for providing integrated services. - Infrastructure and institutional development. - Organic farming methods to exploit the demand in urban centers shall be put in place. - Develop the state as a logistics hub - Processing and value addition of agriculture and horticulture produce shall ensure better unit price realization to the farmers. - Strengthening of institutional capacity of cooperative based dairy. - Initiative for entrepreneurship development programmes
Fisheries	- Increase fish production in the state from the current level of 85,000 MT to 1,45,000 MT. - Promote training and welfare programmes for the fisherman
Water Supply	- Expand drinking water supply coverage to all habitations. - Make a paradigm shift from overwhelming dependence on ground water to surface water sources. - Regulatory reforms to improve rules and monitoring process
Environment	- Surface water sources shall be protected for quality. - Pollution control through Zero Waste Technologies for pollution control shall be brought in. - Regulatory reforms to improve rules and monitoring process
Energy	- Keep the state power surplus by addition to the power generation capacity - Increase in efficiency and reduction in losses in Transmission and Distribution sector - Production of renewable energy through productive utilization of wasteland as well as lands in the scheduled areas - Diversification of energy portfolio by reducing the conventional energy demand by 10% - Promote Decentralized / Solar Photovoltaic systems. - Promote environment friendly and energy efficient green buildings - Promote private investments in the renewable energy sector

SYSTEM ANALYSIS AND SCENARIOS

System analysis and Scenarios

With an economic growth rate of 11% in financial year 2013-14 due to good performance of agriculture sector and expansion of services sector, Madhya Pradesh is the leading state in India in terms of growth. The growth rate has been consistently more than 9% since year 2009-10.

Based on the analysis of the Water Resources System and in order to achieve the vision of the Government, it is necessary to analyze the system to ascertain its flexibility and/ or limitations in meeting the pressures of growth in a sustainable manner. The analysis leads to the basis of identifying suitable measures and strategies in meeting the evident challenges.

The leading area of enquiry is the status of water demand and supply - both in terms of quality and quantity. In terms of water demand- domestic (includes drinking), agriculture and industrial water demand components have been projected and analyzed.

Demand Analysis-Domestic Water:

The per capita demand for urban area till 2031 is taken as 135 lpcd. In absence of any forecast beyond 2031, it is appropriate to take 150 lpcd for urban area from 2031 to 2051. For rural area present per capita demand is taken as 45 lpcd. In absence of any future forecast for per capita demand, for the purpose of assessing the future demand, 55 lpcd for 2021, 70 lpcd in 2031, 85 lpcd in 2041 and 100 lpcd in 2051 has been taken as the per capita use.

Assessment of Population of the urban and rural areas of the district for estimating future domestic water demand has been done using following methods:

1. Arithmetic Mean Method
2. Geometrical calculation method
3. Incremental increase method
4. Logistic curve method
5. By Research paper:-*Demographic Projections for India 2006-2051: Regional variations". presented by Aslam Mahmood and Amitabh Kundu Jawaharlal Nehru University New Delhi*

To find out best appropriate method for future projection, populations of the year 1981 is taken as the base year and the population of successive three decades calculated using above methods. The population so arrived at has been compared with the actual figures of census. The method which gives the least variation has been used for population projection from the year 2021 to 2051.

For assessment of urban and rural population, average 2% decadal decrease of rural population has been taken. This is based on the analysis of the rural population data from year 1901 to 2011, which shows average % decadal decrease. The projected population of the districts in Sind sub-basin is as shown in Table 36 and projected domestic water demand is shown in Figure 108 and Figure 109.

Table 36: District wise Present and Projected Population of Sind sub-basin

Year	Vidisha	Ashok nagar	Guna	Shivpuri	Datia	Gwalior	Sheopur	Morena	Bhind
2011	1,458,875	845,071	1,241,519	1,726,050	786,754	2,032,036	687,861	1,965,970	1,703,005
2021	1,719,588	992,371	2,399,257	2,076,300	1,106,060	2,078,726	704,147	3,048,518	1,856,543
2031	1,896,824	1,165,347	2,656,864	2,299,458	1,273,961	2,236,307	822,253	3,365,031	2,007,364
2041	2,004,533	1,368,473	2,813,416	2,435,075	1,375,998	2,332,071	950,989	3,557,381	2,099,020
2051	2,065,494	1,607,004	2,902,022	2,511,832	1,433,749	2,386,272	1,090,355	3,666,247	2,150,896

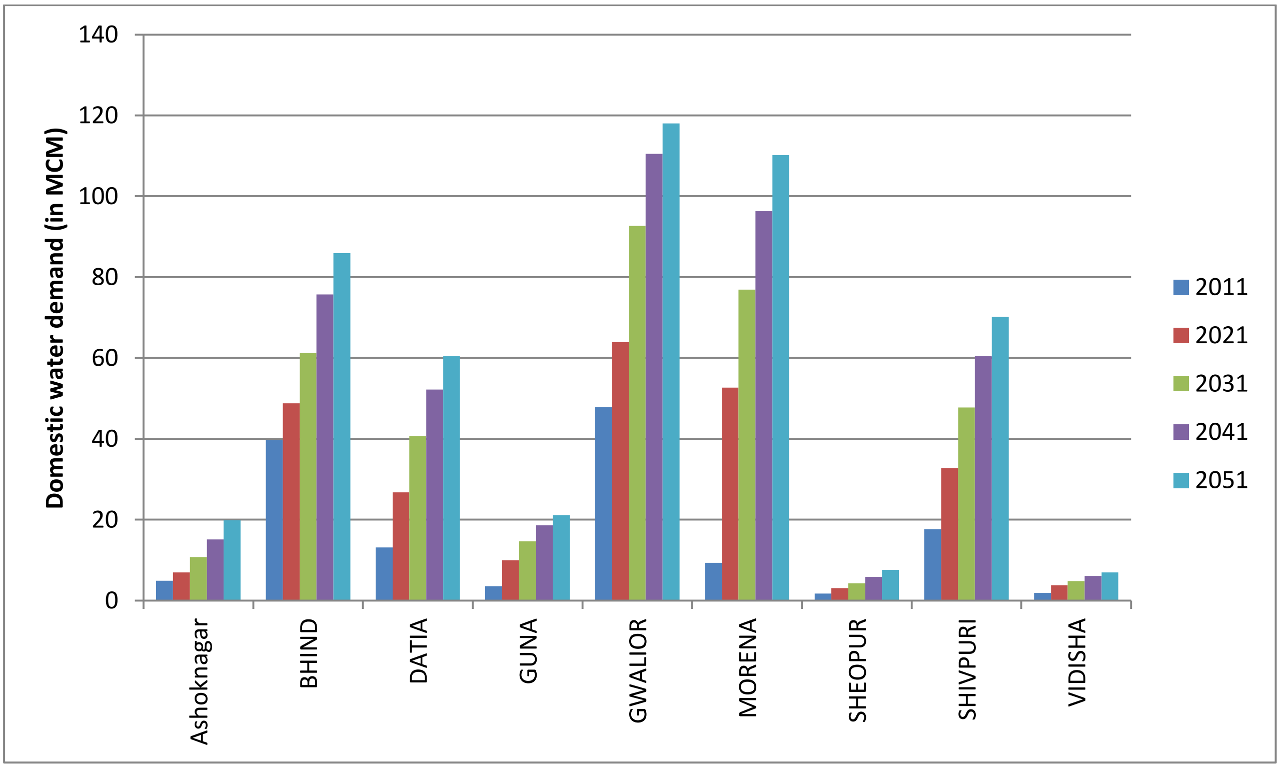


Figure 108 : District wise Projected Domestic water demand for 2011 to 2051

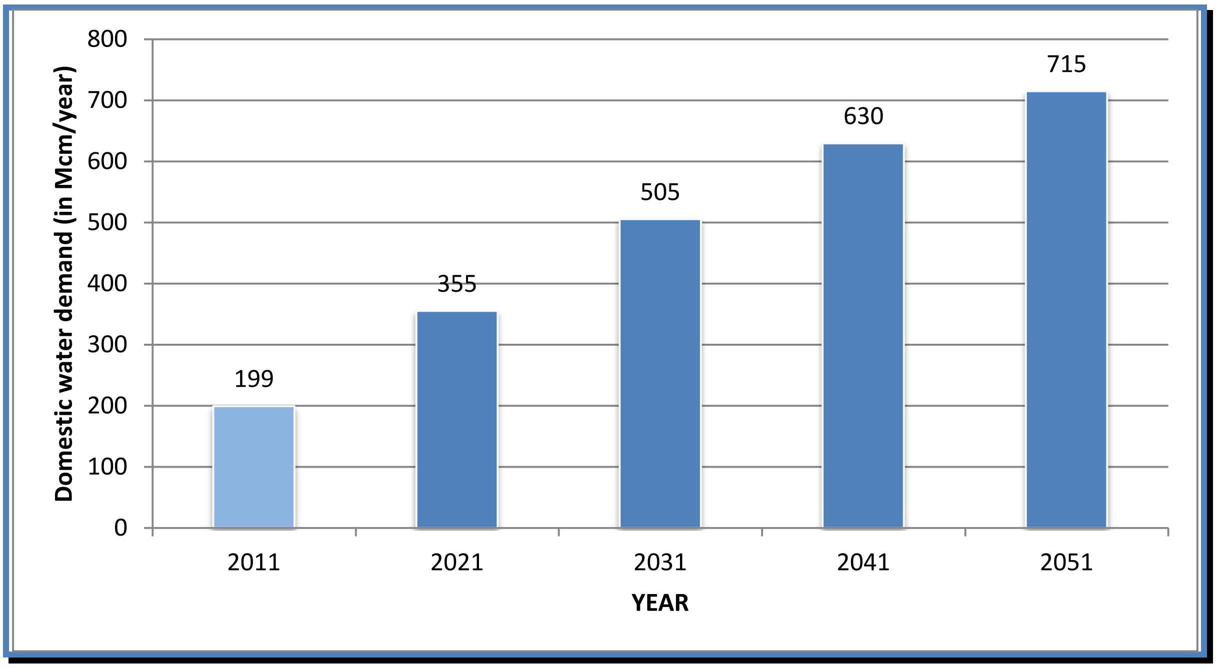


Figure 109 : Projected Domestic Water Demand of Sind sub-basin

Demand Analysis - Agriculture Water:

Determining the future water demand for agriculture use is a much more complicated than the calculation of the demand of water for domestic supply. In agriculture there are many factors that have to be included in the water demand calculation such as the cropping pattern, crop varieties, cropping intensities, irrigation methods, water use efficiency, effect of climatic change, effective rainfall, evapo-transpiration etc. The agricultural (irrigated) area, crops to be grown, cropping intensities etc. are choice of farmers. By increasing the irrigation area and cropping intensities a higher level of agricultural output will be gained. At a certain moment the available water will become leading factor to choose the crop. Market rates and government policies also affect the choice of the cropping pattern.

Scenarios

In spite of above said factors we tried to find future demand taking 3 Scenario. In Scenario 1 it is assumed that kharif sown area increase from 684 to 980 Th.ha i.e. area of uncultivated land in kharif season is now cultivated by 50%. In Scenario 2 kharif crop area becomes 1277 Th.ha i.e 100% double crop in basin or crop intensity is 200% and in Scenario 3 no changes in present area of cultivation (Table 37) but change in cropping pattern. For each scenario cropping pattern is taken as shown in Table 38.

Table 37: Cultivated Area under Different Scenarios (in Th. ha)

Crop Season	Base line (2013)	Scenario 1	Scenario 2	Scenario 3	Remark
Rabi	1277	1277	1277	1277	No change in Rabi area
Kharif	684	980	1277	684	**Scenario 1** kharif sown area increase from 684 to 980 Th.ha i.e. area of uncultivated land in kharif season is now cultivated by 50% **Scenario 2** kharif crop area becomes 1277 Th.ha. i.e 100% double crop in basin or crop intensity is 200% **Scenario 3** no changes in present area of cultivation, but change in cropping pattern

Table 38: Percentage Sown area of Major Crops in different Scenarios

Crop season	Crop	Sown area in %			
		Base line (2013)	Scenario 1	Scenario 2	Scenario 3
Rabi	Wheat	44	50	60	30
	Mustard	32	25	30	30
	Gram	16	25	10	40
Kharif	Soyabean	33	60	55	50
	Bajra	17	15	10	40
	Paddy	10	25	35	10

For different scenarios, district wise, month wise and crop wise Crop Water Requirement in field (CWR) and Net Irrigation Requirement (NIR) has been worked out and are shown in Table 39 to Table 44.

Scenario 1:

Table 39: Scenario 1 - Estimated Water Requirement

S.No	District	Area in Th. ha		Crop Water Requirement in field (MCM)			Net Irrigation Requirement in field (MCM)		
		Rabi	Kharif	Rabi	Kharif	Total	Rabi	Kharif	Total
1	Ashoknagar	85	70	330	443	773	330	131	**461**
2	Bhind	300	163	1083	997	2080	1083	383	**1466**
3	Datia	229	164	846	1007	1853	846	313	**1159**
4	Guna	32	43	125	269	394	125	71	**196**
5	Gwalior	197	144	709	885	1594	709	296	**1005**
6	Morena	184	128	662	786	1448	662	279	**941**
7	Sheopur	23	21	90	130	220	90	60	**150**
8	Shivpuri	190	215	743	1366	2109	743	450	**1193**
9	Vidisha	39	34	133	205	338	133	62	**195**
	Total	1279	982	4721	6088	10809	4721	2045	6766

Table 40: Scenario 1 - Estimated Monthly Crop Water Requirement in MCM

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	Total
CWR	1342	1809	1710	1227	511	997	1209	1304	700	0	0	0	**10809**
NIR	878	504	174	489	511	997	1209	1304	700	0	0	0	**6766**

Scenario 2:

Table 41: Scenario 2 - Estimated Water Requirement

S.No	District	Area in Th. ha		Crop Water Requirement in field (MCM)			Net Irrigation Requirement in field (MCM)		
		Rabi	Kharif	Rabi	Kharif	Total	Rabi	Kharif	Total
1	Ashoknagar	85	80	339	557	896	339	180	**519**
2	Bhind	300	293	1111	1979	3090	1111	805	**1916**
3	Datia	229	220	867	1490	2357	867	511	**1378**
4	Guna	32	43	128	296	424	128	86	**214**
5	Gwalior	197	190	728	1287	2015	728	468	**1196**
6	Morena	184	175	679	1185	1864	679	454	**1133**
7	Sheopur	23	23	92	161	253	92	78	**170**
8	Shivpuri	190	215	764	1502	2266	764	536	**1300**
9	Vidisha	39	39	137	263	400	137	87	**224**
	Total	1279	1278	4845	8720	13565	4845	3205	8050

Table 42: Scenario 2 - Estimated Monthly Crop Water Requirement in MCM

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	Total
CWR	1839	2698	2353	1830	417	1060	1201	1328	839	0	0	0	**13565**
NIR	1204	928	287	786	417	1060	1201	1328	839	0	0	0	**8050**

Scenario 3:

Table 43: Scenario 3 - Estimated Water Requirement

S.No	District	Area		Crop Water Requirement in field (MCM)			Net Irrigation Requirement in field (MCM)		
		Rabi	Kharif	Rabi	Kharif	Total	Rabi	Kharif	Total
1	Ashoknagar	85	55	316	297	613	316	72	**388**
2	Bhind	300	63	1037	329	1366	1037	112	**1149**
3	Datia	229	99	812	517	1329	812	128	**940**
4	Guna	32	43	120	230	350	120	50	**170**
5	Gwalior	197	91	679	476	1155	679	132	**811**
6	Morena	184	73	634	379	1013	634	114	**748**
7	Sheopur	23	18	86	98	184	86	41	**127**
8	Shivpuri	190	215	710	1169	1879	710	325	**1035**
9	Vidisha	39	28	127	145	272	127	36	**163**
Total		**1279**	**685**	**4521**	**3640**	**8161**	**4521**	**1010**	**5531**

Table 44: Scenario 3 - Estimated Monthly Crop Water Requirement in MCM

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	Total
CWR	872	986	1111	671	712	876	1235	1279	419	0	0	0	**8161**
NIR	572	141	71	226	712	876	1235	1279	419	0	0	0	**5531**

Crop water requirement and net irrigation requirement for baseline year 2013 is shown in Table 28. Total CWR and NIR are summarized and shown in Table 45.

Table 45: Scenario wise estimated Crop water requirement (CWR) and net irrigation requirement (NIR) in MCM

Scenario	CWR in MCM	NIR in MCM
Baseline (2013)	8426	5819
Scenario 1	10809	6766
Scenario 2	13565	8050
Scenario 3	8161	5531

Groundwater Development Scenario:

The CGWB has estimated the groundwater availability and draft (abstractions) classified on administrative units blocks and districts. The current groundwater draft and the projected draft for year 2033 based on agriculture, domestic and industrial demands, as estimated by CGWB is tabulated in Table 46. The gross groundwater abstractions is depicted, district wise by map in Figure 110.

CGWB has instead of agriculture demand, calculated the projected water likely to be available for irrigation purpose. From the table, it appears that some scope for groundwater development exists in Morena and Bhind districts. On the other side the groundwater resources of Shivpuri requires close monitoring and protection from increased abstractions.

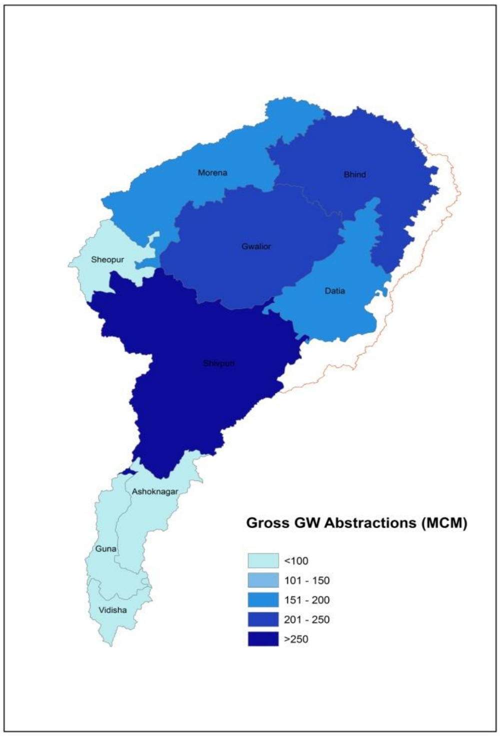


Figure 110 : Gross GW Abstractions in MCM

Table 46: Net Available Groundwater Resource, Utilization and Stage Of Development

S. No.	District	Net Ground Water Availability (MCM)	Annual Ground Water Draft (MCM)			Allocation For Domestic & Industrial Water Uses-Year 2033 (MCM)	Net Ground Water Availability for Future (Year 2033) Irrigation use (MCM)	Stage of ground water development (%)
			Irrigation	Domestic& Industrial Water Supply	Total			
1	Ashoknagar	121.28	45.22	5.44	50.66	7.73	68.32	**42%**
2	Bhind	552.52	183.21	25.56	208.76	36.74	332.57	**38%**
3	Datia	334.20	175.95	15.68	191.63	18.21	140.04	**57%**
4	Guna	120.73	63.93	4.85	68.78	6.93	49.87	**57%**
5	Gwalior	507.86	192.21	23.36	215.57	36.49	279.16	**42%**
6	Morena	456.11	164.63	31.31	195.95	48.44	243.03	**43%**
7	Sheopur	67.45	22.48	2.18	24.67	2.96	42.02	**37%**
8	Shivpuri	480.75	307.42	21.99	329.41	29.91	143.42	**69%**
9	Vidisha	55.73	25.42	2.46	27.88	3.46	26.85	**50%**
Total		**2696.63**	**1180.47**	**132.83**	**1313.31**	**190.88**	**1325.28**	49%

Based on the stage of groundwater development i.e. ratio of annual groundwater draft and net annual groundwater availability, the blocks/ districts are classified as safe, semi-critical, critical and over-exploited. Criteria for categorization of assessment unit are given in Table 47.

Table 47: Criteria for Categorization of Assessment Units

Stage of Ground Water Development	Significant Long Term Water level Decline trend		Category
	Pre-Monsoon	Post-Monsoon	
<=70%	No	No	Safe
>70% and <=90%	No/Yes	Yes/No	Semi-Critical
>90% and <=100%	Yes	Yes	Critical
>100%	No/Yes	Yes/No	Over-Exploited

The long term ground water level data should be for the period of 10 years. As per Central Expert Committee of CGWB, the significant rate of water level decline may be taken between 10 and 20 cm per year depending upon the local hydro-geological conditions. In Sind sub-basin, the significant rate of water level decline is considered more than 10 cm per year for alluvium as well as hard rock.

Based on the categorization criteria, all the districts in the basin are in the category of "safe". Yet, the groundwater development stage of Shivpuri, Guna and Datia districts are very high.

The stage of development in Shivpuri district (68%) is quite close to being in the "semi-critical" category.

For critical analysis of GW status, the categorization done on the basis of small assessment units i.e. blocks. Out of 24 blocks in the basin, 17 blocks found "safe" while 7 blocks Non-command area fall under "Semi-Critical" category.

None of the blocks come under Critical or Over-exploited category as shown in Table 47 and Figure 111.

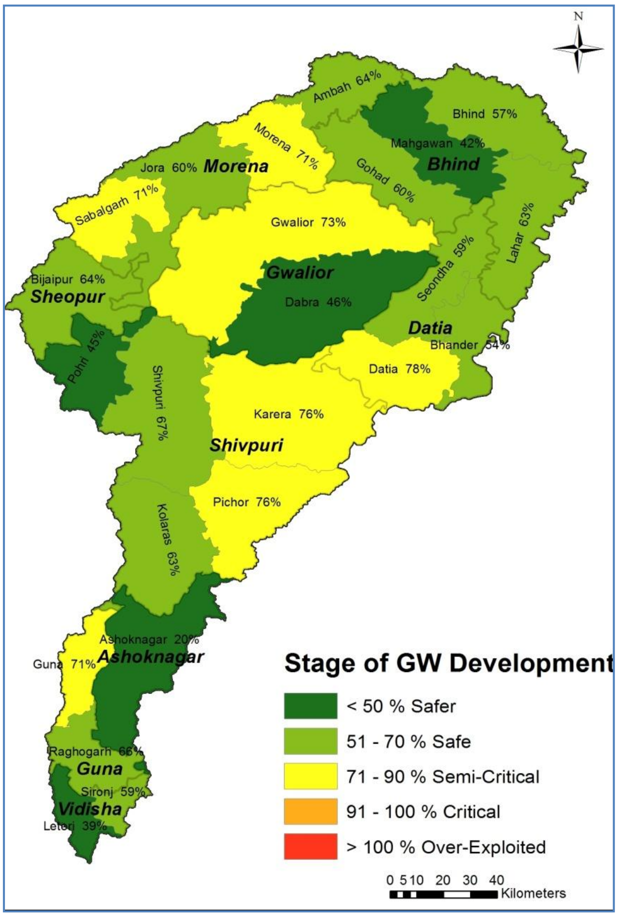


Figure 111: Ground water status in Sind sub-basin

Table 48: Block wise Categorization of Ground Water

Sno	District	Assessment Unit	Sub-unit	Stage of Ground Water Development %	Category
1	Asoknagar	Ashoknagar	Command	-	-
2	Asoknagar	Ashoknagar	Non-Command	20	Safe
3	Bhind	Bhind	Command	16	Safe
4	Bhind	Bhind	Non-Command	57	Safe
5	Bhind	Gohad	Command	20	Safe
6	Bhind	Gohad	Non-Command	60	Safe
7	Bhind	Lahar	Command	19	Safe
8	Bhind	Lahar	Non-Command	63	Safe
9	Bhind	Mehgaon	Command	16	Safe
10	Bhind	Mehgaon	Non-Command	42	Safe
11	Datia	Bhander	Command	19	Safe
12	Datia	Bhander	Non-Command	54	Safe
13	Datia	Datia	Command	42	Safe
14	Datia	Datia	Non-Command	78	**Semi-critical**
15	Datia	Seondha	Command	39	Safe
16	Datia	Seondha	Non-Command	59	Safe
17	Guna	Guna	Command	-	-
18	Guna	Guna	Non-Command	71	**Semi-critical**
19	Guna	Raghogarh	Command	10	Safe
20	Guna	Raghogarh	Non-Command	66	Safe
21	Gwalior	Dabra	Command	20	Safe
22	Gwalior	Dabra	Non-Command	46	Safe
23	Gwalior	Morar	Command	-	-
24	Gwalior	Morar	Non-Command	73	**Semi-critical**
25	Morena	Ambah	Command	64	Safe
26	Morena	Ambah	Non-Command	64	-
27	Morena	Joura	Command	21	Safe
28	Morena	Joura	Non-Command	60	Safe
29	Morena	Morena	Command	17	Safe
30	Morena	Morena	Non-Command	71	**Semi Critical**
31	Morena	Sabalgarh	Command	18	Safe
32	Morena	Sabalgarh	Non-Command	71	**Semi-Critical**
33	Sheopur	Vijaypur	Command	26	Safe
34	Sheopur	Vijaypur	Non-Command	64	Safe
35	Shivpuri	Karera	Command	36	Safe
36	Shivpuri	Karera	Non-Command	76	**Semi-Critical**
37	Shivpuri	Kolaras	Command	-	-
38	Shivpuri	Kolaras	Non-Command	63	Safe
39	Shivpuri	Pichor	Command	29	Safe
40	Shivpuri	Pichor	Non-Command	76	**Semi-Critical**
41	Shivpuri	Pohri	Command	15	Safe

Sno	District	Assessment Unit	Sub-unit	Stage of Ground Water Development %	Category
42	Shivpuri	Pohri	Non-Command	45	Safe
43	Shivpuri	Shivpuri	Command	16	Safe
44	Shivpuri	Shivpuri	Non-Command	67	Safe
45	Vidisha	Lateri	Command	-	-
46	Vidisha	Lateri	Non-Command	39	Safe
47	Vidisha	Sironj	Command	9	Safe
48	Vidisha	Sironj	Non-Command	59	Safe

Development Scenario

The ground water resources of the Districts show variation in the resource available and stage of ground water development. In sub-basin, the ground water development is concentrated mainly in Shivpuri, Datia and Guna. Three districts in the basin have stage of development between 50% and 70 %, which requires close monitoring and protection from increased abstractions. Other parts in six districts of the sub-basin have low development of ground water have even below 50 % where GW development works can be planned. Shivpuri district reached at highest ground water development of 69% and requires strict GW management. Sheopur & Bhind with 37% & 38% of development are lowest developed districts in sub-basin. The overall development of sub-basin in ground water point of view is 49 %, which is moderate and safe.

CGWB has estimated the groundwater availability and draft (abstractions) classified on administrative units -blocks and districts. Based on these estimates, the net available rechargeable groundwater resource, utilization and stage of development in Sind sub-basin is given in Table 49.

Table 49: Groundwater Status at a glance

Particulars	
Area of sub-basin	26,082 km^2
Total number of districts	9
Total number of blocks	24
Net annual ground water availability	2697 MCM
Existing gross ground water draft for irrigation	1180 MCM
Existing gross ground water draft for domestic & industrial water supply	133 MCM
Existing gross ground water draft for all uses	1313 MCM
Provision for domestic, and industrial requirement supply to next 25 year	191 MCM
Net ground water availability for future irrigation development	1325 MCM
Number of safe districts	9
Number of safe blocks	17
Number of semi-critical blocks	7
Number of critical blocks	0
Number of over exploited blocks	0

CGWB estimates that the groundwater demand for domestic and industrial use would increase by 43.7% till 2033. Only 14.2% more groundwater would be available for irrigation use than the current abstraction levels. In the line of sight of GoMP's vision, protection of groundwater and promotion of groundwater use in a sustainable manner is an issue/challenge for Sind sub-basin.

Drought Analysis:

The spatial and temporal uneven distribution of rainfall leads to occurrence of drought in different regions. The impacts of droughts are gradual yet immense on the food security, nutritional and other development indices.

The Indian Meteorological Department defines drought in any area when the rainfall deficiency in that area is more or equal to 25% of long term normal. It is further classified in to moderate and severe drought depending upon the rainfall. A period of drought is defined as a year or season in which the total rainfall is less than 75% of the normal. It may further be classified as a year or season of 'moderate drought' if rainfall deficit is between 26 percent and 50 percent and a year or season of 'severe drought' when it is more than 50 percent. When during a long period of years, drought as defined above, occur on at least 20 percent of the years over an area that may be classified as a 'drought prone area.' If the frequency is 40 percent or more, then the area may be termed as 'chronically drought prone area'.

Droughts are common in the basin as well as in the state and country. Due to a string of famines in the pre-independence era, drought management is a fairly institutionalized yet evolving system in the state. The Relief Commissioner and Revenue Administration plays an important role in drought management with the coordination of other departments.

The average annual rainfall of the basin is 875.5 mm. The length of data (1901-2013) for metrological drought analysis is taken from data of 9 district of Sind sub-basin. About 90 % (788 mm) of the annual rainfall occurs during the monsoon period from June to September.

The annual rainfall variation from 1901 to 2013 has been analyzed (Figure 112). Considering the magnitude of percentage rainfall variation from mean and duration of drought, the following are observed:

1. Overall the basin has 'moderate drought' conditions with a highest intensity of 46.1% in the year 1913.
2. In long term data base, two spells of drought years 1986 -1987 and 1991-1992 are identified.
3. Year 2002 had the severest drought in recent history (independent India). This is confirmed from administrative reports of Sheopur, Morena, Bhind, Gwalior, Shivpuri, Guna & Datia being officially declared drought affected.

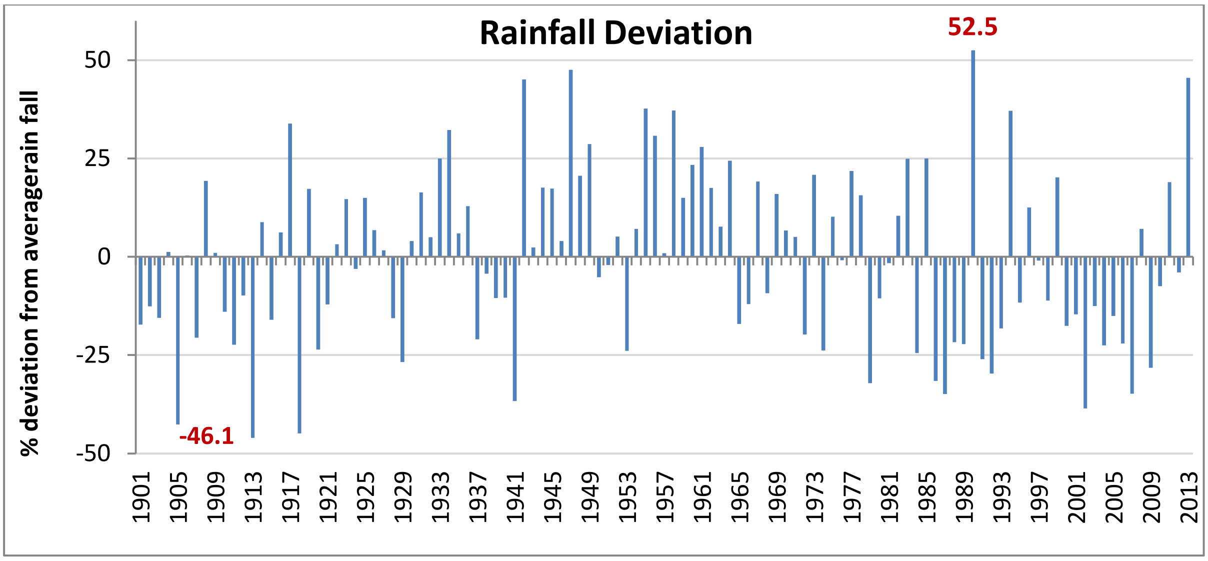


Figure 112: Yearly Rainfall Deviation

District wise drought analysis

Out of 9 districts in Sind sub-basin, none of the districts can be categorized as drought prone area on the basis of long series data (1901-2013). Bhind, Vidisha, Morena and Gwalior districts receive low rainfall and having percentage of drought years for 1901-2013 data are 17%, 16%, 16% and 16% respectively (Table 50).

It is evident from the rainfall deviation study that the incidence of deficient rainfall resulting in droughts is more evident in the last 40 years.

If we consider the long series data for years 1974-2013, the situation of most of the districts changes to being drought-prone.

Table 50: Rainfall Analysis for Drought

District	RF Data series 1901-2013		RF Data series 1974-2013	
	No. of Drought Years	% of drought years in 113 years	No. of Drought Years	% of drought years in 40 years
Datia	16	14%	9	23%
Bhind	19	17%	10	25%
Vidisha	18	16%	9	23%
Ashoknagar	17	15%	11	28%
Guna	15	13%	9	23%
Shivpuri	13	12%	7	18%
Sheopur	15	13%	6	15%
Morena	18	16%	8	20%
Gwalior	18	16%	8	20%
Average	**16.56**	15%	**8.56**	22%

It is inferred from the data that the occurrence of droughts in different districts show an increasing trend in recent years. As the classification of drought prone area under the Drought Prone Area Program (DPAP) is based on classification done in 1973-74, a review of drought prone area based on recent data and better defined "long series" by the central program so that its benefits reach the actual drought affected regions.

Flood Analysis:

As per Indian Metrological Department (IMD) excess rainfall is considered, if the rainfall is excess of 20% of normal rainfall. Considering the magnitude of percentage rainfall variation from mean rainfall, the district wise characteristics are shown in Table 51.

Table 51: Rainfall Analysis for Excess Rainfall Source- www.nih.ernet.in

Sno	District	RF Data series 1901-2013			RF Data series 1974-2013		
		No of excess RF year	% of flood years in 113 years	Range of rainfall excess from normal in %	No of excess RF year	% of excess RF years in 40 years	Range of rainfall excess from normal in %
1	Gwalior	23	20%	1.36 % (1909)-52.2% (1942)	6	15%	6.3 % (1981)-51.8 % (1990)
2	Datia	27	24%	0.5% (1946)-58.0 % (1947)	8	20%	2.4 % (1976)-56.2 % (1990)
3	Bhind	25	22%	0.2 % (1976)-55.0% (1947)	7	18%	0.2 % (1976)-49.8% (1990)
4	Vidisha	24	21%	0.2 % (1967)-74.7 % (1934)	8	20%	0.2%(2005)-64.6%(1990)
5	Ashoknagar	18	16%	0.1 % (1927)-72.6 % (2013)	6	15%	0.3 % (2010)-72.6 % (2013)
6	Guna	16	14%	0.6 % (1916)-96.0 % (2013)	5	13%	2.8 % (1997)-96.0 % (2013)
7	Shivpuri	23	20%	0.1 % (1997)-53.7 % (1990)	7	18%	0.1 % (1997)-53.7 % (1990)
8	Morena	23	20%	0.6 % (1950)-53.8 % (1942)	7	18%	2.0 % (1982)-45.2 % (1990)
9	Sheopur	22	19%	0.5 % (1932)-46.8 % (1942)	7	18%	5.0 % (1978)-42.1 % (1994)
Sind sub-basin		**21**	**19%**	**0.4 % (1906)-52.5 % (1990)**	**7**	**18%**	**7.1 % (2008)-52.5 % (1990)**

No area in the Sind sub-basin in Madhya Pradesh falls under the flood prone area mapping of India (Figure 113).

The Central Water Commission has a national network of flood forecasting station and the nearest are located at Etawah and Auraiya in Uttar Pradesh, close to the confluence of Sind with Yamuna.

Madikheda dam is the largest reservoir with high overflow discharge during events of unprecedented rains. Therefore an attempt to create a catchment model for flood forecasting has been made using HEC-HMS and following data.

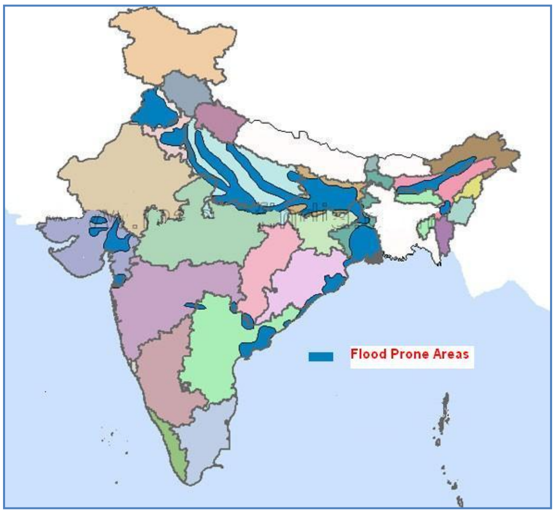


Figure 113 : Flood Prone Area in India

Table 52: Data used for HEC-HMS modeling

Type of Data	Spatial Variation	Temporal variation	Remark
Precipitation	7 Rain gauge Station	Daily	Manually Operated
Discharge	1 Gauge Discharge Site	Daily	Manually Operated
Land Use Map	Whole Basin	NA	Not Recent
Land Cover Map	Whole Basin	NA	Not Recent

Basin model with all hydrological elements is shown in Figure 114. As the available data on precipitation and discharge were on a daily scale, the correction factors and weights were applied to convert the data into 3 hourly increments using TRMM Online Visualization and Analysis System (TOVAS).

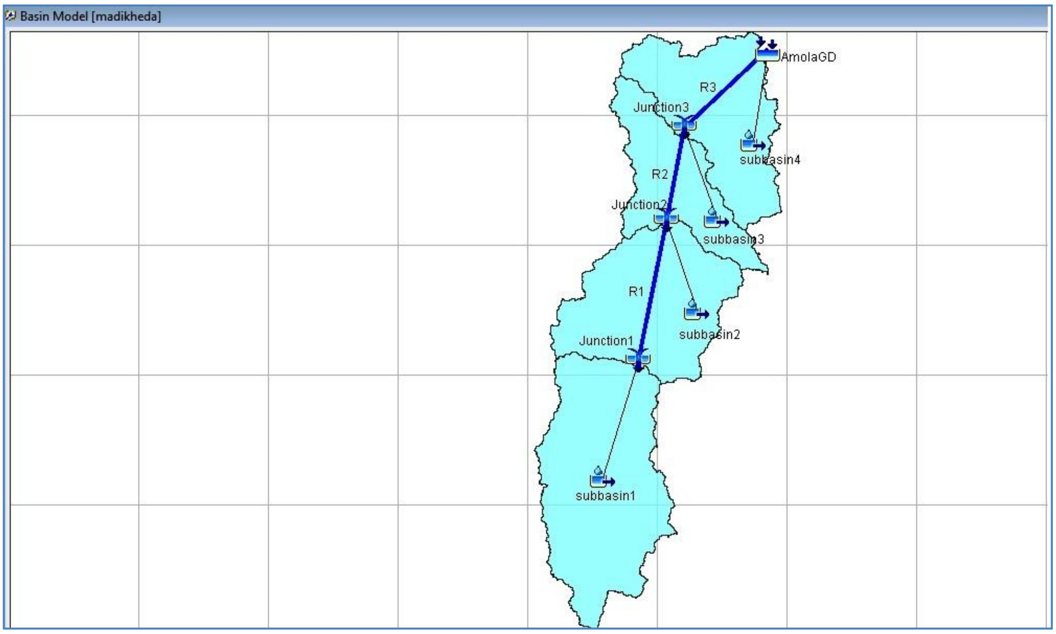


Figure 114 : Basin Model - Madikheda

Though for some of the flood events, the calibrations were satisfactory (Figure 115), in most of the cases, satisfactory calibration could not be achieved.

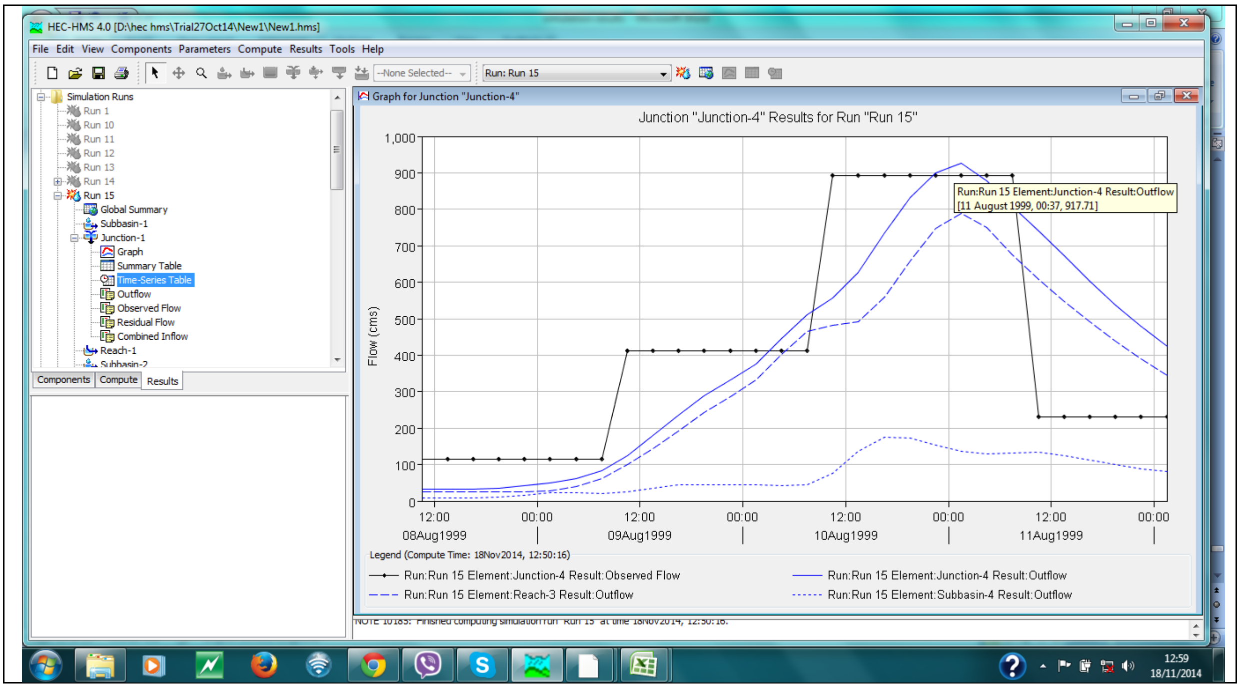


Figure 115 : Sample Calibration

The apparent reasons for the inconsistency in model behavior are:

1. Lack of precipitation data on hourly/ 3-hourly duration requiring its adjustments with TRMM data. TRMM has a very large grid and therefore fails to capture spatial variations.
2. Inconsistency and gaps in discharge data of the 2 gauge-discharge stations.

However keeping in mind that Madikheda dam is a relatively new dam (2008), the model can be further tested with new and reliable data in coming years.

Demand and Allocation Analysis Using WAFLEX

WAFLEX

In order to understand the demand and supply situation of the surface water component, spreadsheet based WAFLEX model was set up. The inflows of the gauged tributaries have been considered. For other important tributaries viz. Parwati, Mahuar, Baisli and Non, simple regionalization method was applied by converting flow measurements of nearby gauge discharge sites into mm/month and then superimposing the depth values onto un-gauged tributary sub-basin.

The list of available gauge discharge stations is given in Table 53.

The inflows into the basin considered show maximum inflows received from Kunwari followed by Parwati and Mahuar. The inflow received from inter-basin transfer is meant for Rabi irrigation from Chambal sub-basin (at Parbati aquaduct) and hence does not follow the usual wet season trend. (Figure 116)

Table 53: Gauge Discharge Stations

GD Code	Station Name
GD1	Behtaghat
GD2	Amola
GD3	Karera
GD4	Goraghat
GD5	LMC_AQ
GD6	Dimni
GD7	Budhara
GD8	Didi
GD9	Khera
GD10	Daboh

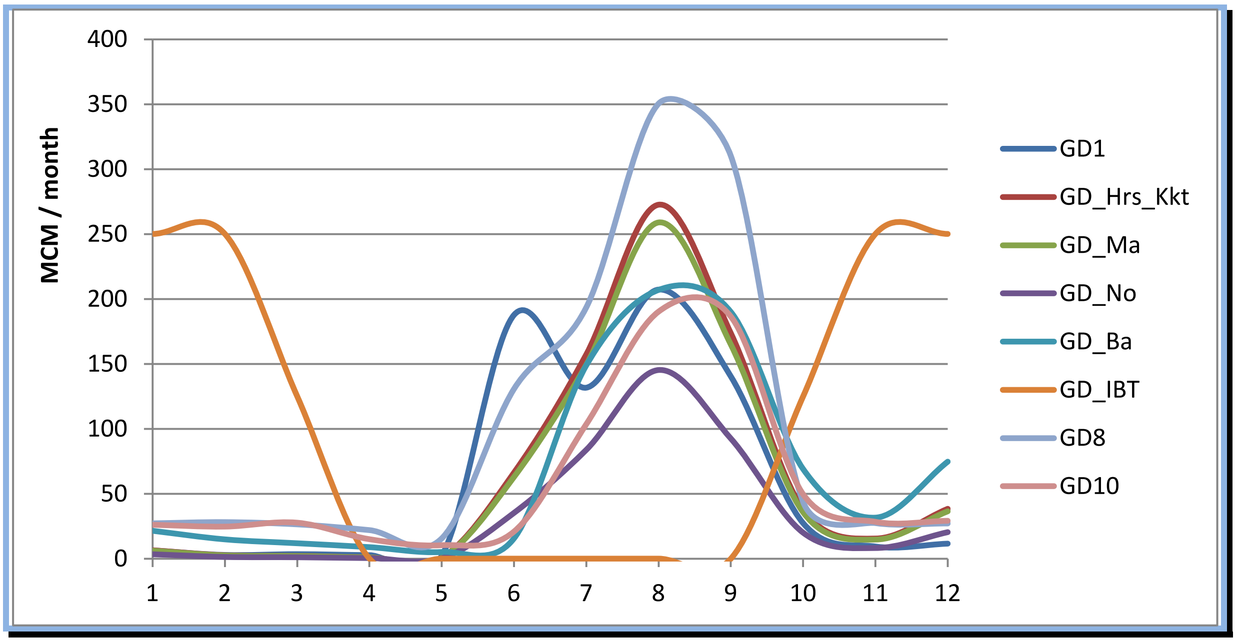


Figure 116 : Monthly Inflows at Different Discharge Gauge Sites

Among the dams- Madikheda, Harsi and Kaketo (including Upper Kaketo) have been considered for their storage capacities. Together, they have storage capacity of 1,175 MCM and water spread area of 9,100 ha catering to more than 200,000 ha of agriculture. The hydropower generation from Madikheda has been considered in the model. Madikheda dam was commissioned in 2008 and in the model it is considered operational from June 2008.

The rainfall time series for Madikheda and Harsi-Kaketo reservoirs have been used for the 295 monthly timesteps from Jun-1988 to Dec-2012 (Figure 117Figure 127).

Madikheda dam releases are based on irrigation demands and hydropower production is incidental.

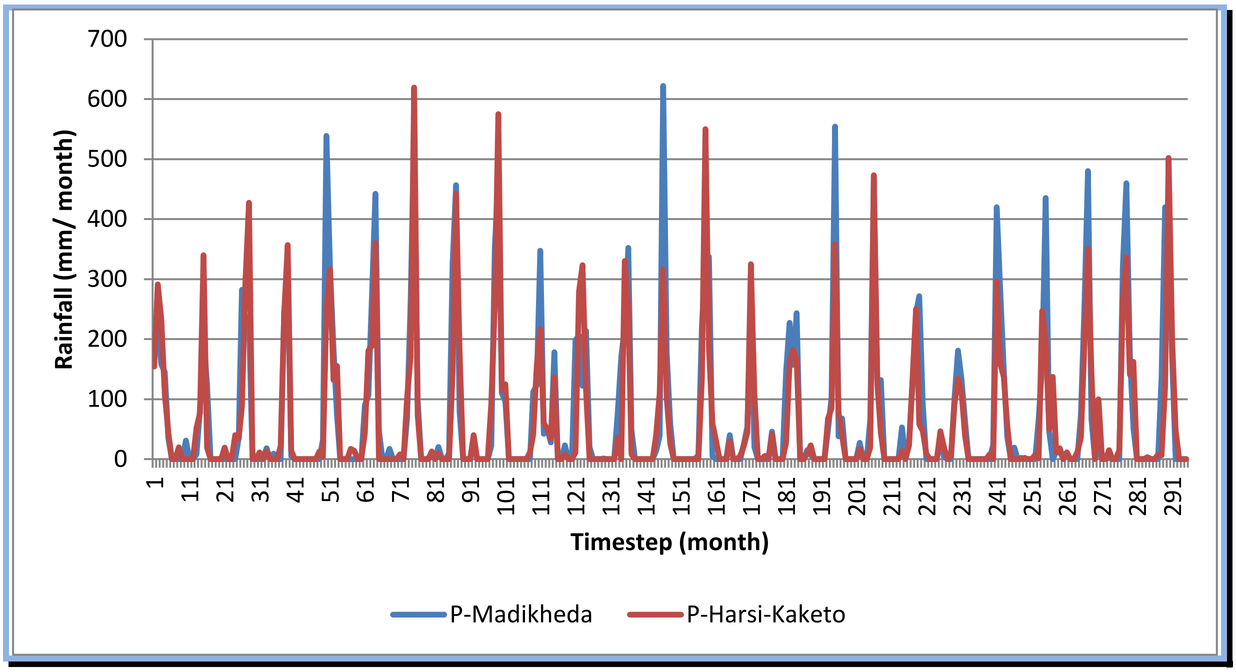


Figure 117 : Monthly Rainfall Pattern of Madikheda and Harsi-Kaketo dam site

Data from Commissioner of Land Records, MP and Department of Agriculture shows that 30% of the gross irrigated area is serviced by surface water sources. Canal irrigation also results in higher return flows than well irrigation and 30% return flows have been adjusted for in demand. FAO publication "Unlocking the Water Potential of Agriculture, 2003" estimates 50% return flows of water withdrawn for agriculture.

A schematic representation of the model is illustrated in Figure 118.

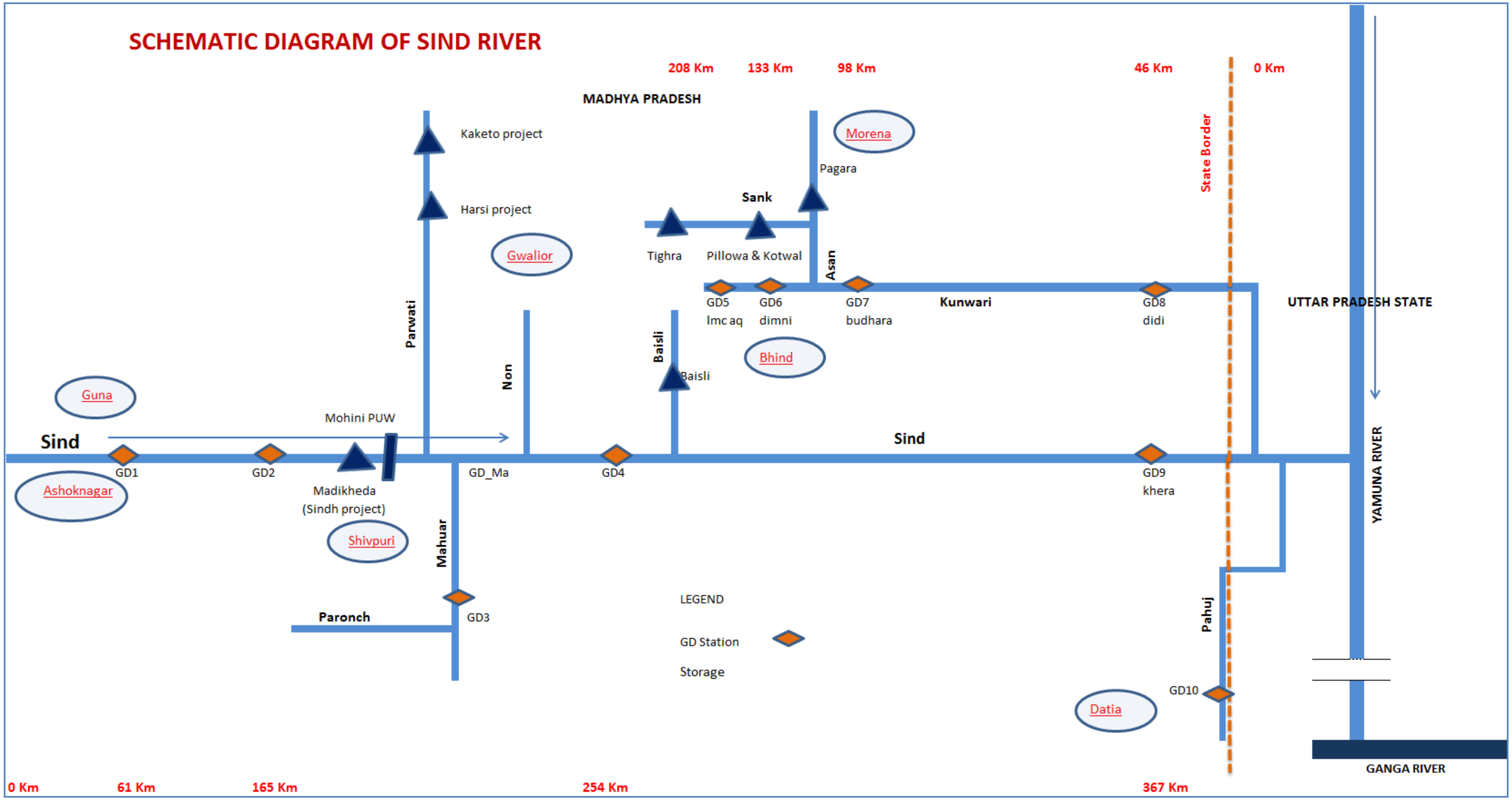


Figure 118: Schematic diagram of Sind sub basin

The following users have been incorporated in the model. "Do", "Ag" and "In" are used as abbreviation for domestic, agriculture and industrial users.

User1: Some parts of Guna and Ashoknagar districts come under other basins and therefore receive water for its various uses from other basins. Proportionate agricultural, domestic and industrial demands have been considered for the area under Sind sub-basin. (Figure 119)

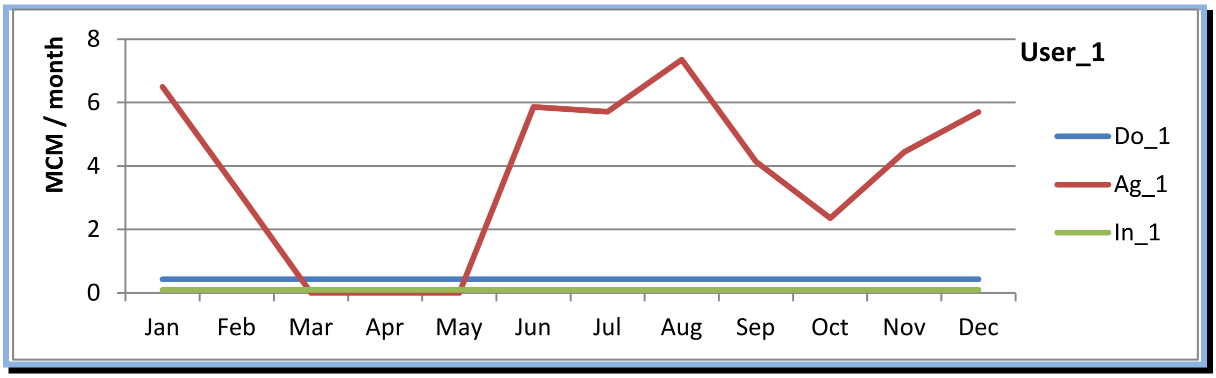


Figure 119 : Monthly Water Demand of User_1

User2: The areas serviced by Madikheda dam (58,000 ha) have been considered for agriculture demand. Also the domestic and industrial water demands have been considered. (Figure 120)

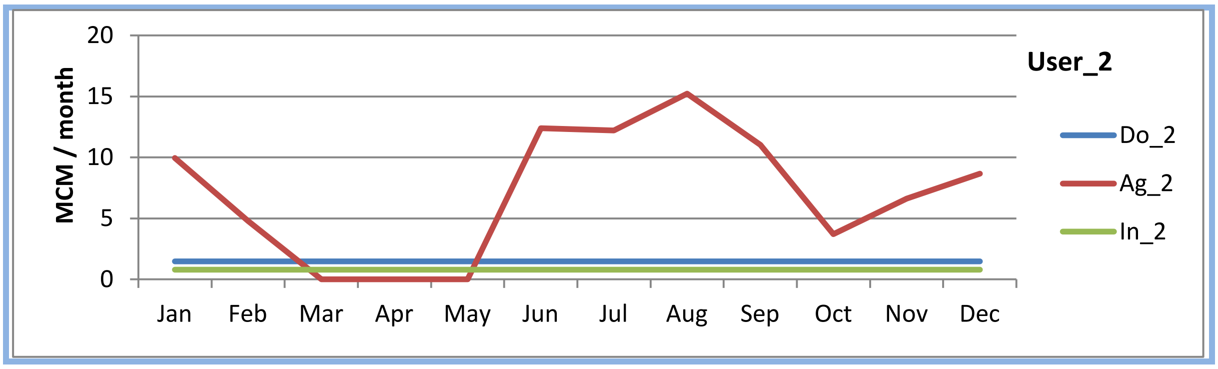


Figure 120 : Monthly Water Demand of User_1

User3: The areas catered to by Harsi-Kaketo complex (70,000 ha) have been considered for agriculture demand. The industrial water demand has also been considered. (Figure 121)

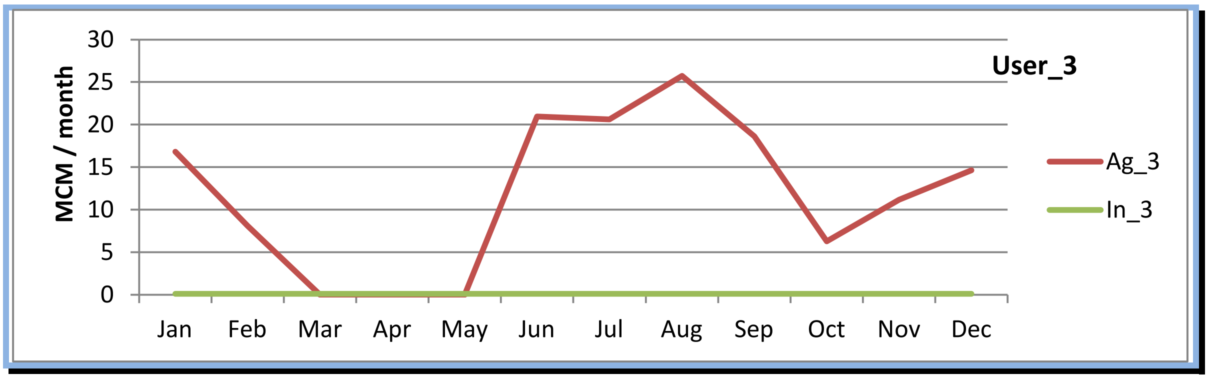


Figure 121 : Monthly Water Demand of User_3

User4: The areas irrigated by Mahuar-Paronch dams (12,000 ha) is considered along with industrial water demand. (Figure 122)

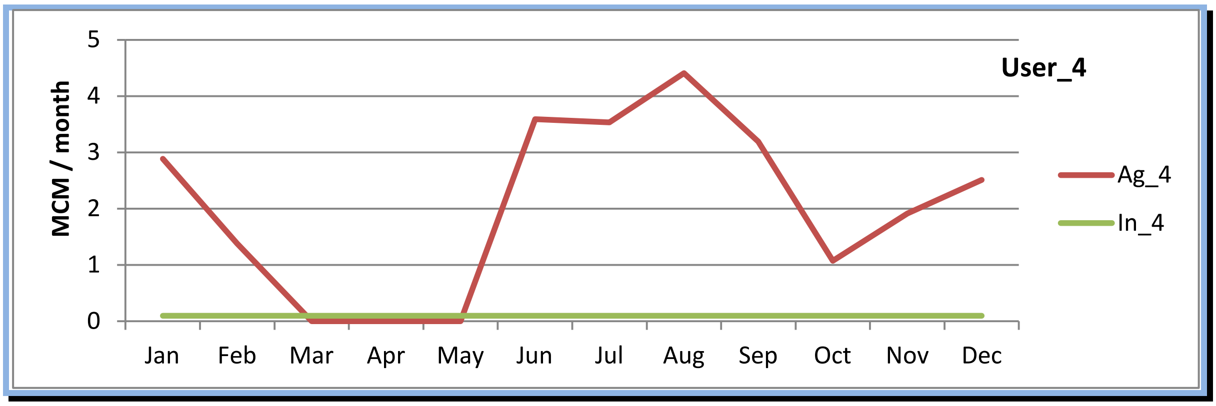


Figure 122 : Monthly Water Demand of User_4

User5: The districts of Morena and Bhind have been considered for this use. 483,500 ha of cropped area are considered for agriculture demand. A little less than half of this area is fed from Chambal Right main Canal system. Remaining 283,500 ha farm area has been considered for agriculture needs. Domestic water supply and industrial water use have also been considered. (Figure 123)

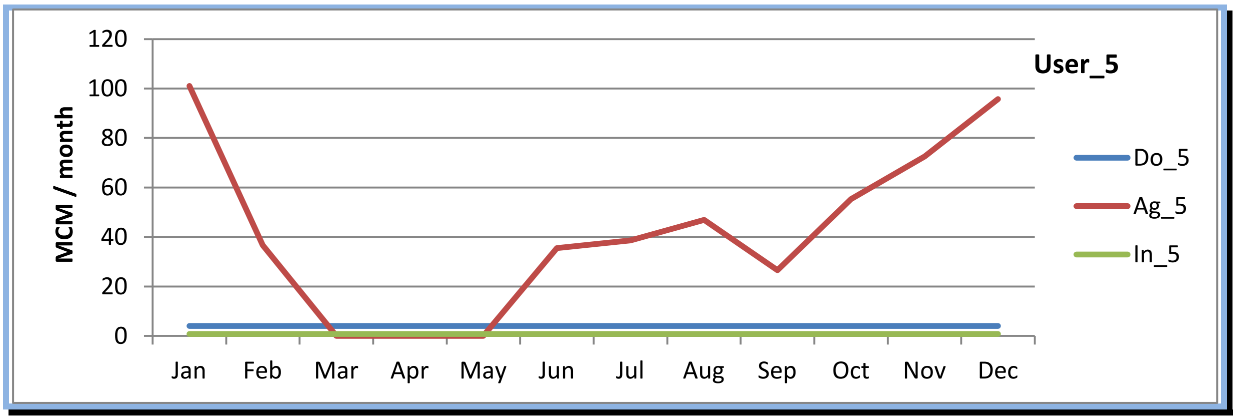


Figure 123 : Monthly Water Demand of User_5

User_IBT: Agriculture water demand of Sheopur, Morena and Bhind districts in 200,000 ha command is catered through inter basin transfer from Chambal. This demand is equal to the inflow from inter basin transfer.

EFR: Although Madhya Pradesh State is not committed to any environmental flow norms for downstream use, an estimated EFR demand based on Tennant method[29] has been derived for nil, 10% MAR and 35% MAR scenarios. (Figure 124) This may not be an accurate assessment of EFR, but could be further refined with biotic demand studies in future.

[29] Tennant D.L., 1976: 'Instream flow regimens for fish, wildlife, recreation, and related environmental resources', in Orsborn, J. F. and Allman, C.H.(Eds), Proceedings of the Symposium and Speciality Conference on Instream Flow Needs II. American Fisheries Society, Bethesda, Maryland. pp. 359–373.

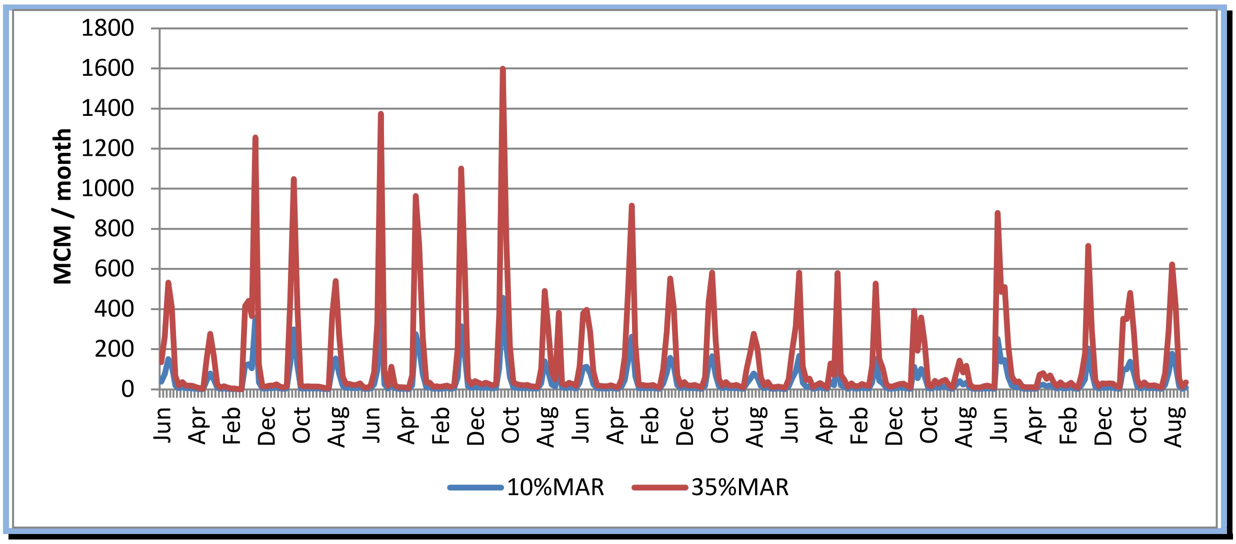


Figure 124 : Estimated Demand for EFR at Sind (MP) sub-basin outlet

Efficiency Criteria of the model:

The evaluation of model performance would be done by comparing the flow at Goraghat gauge discharge site (GD4) and hydropower generation at Madikheda. The criteria used to assess the model performance are coefficient of determination (r^2) and Nash Sutcliffe Efficiency (NSE).

Table 54: Scenarios - Conditions and Basis

Scenario	Conditions	Basis
1a	Baseline scenario with nil EFR	Current scenario
1b	Baseline scenario with 10% MAR as EFR demand	To assess outflow and change in supply
1c	Baseline scenario with 35% MAR as EFR demand	To assess outflow and change in supply
2	2033- No change in inflows, irrigation demand up 5%, domestic demand 2.5 times current and industrial demand 27% more, EFR @35% MAR	IPCC Fourth Assessment Report: Climate Change 2007, Working Group II (estimation of 0.5% more inflows taken as no change), population forecast and industrial growth
3	2033- No change in inflows, irrigation demand up 15%, domestic demand 1.25 times current and industrial demand 27% more, EFR@ 35% MAR	"India's water supply and demand from 2025 to 2050" : Amarsinghe (IWMI), Tushaar Shah & Anand predict 14% growth in agriculture demand, 113% more domestic demand and 27% more industrial demand in Ganga basin

Scenario	Conditions	Basis
4	2033- No change in inflows, irrigation demand up ~60% so as to irrigate for 100% Kharif crops, domestic demand 1.25 times current and industrial demand 27% more, EFR@ 35% MAR	Scenario 2 of the crop water requirement chapter in the plan which has the highest agricultural demand

Results - WAFLEX Calibration

The calibration of the model is observed by comparing the flow at discharge gauge site GD4-Goraghat (Figure 125) and energy production of Madikheda dam (Figure 126). Data on actual energy production of Madikheda dam is available from Jan-2011 to Dec-2012 from the Central Electricity Authority of India.

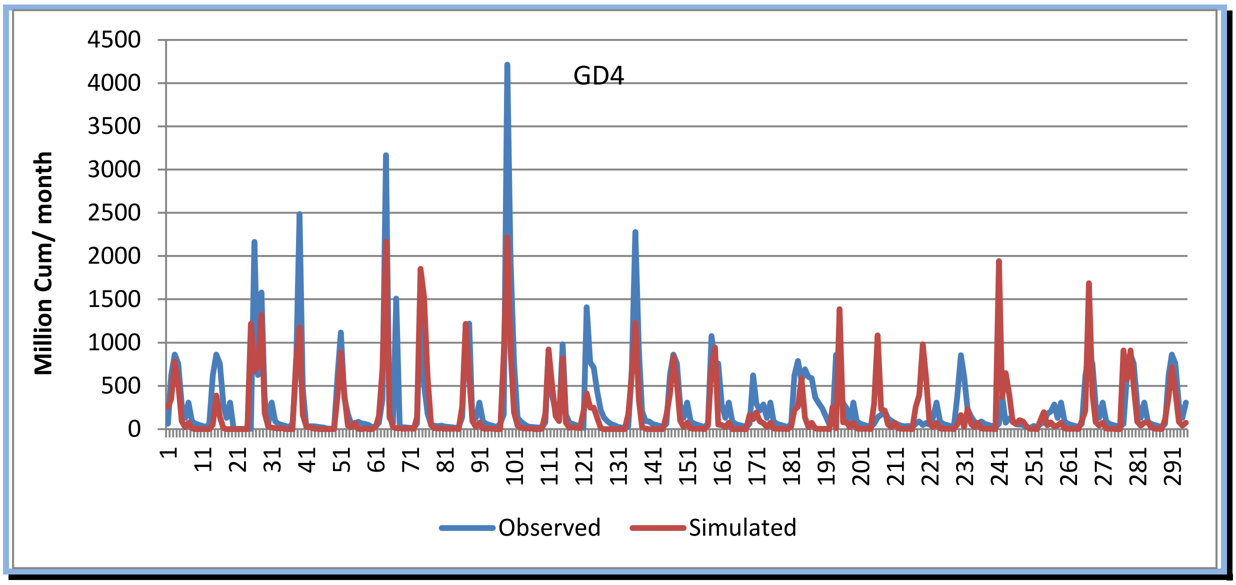


Figure 125 : Observed Vs Simulated Flow at Goraghat GD

It is observed that the model does not imitate some very high monsoon peaks. These variations could be due to the inflows considered by regionalization i.e. from Parwati, Non and Mahuar (data deficient) yielding more flows in few years. As a result the NSE comes to 0.456 and r^2 is 0.493. It is felt that actual gauging of the important tributaries of Parwati and Mahuar would result in better evaluation of the model.

The model calibration is slightly better for hydropower generation with NSE 0.684 and r^2 0.75.

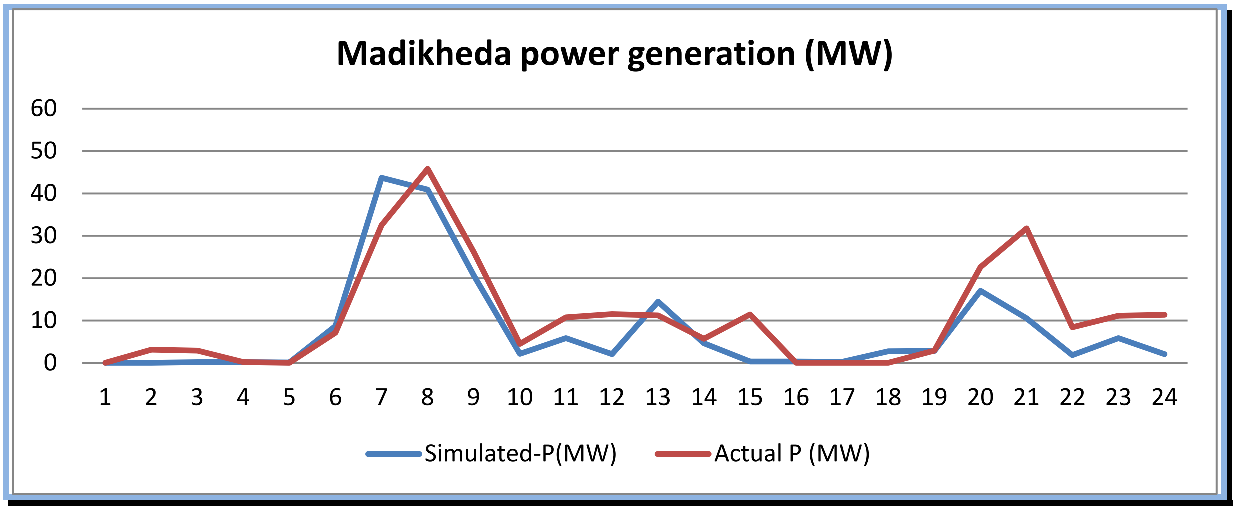


Figure 126 : Madikheda Power Generation (MW) - Simulated Vs Actual

Water Allocation

68.7% of the inflows, outflows from the Madhya Pradesh side of sub-basin into Uttar Pradesh. (Figure 127 and Figure 128)

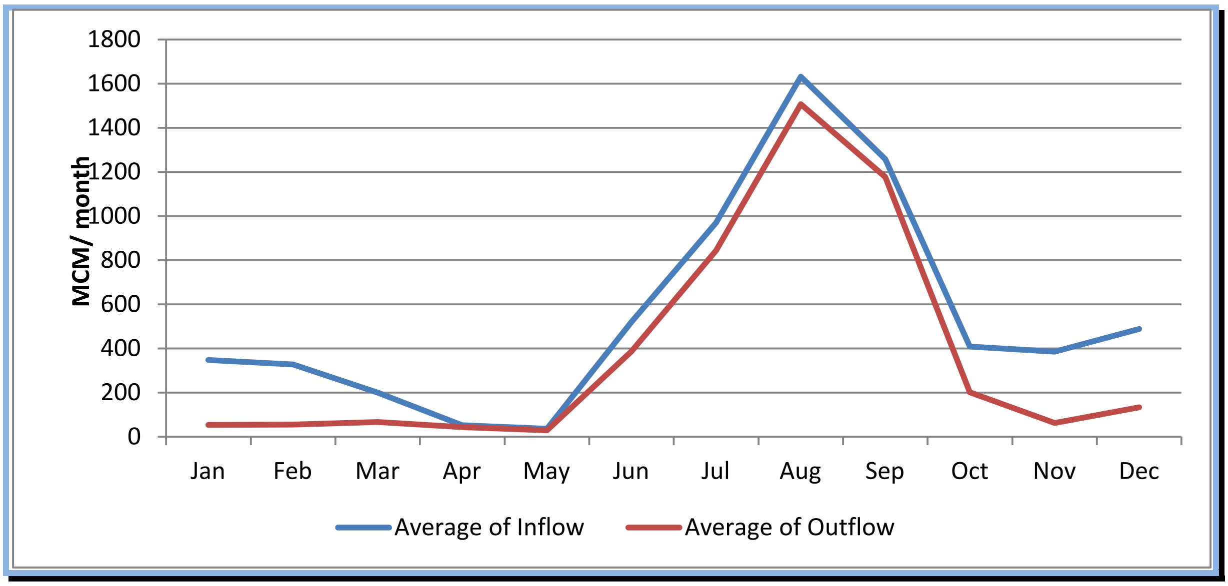


Figure 127 : Average Monthly Inflow Vs Outflow

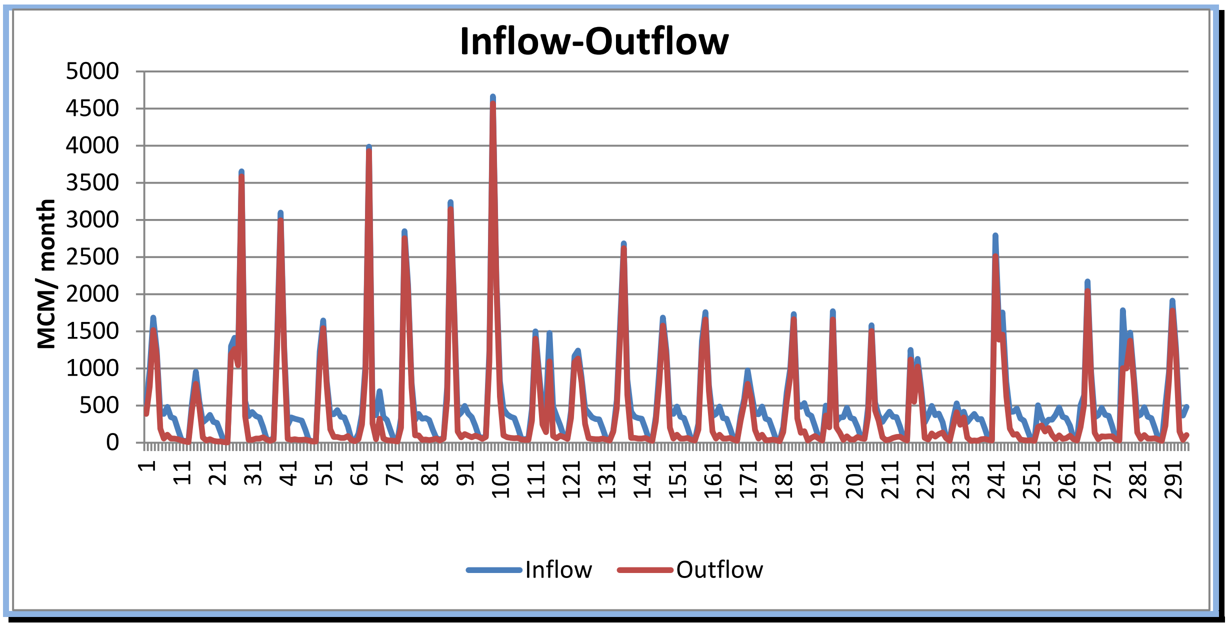


Figure 128 : Month wise Inflow Vs Outflow

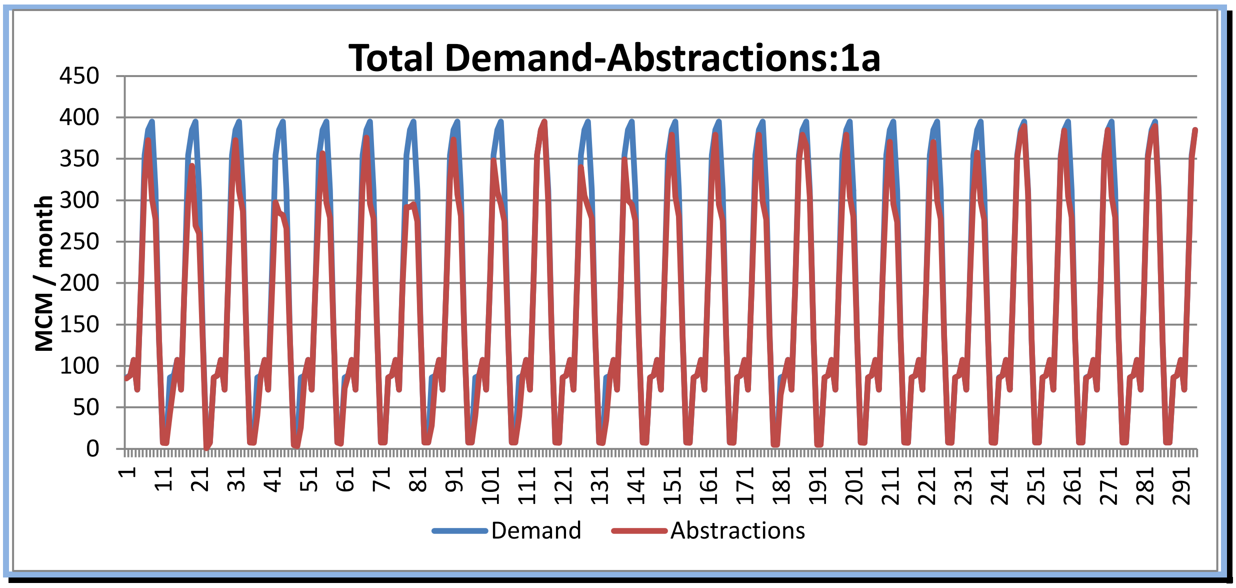


Figure 129 : Scenario 1a - Total Demand Vs Abstractions

Due to spatial mismatch of water availability and demand, shortages are evident in the basin (Figure 129). The agricultural demands from Madikheda and of Morena & Bhind districts (non-Chambal IBT) show shortages (Figure 130). Majority of these shortages (nearly 80%) are seen to occur during the Rabi (winter-crop) season. However, the shortage after the commissioning of Madikheda dam in the year 2008, eases to 9% in the period 2008-2012.

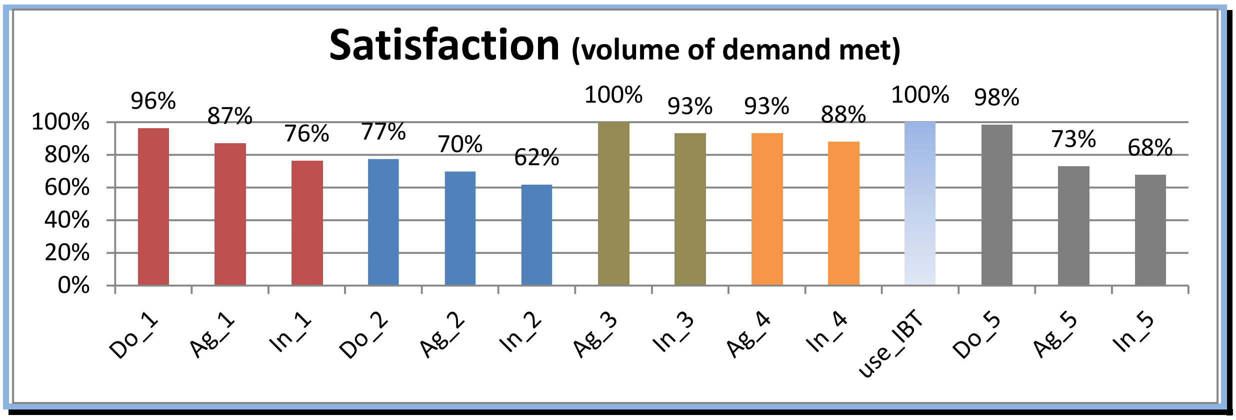


Figure 130 : Scenario 1a- satisfaction in terms of Volume of Demand met

However, the shortage after the commissioning of Madikheda dam in the year 2008, eases to 9% in the period 2008-2012. As Madikheda is a recently constructed dam and as it does not directly command Morena and Bhind districts, it is difficult to ascribe the easing of shortage to its existence. It only indicates that the inter-basin transfer through Chambal canal alone is not enough for meeting the irrigation demands of Bhind and Morena districts.

With consideration of 10% MAR (1b) and 35% MAR (1c) as e-flow or EFR demand, the average annual outflow of 4.55 BCM is enough to meet the e-flow requirement at all times without affecting the satisfaction level of the users due to considerable inflows from Kunwari and Pahuj reaching Sind river before its confluence with Yamuna river (Figure 131 and Figure 132).

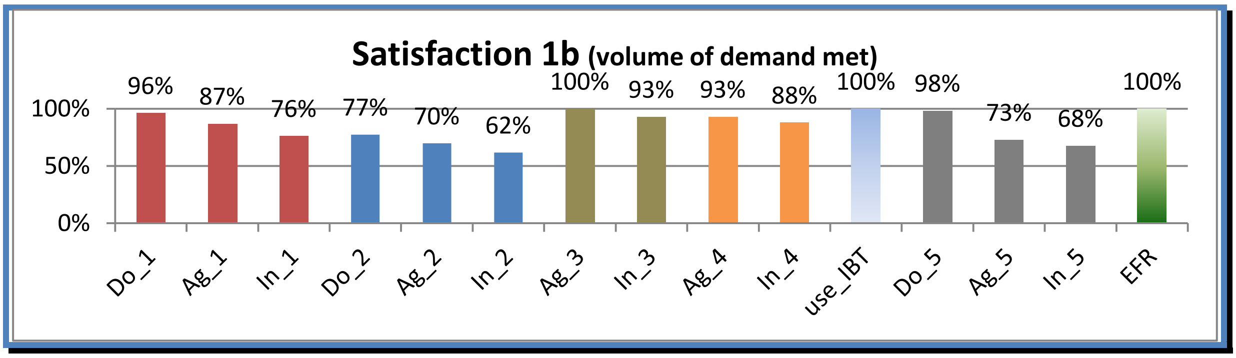


Figure 131 : Scenario 1b - Satisfaction in terms of Volume of Demand met

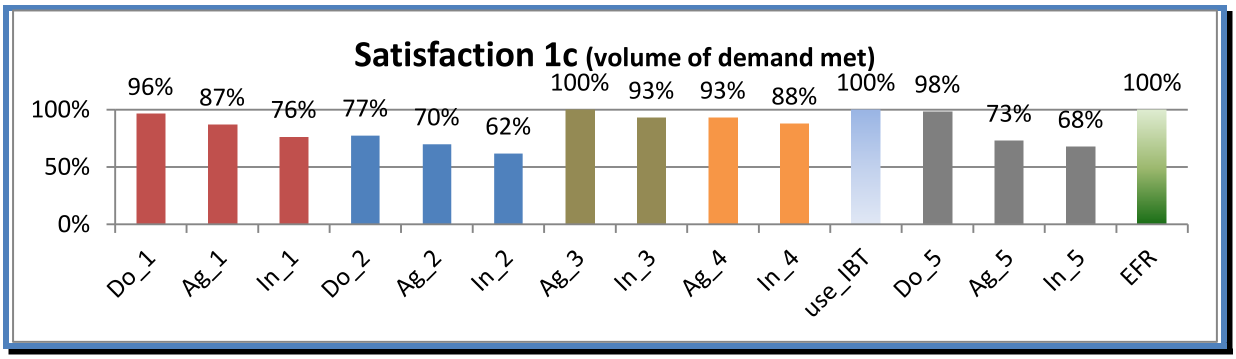


Figure 132 : Scenario 1c - Satisfaction in terms of Volume of Demand met

In case of future scenario 2, with no change in inflows, irrigation demand up by 5%, domestic demand 2.5 times current and industrial demand 27% more and EFR demand of 35% MAR, the availability for users dependent on Madikheda and industrial user in Morena and Bhind districts get affected (Figure 133).

For scenario 3, with no change in inflows, irrigation demand up 15%, domestic demand 1.25 times current and industrial demand 27% more and EFR demand at 35% MAR, the satisfaction levels are slightly better than in scenario 2 (Figure 134).

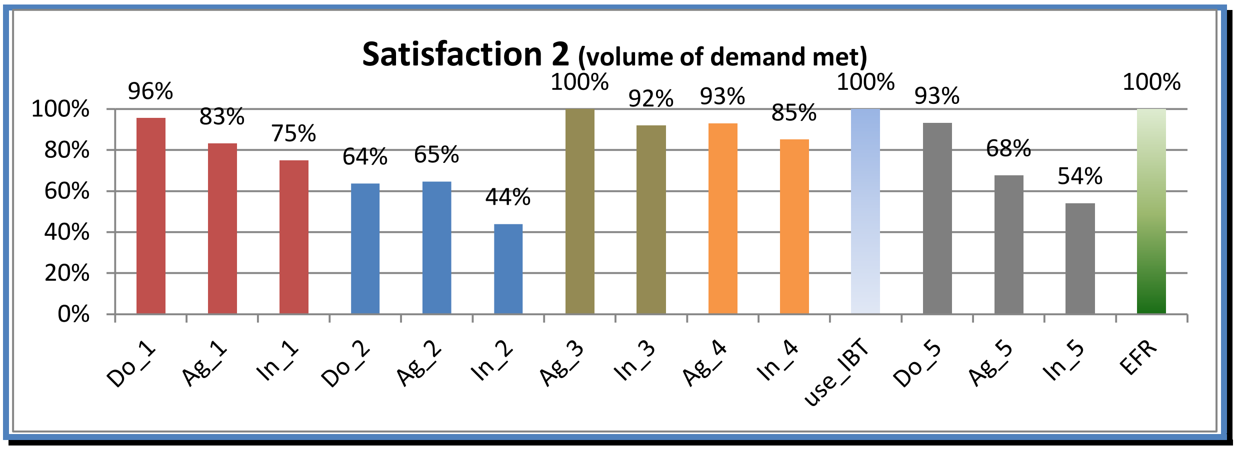


Figure 133 : Scenario 2 - Satisfaction in terms of Volume of Demand met

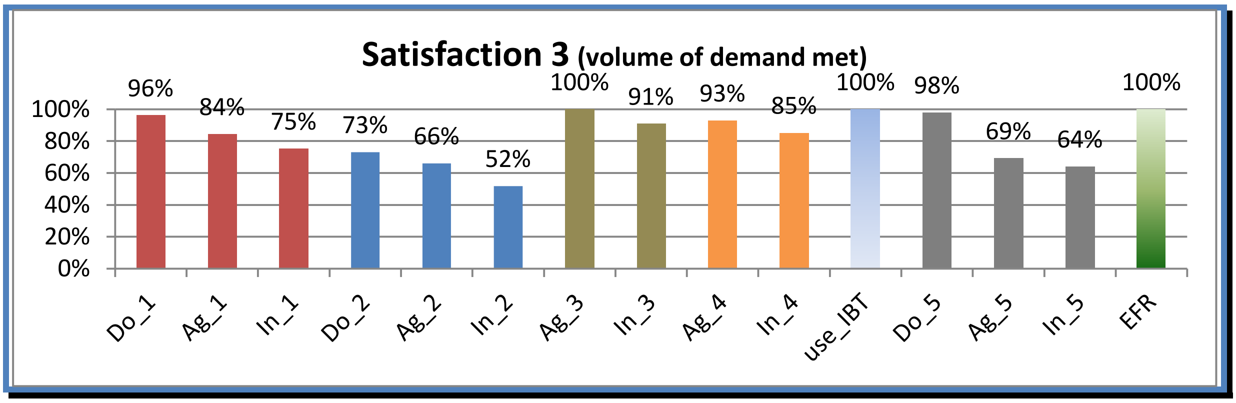


Figure 134 : Scenario 3 - Satisfaction in terms of Volume of Demand met

For scenario 4, with no change in inflows, irrigation demand up by 60% by volume with increase in Kharif demand, domestic demand 1.25 times current and industrial demand 27% more and EFR demand at 35% MAR, the industrial users are affected the most (Figure 135).

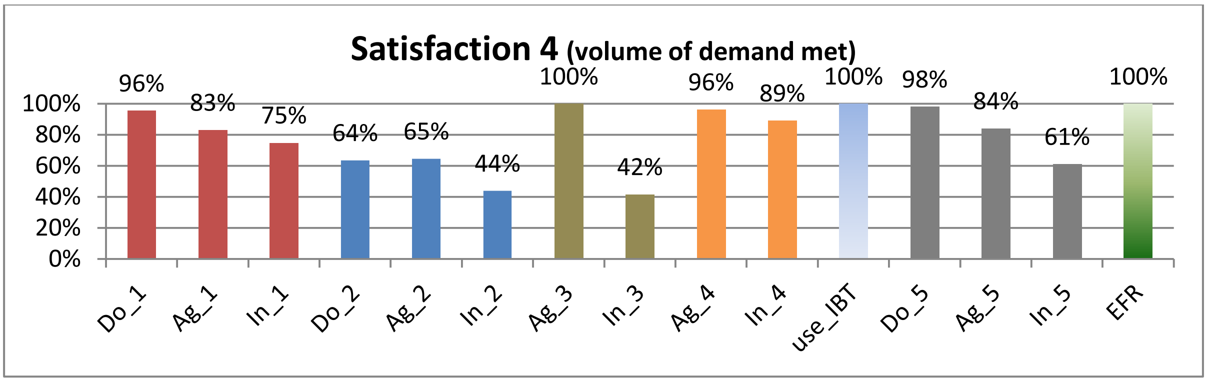


Figure 135 : Scenario 4 - Satisfaction in terms of Volume of Demand met

Very high outflows of Sind sub-basin drains into Yamuna after assuming 35% of MAR as environmental flow demand means Sind is not a closed or over-committed basin. There is scope for water resources development in the basin and the potential of development is at least 1.5 BCM. Temporal variation in water availability and water demand calls for scoping of additional water resources development particularly in the stretch between Non to Baisli river confluence. Due to the spatial and temporal variations in the availability of water and GoMP vision to maximize surface water use, ensuring adequate supply of water for all uses especially to water scarce regions in the basin is a primary issue and challenge.

ISSUES & OBJECTIVES

Issues and Objectives

The situation and system analysis of Sind sub-basin shows that it is vulnerable to the following:

1. Spatial and temporal variation in rainfall impacts the availability and distribution of water amongst uses and users.
2. The basin is highly dependent on agriculture as an economic activity and therefore agriculture dominates all water use.
3. Low water use efficiency in agriculture use leads to avoidable misuse of water resource.
4. Urbanization and urban agglomeration in the basin is evident and with increased population concentration, competing water use shall make allocation decisions more difficult in future.
5. Sind sub-basin has a large forest cover and water resources development needs to balance and maintain its ecological and environmental uniqueness.

Issues and Problems Identification:

In the chapters describing Situation Analysis, System analysis and scenario, a number of challenges and issues in Sind sub-basin have been mentioned.

The shortlist of the current and potential issues can be summarized as below:

1. Poor Scientific Knowledge base for Planning
2. Un-balanced Water Supply & Demand
3. Low Water Use Efficiency
4. Ground Water Depletion
5. Water Quality Deterioration
6. Drought & Flood
7. Poor Co-ordination & Participation
8. Soil Erosion

These issues were discussed with a group of 141 Water Resources Department engineers in Bhopal on 21st July 2014. These issues were also tested in a small group of stakeholders at Shivpuri on 26th July 2014 comprising 3 WUA Presidents, 14 farmers, Deputy Directors of Agriculture, Fisheries and Horticulture, representatives of Municipal Council of Shivpuri, Public Health Engineering Department and Water Resources Department. The latter meeting showed the stakeholder opinion on these issues:

Table 55: Stakeholder Opinion on Identified Issues

Issues	Agree	Disagree	No opinion
Low Water Use Efficiency	44%	4%	52%
Poor Co-ordination & Participation	40%	0%	60%
Drought & Flood	32%	4%	64%
Ground Water Depletion	36%	12%	52%
Poor Scientific Knowledge base for Planning	40%	44%	16%
Un balanced Water Supply & Demand	4%	4%	92%
Soil Erosion	4%	60%	36%
Water Quality Deterioration	0%	64%	36%

The size of stakeholder consultation was very small for representing the Sind sub-basin. Though issues like water quality deterioration, supply-demand mismatch and erosion were not identified as crucial issues by the stakeholders, most of the discussion and advice given by them indicated their importance. For example, the farmers wanted more attention be paid to land leveling and land shaping to prevent erosion of field top-soil. However as erosion problems were more on the farm level and related to the agriculture department's domain of intervention, the plan does not suggest measures to contain the issue.

Though some valid stakeholder interaction has occurred during the formulation of the basin plan and visits to the basin, there is scope for wider consultation in future to enrich the plan.

Poor scientific knowledge base- This has been identified as a problem for the baseline study of the Sind sub basin. During the visit to MP and the sub basin, data was collected from various sources. During the process of data collection, it was felt that the data was not easily available and the quality of available data was also not up to the standards. This leads to the conclusion that data collection, validation and assimilation is completely fragmented and the maintenance of the quality and quantity of data is not up to the mark.

After going through the existing institutional set up, which is responsible for data collection and storage, the bottle neck/causes for the same are observed. Non-functioning of existing institutions and improper monitoring and analysis seems to be a prime cause for the problem. The other causes are lack of required human resources for quality data collection and fragmentation in institutional responsibilities.

The effect of this problem is that it becomes difficult to make an integrated plan. Also a sustainable long term plan cannot be made due to the lack of data which is the basic requirement of any plan. The use available resources cannot be optimized.

Poor Co-ordination and participation- In the stakeholder meeting that was held in the sub basin in the month of July, this problem was agreed upon by the majority. Although it is the responsibility of the water resources department to develop the water resources but still there are various departments involved in the planning, management and implementation of water related activities like the Department of Agriculture, Rural Development and Urban Development.

As already mentioned in the above para, the involvement of multiple departments in water conservation activity is the major cause of this problem. Lack of co ordination between the various departments and lack of participation by the various stakeholder results in un holistic planning and implementation in water conservation and management.

The effect of this problem is that the public money is mis-utilized. It has adverse effect on the downstream area and it may result in failure of water conservation structures.

Low water use Efficiency- Water use efficiency in agriculture is pre dominantly observed and marked problem in the sub basin. In foregoing chapters the test check in sample projects of the sub basin has been attempted and compared with the prevailing guidelines/ bench marks. With the observation of these projects and exponentiating the results to the basin, it can be said that the water use efficiency in the sub basin is low compared to the achievable limits.

There are numerous causes but few of them are listed, when the scale is dropped down from basin to project level. Due to poor management of the existing infrastructure, seepage, evaporation and leakage takes place which leads to distribution and conveyance losses from storage to delivery point which in turn causes low water use efficiency. Second, other vulnerable cause is the prevailing irrigation practices i.e. flood irrigation and lack of awareness amongst farmers about actual crop water requirement. This might be seen as poor extension services. Also low water pricing leads to misuse and wastage of water.

The effect of this problem is that the water demand increases as the quantity of water that is available for use is less than the actual quantity that was available before losses. It leads to dissatisfaction amongst the various users, loss of opportunity for other uses, head to tail distribution inequality, low water productivity. Due to non equitable distribution of water, salinity and water logging also occurs.

Unbalance water supply demand - Water is essential to sustain life and as Water is the subject of the State, providing adequate quantity of water to every individual is the responsibility of the State. This problem was identified in the outline and confirmed in the system analysis and limited stakeholder consultation.

The major cause of this problem is the temporal and spatial variation of availability of water and its uses. Water is the basic commodity to fulfill the needs of every individual and so it is priced very low. There is no volumetric monitoring and control of water for domestic and agricultural use. It is charged at a flat rate. Low technology and lack of storage and distribution network are also important causes of this problem.

The effects of this problem are low productivity levels. Variations in the availability of water lead to inequitable supply levels and user dissatisfaction. As already mentioned; that Water in the State is very low priced so there is a lot of wastage of Water.

Water quality deterioration - Quality of water is an essential parameter in ensuring human health, crop production and sustainable ecosystem. As Water is essential to sustain life, adequate, safe and accessible supply must be available to all.

There are many important causes of this problem. In many big cities of the sub basin, the capacity of the waste water treatment plants is low and there is low coverage of the sewerage network and poor solid waste management. This causes the contaminated water to meet the rivers which in turn deteriorate the quality of the river water. There is insufficient water quality monitoring stations in the sub basin.

When people consume bad quality Water, it has detrimental effect on their health. The effect of this problem is that the ecological and environmental balance is disturbed. There are a lot of issues/complications in downstream treatment.

Ground Water depletion - Ground water is an important water resource and it provides water for agriculture as well as domestic use. It is a reserve of fresh water. Lowering of the water table has been identified as a problem in stake holder meeting.

This problem is caused due to over exploitation and abstraction of ground water. The people are not aware of the importance of ground water and the bad effects of over abstraction. Lower access to surface water leads to abstraction of ground water. Lack of enforcement of ground water abstraction rules is also a cause of this problem. Unawareness about the various techniques of ground water recharge also causes this problem.

Over abstraction of ground water effects the water table which results in lowering of the water table and ultimately in desertification of the land. The quality of the water is also deteriorated. Over exploitation of ground water leads to shortage in ground water availability.

A few problem trees illustrated in Figure 136 to Figure 140 are representing the cause-effect relationship.

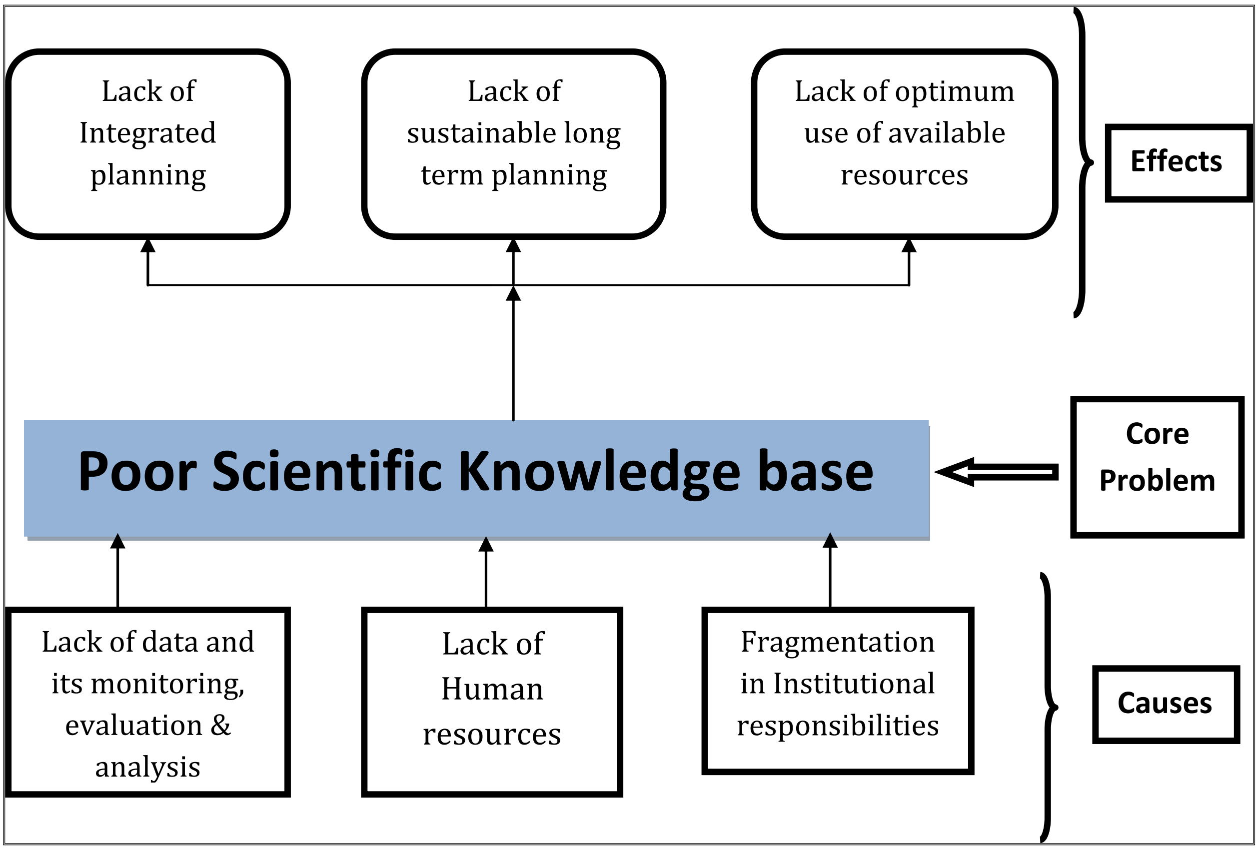


Figure 136: Problem Tree - Poor Scientific Knowledge Base

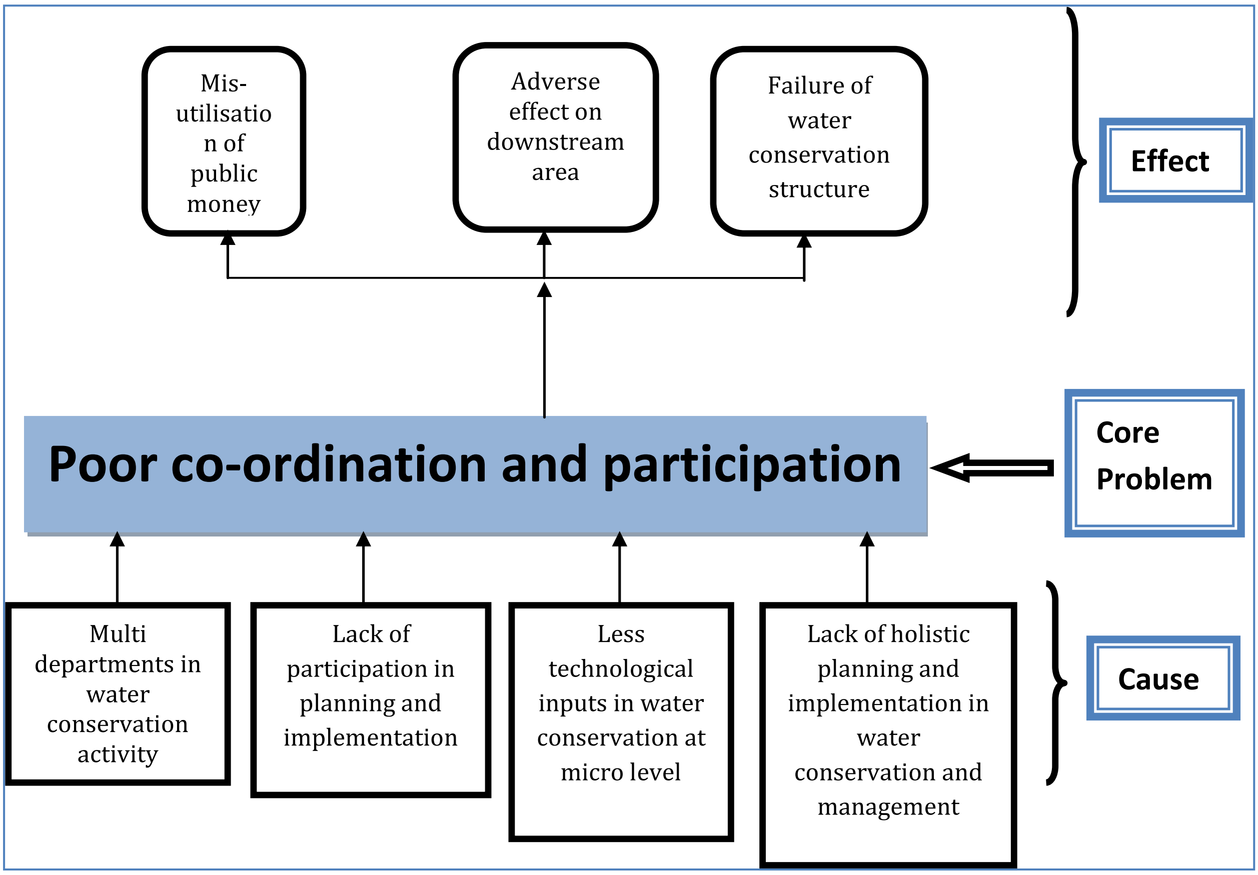


Figure 137: Problem Tree - Poor coordination

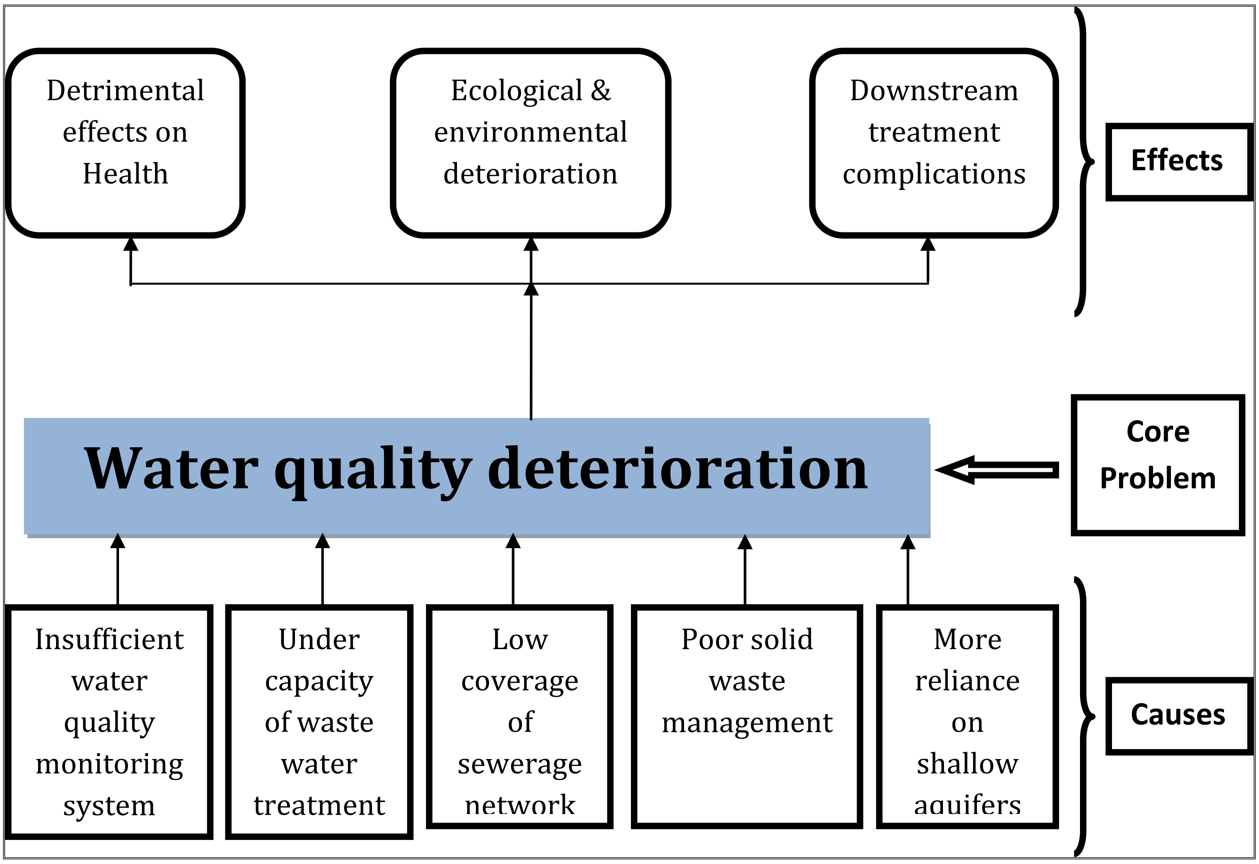


Figure 138: Problem Tree -Water Quality Deterioration

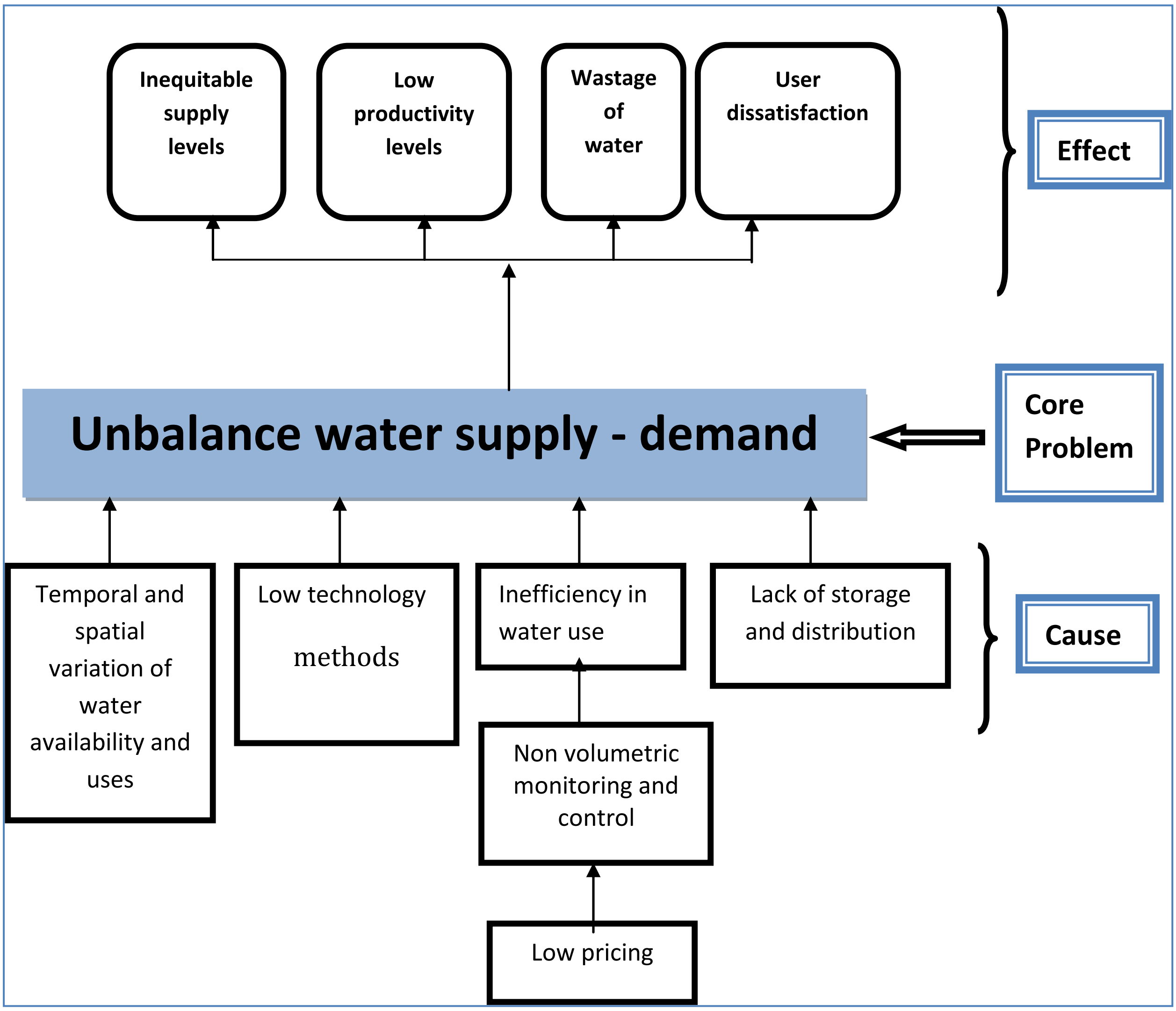


Figure 139: Problem Tree - Unbalance water supply - demand

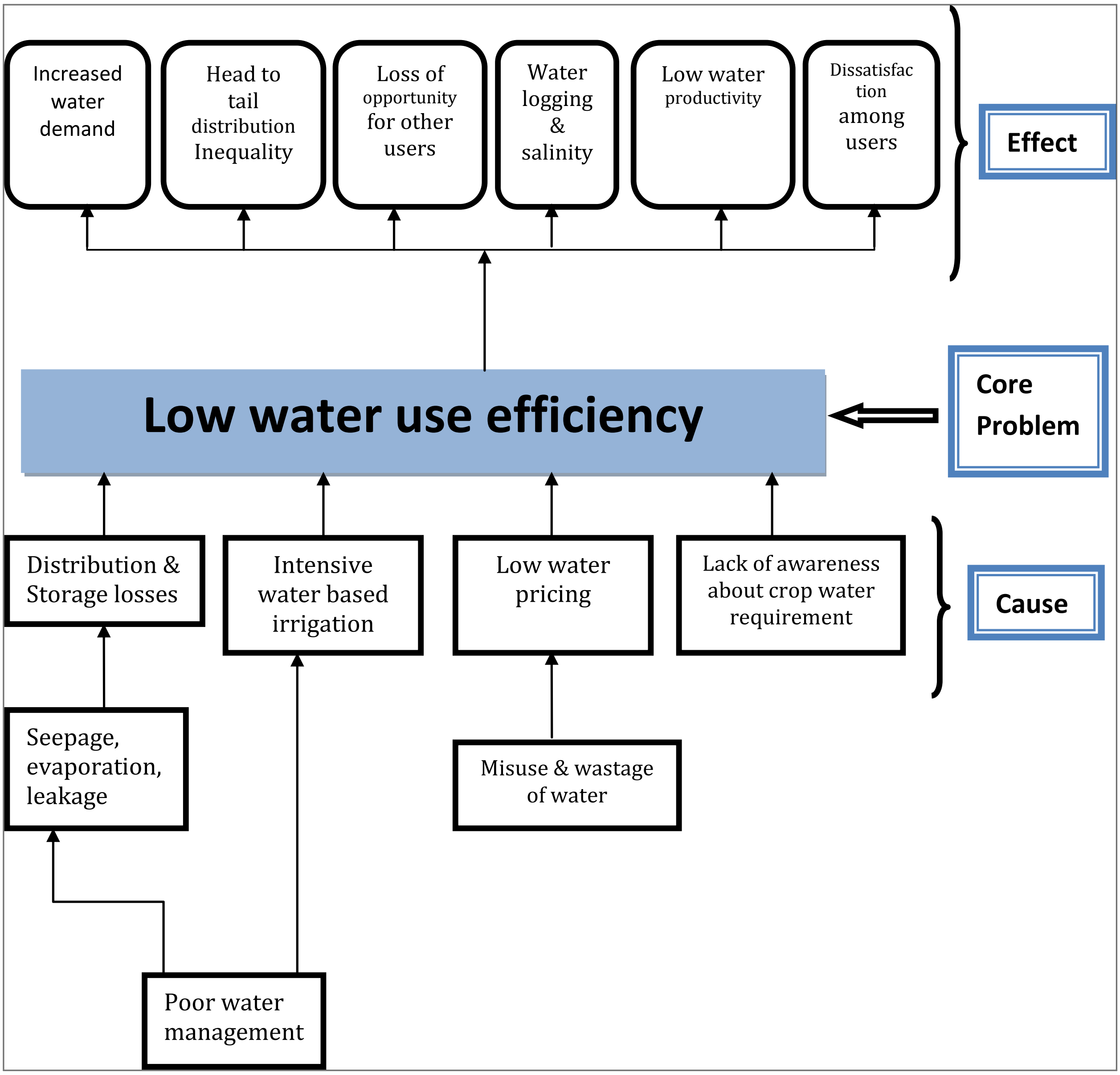


Figure 140: Problem Tree - Low Water Use Efficiency

Goal:

Based on Situation Analysis, System analysis, Scenarios and interaction with important stakeholders and decision makers, the proposed overarching goal of the planning process for Sind sub-basin to meet efficiency, equity and ecological sustainability principles of IWRM is:

"to protect and develop water resources for present and future needs to ensure the health of the citizens, securing food production through agriculture use and participation in economic development by agriculture, energy and industrial sectors."

This goal can be achieved only through small but significant objectives in every aspect of water resources plan.

Objectives:

Pursuant to the situation, system and problem analysis, specific objectives for the Sind River basin plan have been identified as below:

1) Ensure availability of water resources data, to improve scientific database and assessment.
2) Improve coordination in management of water resources.
3) Supply of suitable quality of water as per designated best use within the basin to ensure health of citizens and to sustain ecosystem.
4) Reliable and adequate supply of water especially to the water scarce regions of Sind sub-basin for agricultural use.
5) Improvement of water use efficiency in agriculture use.
6) Promote sustainable ground water use

In the following chapter of Measures and Strategy, each objective is discussed and the proposed measures with its perceived impact are given.

MEASURES AND STRATEGY

Measures and Strategy:

The issues and objectives, listed in previous chapter, are broken down further into a set of sub-objectives such that, the sub-objective leads to the completion of primary objective. The details for criteria and indicators for ensuring the sub objectives and their likely impact are shown in the tables in this chapter. To achieve the sub objectives and subsequently the objectives, the measures are also suggested as part of the strategy formulation. Each objective is designated as obj. <serial number>, (like Obj. 1) so as to have a unique identity of the measure. Similarly each measure is shown by a unique number, like M-1 for measure number 1 and so on. This is to help better understanding of the tables.

The evaluation of the proposed measures is indicated in qualitative terms based on whether the measure would positively or negatively impact the criteria. To denote perceived level of impact of measures; positive or negative or both or blank signs are used. The degree of impact has been denoted in the tables as per description in the in Table 56.

Table 56: Perceived level of impact

Degree of impact	Positive/Favourable	Negative/Adverse
High	+++	- - -
Medium	++	- -
Low	+	-
No impact	Blank/ Not applicable	
Can't say	+/-	

Obj1. Ensure availability of water resources data, to improve scientific database and assessment:

It follows that current data and information be studied to know the baseline condition of the Sind river basin. Accordingly, with specific objective of the baseline study of the Sind river basin; to develop comprehensive understanding of the current surface and ground water availability, agriculture and non agriculture uses, quality of water at various locations as well as understanding holistically present and future projected changes in availability and demand;, a database was collected from different sources, during the visit to Madhya Pradesh and the sub-basin in the month of Jun - Aug 2014. The identified sources of data were mainly Central Water Commission, Central Ground Water Board, Central Pollution Control Board, State Data Center of MP Water Resources Department, and Madhya Pradesh State departments - Urban Development Department, Agriculture Department, and Industry Department etc.

During the data collection process, it was felt that it is very difficult to ascertain availability and to obtain data from various departments or agencies. Also, the quality of data is not up to the mark. In most of the datasets received, preliminary analysis has not been done to ensure the reliability of data. The data is not easily accessible even for inter-departmental use as most of the departments do not publish data. Due to this, a good knowledge base for planning remains unavailable to planners.

To ensure availability of water resources data, four sub-objectives have been identified as described in the Table 57. To achieve these sub-objectives and the overall primary objective, the measures suggested are as follow;

M-1 Re-structuring of State Water Resources Data Analysis Center (SWaRDAC) of MP WRD-Hydrometeorology and Groundwater wing:

There are existing formations within the MP WRD which are engaged in the field data measurement, collection, analysis, research and dissemination of water resources data of the state. These formations are - SWaRDAC, Hydrometeorology, Groundwater circle and Research & Development Directorate. Currently all these along with 4 other directorates (Dam Safety, Dam & Water science cell, Specifications, Rate & Cost, and Canal Cell) are working under Bureau of Design for Hydel & Irrigation projects (BODHI). The SWaRDAC since its inception has not been fully recognized as an organization for which it is established. SWaRDAC can be used as an institution after reorganizing it to the requirement to achieve this objective.

M-2 Installing new field stations for hydrological and water quality data at strategic locations:

During the preparation of the plan, lack of an even distribution of hydrological monitoring stations with availability of verified data was a hindrance to quantitative hydrological analysis. On many occasions, regionalization or statistical methods had to be resorted to.

Actual data of flow measurements of rivers leaving the state is also not available and therefore indirect methods of assessment need to be applied. Though it is known that pollution may be an issue in some stretches of the river, WRD does not measure water quality data nor is the data readily accessible from other departments except some periodic reports. Without a clear benchmark of the status of the sub basin backed by reliable data, planning for the same on a scientific basis would remain a challenge. However, such installation of data acquiring stations needs to be cost effective and optimal.

Therefore, this measure needs to be taken up at strategic locations as identified below.

(i) Gauge and discharge site on Mahuar river
(ii) Gauge and discharge site on Parwati river
(iii) Gauge and discharge site at state border on Sind river.
(iv) Gauge & discharge and Silt measuring site on Sind river near Nai sarai (Ashoknagar)

Automatic rain gauge stations at Rannod (Shivpuri), Nai sarai (Ashoknagar) and Aron (Guna). Existing and proposed GD sites and raingauge stations are shown in Figure 141 and Figure 142.

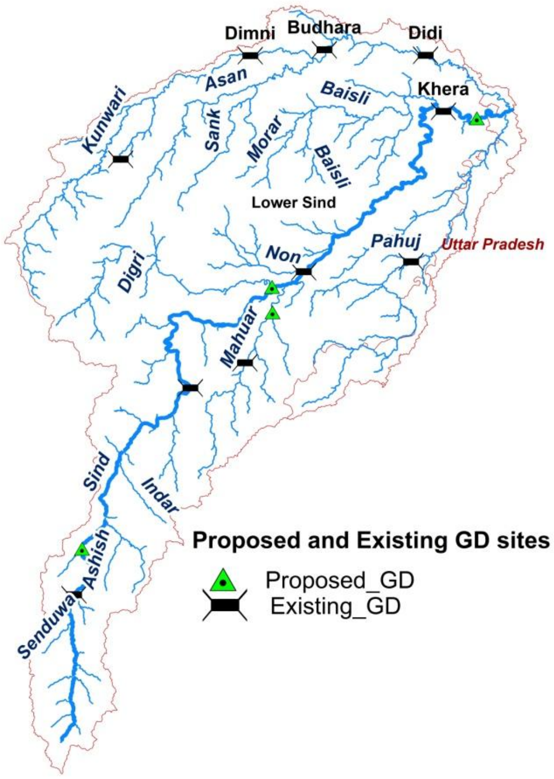


Figure 141: Proposed and Existing GD sites

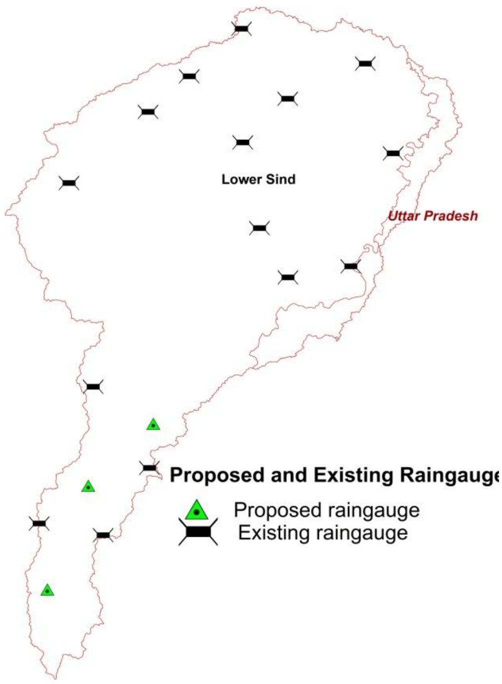


Figure 142: Proposed and Existing Raingauge stations

The monitoring of water quality is also recommended. CPCB has only 2 monitoring stations within the Sind sub-basin. Strengthening the existing Water Quality Monitoring Network is very important to study both immediate and long term impacts of the measures and to know impact of interventions. WQ testing of certain important parameters at regular intervals and at crucial locations/points is a must in order to identify specific existing or emerging water quality problems, seasonal variation in quality parameters etc. To have a wide network throughout the basin, five additional monitoring stations are proposed to be established at important locations.

There is a need to establish additional monitoring stations at some significant locations (Figure 143). In addition to the existing two stations, 5 important locations have been identified for establishing Water quality monitoring stations as under:

(i) One each at downstream of the towns of Gwalior and Morena on Morar and Asan tributaries.

(ii) One each near major reservoirs Harsi and Madikheda

(iii) One downstream of Datia town on Pahuj river

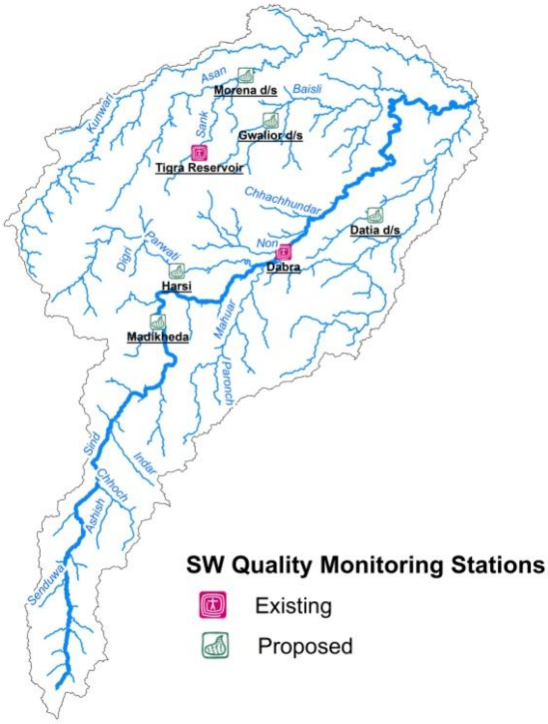


Figure 143: Surface Water Quality Monitoring Stations

The monitoring at these stations is proposed be done for pre and post monsoon period as well as pre and post irrigation (Rabi) period. The basic parameters such as pH, colour, turbidity, DO, BOD, COD, nitrate, nitrite, total coliform, total dissolved solids, ammonia and electrical conductivity are monitored at all stations regularly. Further detail for establishing quality monitoring stations is given at Appendix-2 .

M-3 Initiate a common portal, for data archival and disclosure, as has been done by the GOI data.gov.in.

Much of the data are not useful for public dissemination but yet are instrumental for inter-departmental and public planning or are historical in nature. For example, data on water quality parameters measured by PHED or UADD can enrich river quality planning by WRD. There is no common or easy platform where details such as monitoring stations, parameters tested, frequency of testing and results are available, not even on the website of respective departments/institutions. Also, the catalogues of available historical data owned by various departments are not available; acquiring such datasets by interested agencies becomes difficult. Information dissemination and sharing of knowledgebase is need of the hour. It is therefore very important to create a common platform where water quality related data of the entire basin is readily available and Water Resources department can take an initiative in this matter and help to form a common web based platform.

On the lines of National Data Sharing and Accessibility Policy (NDSAP) 2012, an integrated platform for public agencies of Madhya Pradesh to share and disseminate data can be established to facilitate a shared and transparent knowledgebase. Such a measure would help in positively addressing the basic IWRM principles namely efficiency, equity and sustainability. With similar objective Government of India has already launched a common portal - www.*data.gov.in* for Central Government organizations.

M-4 Use of departmental websites for data dissemination with 'public data' and 'Data for departmental use' sections:

Various departments and agencies continue to implement and monitor schemes, programs and projects for which they publish status reports at different intervals. Such reports and information are catered towards specific project monitoring policy and access to these varies for different departments. The stakeholder departments involved with water management can facilitate each other's short term planning and decision making process by making available basic data to each other on their websites. A majority of this data and information can also be made available for unrestricted public use for the benefit of citizens.

All the above stated measures are addressing the root cause of the problem of poor scientific knowledge base as illustrated in the problem tree.

Table 57: Showing Objective 1 and its Sub objective, Criteria, Indicators, Proposed measures and Impact

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of		
						C-1	C-2	C-3
1	Ensure availability of water resources data, to improve scientific database and assessment		C-1 Collection of adequate and reliable hydrological data	1. Repository size with coverage of river network				
			C-2 Processing and analysis of collected data	2. Ready to use in different formats				
			C-3 Dissemination of data	3. Easy availability				
		1.1 Improvement in basic data collection of hydro-meteorological parameters from existing field stations			**M-1**: Re-structuring of State Water Resources Data Analysis Center (SWaRDAC) of MP Water Resources Department, Hydrometeorology and Ground water wing of the department with responsibility for data collection, analysis	++	+++	+/-
		1.2 Improvement in processing and analysis of collected data.			**M-2**: Installing new field stations for hydrological and water quality data at strategic locations	+++	++	+/-
		1.3 For cross cutting and historical database, ensure data access to & from CGWB, IMD, CWC, CPCB, SPCB and Agriculture department			**M-3**: Initiate a common portal, for data archival and disclosure, as has been done by the GOI *data.gov.in*	+++	++	+++
		1.4 Improvement in dissemination of processed and analyzed data.			**M-4**: Use of departmental websites for data dissemination with 'public data' and 'Data for departmental use' sections		++	+++

Obj. 2. Improve coordination in management of water resources:

Although the responsibility of water resource development rests with Water Resources Department, still the schemes for ground water use (i.e. tube wells and dug wells) for agriculture purposes are planned and implemented by the Department of Agriculture and by private cultivators. Soil and water conservation works are also planned and carried out under several schemes and programmes by Department of Rural Development. The management of water for drinking and domestic use rests with PHED for rural areas and with Urban Development Department (through *Muncipal corporations/ local bodies*) for urban areas. The water is also used for industrial purpose, fisheries, power generation and recreation.

As discussed in the section on AIS, there exist different coordination mechanisms at various levels to facilitate participation in water management decisions for various stakeholders. These coordination mechanisms are particularly strong at the state level. Yet there is also immense scope for improving upon coordination and participation at the district level. Therefore coordination and participation has been shortlisted as an issue in the sub-basin. In the limited stakeholder consultation in the sub-basin, this issue was agreed upon by a majority. Hence, improving coordination in management of water resources is one of the objectives of the plan with the sub objectives of improving inter-sectoral coordination and improving WUA participation in irrigation management as described in the Table 59. To achieve these sub objectives the following measures are proposed:

M-5 Expanding and Empowering the District Level Water Utilization Committee and State Level Water Utilization Committee for information on current and future state of small water related infrastructure:

There are two existing institutions which have representation of most of the stakeholders/ users:

(i) District Level Water Utilization Committee (DLWUC): chaired by the Collector of the district. The Executive Engineer Water Resources Department is the member secretary of this committee and the district level stakeholders like the departments of agriculture, PHED, municipal bodies and fisheries are the members of the committee and users are represented by WUAs and allocation applicants viz. industry. Presently the mandate of the DLWUC is limited to the release of water for irrigation, drinking water and recommending industrial allocation. The DLWUC can play an important coordinating role in planning, sustainable use of water, water conservation activity, improving water use efficiency.

(ii) State Level Water Utilization Committee (SLWUC): headed by Chief Secretary of the State. This committee has State level heads of the departments who are the stakeholders for water use. This Committee can also act as an authority for integration, policy formulation and monitoring of the different water uses in the state.

MP WRD is primarily concerned with the water resources development for command areas greater than 40 hectares. The information about the sectoral departments' works is not readily available to other departments at the district level. For effective planning and management of water and related resources, sharing of the following information between departments at the DLWUC and SLWUC is necessary:

(i) Location, catchment and design command area/ use of existing water related infrastructure.
(ii) Actual service levels like serviced irrigation area, water supply, recharge, soil reclamation.
(iii) Future development plans.

M-6 Transferring management of minor water resources assets to WUAs - Irrigation Management Transfer (IMT):

In 1999 State enacted PIM act for better management of irrigation water. Participatory Irrigation Management (PIM) is an effort to promote a partnership-based relationship between the government or the provider of irrigation water, and the farmer or the receiver of water. This Act relates to WRD relationships with farmers/water users in the command area. It covers all command areas irrigated or capable of being irrigated either by gravitational flow or by lift or any other method from Government or Government aided sources. The PIM act has provisions for levying of fee by WUAs. Presently the state government supports WUAs for operation and maintenance grant, administrative expenses, capacity building with some control.

For participative operation and maintenance of irrigation infrastructure and to ensure efficient and equitable water supply and distribution; it is necessary to expand functional and administrative autonomy of the WUAs. In Turkey this work has been done successfully, which was witnessed by the participants in Batman province during field trip in November 2014 through Irrigation Management Transfer (IMT). In Madhya Pradesh three pilots for IMT have been carried out in Satak (Khargone), Undasa (Ujjain), Intkhedi LIS (Bhopal). The outcomes of these pilots are encouraging. Summary of these pilot projects is given in Table 58.

Table 58: Features, outcomes and impact of IMT pilots in Madhya Pradesh

Satak, Kasarwad, Khargone	Undasa, Ujjain	Intkhedi, Lift Irrigation Scheme Bhopal
Minor Tank project -1800 ha irrigable area 53 km network, 17 villages, one WUA with 1750 users. Transfer of Canal Network to WUA in year 2000.	Minor Tank project – 600 ha irrigable area, canal network 23 km, 3 villages, one WUA with 260 users - Operational Transfer to WUAs	Existing Water Source, Canal Network, Informal Transfer to Farmers Farmers jointly undertake • Maintenance of Canal

WUA undertakes • Maintenance of Canal Systems, Water Management • Supports Revenue Recovery	WUA undertakes • Maintenance of Canal Systems and Water Management • Undertakes Revenue Recovery	Systems and Pumps • Water Management Pays for Electrical Expenses for Pumping
Outcome : Improved Canal Management, Reduced O&M Costs, Equitable and Timely Water Supply, Low Conflicts	Outcome : Improved Canal Management, Equitable and Timely Water Supply, Low Conflicts	Outcome : Improved Water Management, Equitable and Timely Water Supply, Low Conflicts
Impacts: Higher area (up to more than 100%), Improved revenue recoveries (up to 95%)	Impacts: Improvements in Revenue Recoveries	Impacts: Improvements in Command Area, Productivity,

(Source: Report on Institutional Strengthening of MPWRD by Royal Haskoning DHV)

The above mentioned outcomes and impact of the pilots suggests that the IMT can be expanded in the command area in a phased manner. To do so, changes are needed in existing PIM act, so that the WUA can retain water cess with them. The financial autonomy would enable the WUAs to hire their own staff for operation and management of canals and inculcate a sense of ownership of the irrigation system. The proposed measures address some of the cause of the problem.

Table 59: Showing Objective 2 and its Sub objective, Criteria, Indicators, Proposed measures and Impact

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of		
						C-1	C-2	C-3
2	Improve coordination in management of water resources		C-1 Users participation	1. Increased and effective participation of user in operation and management				
			C-2 Sectoral coordination	2. Increase in number of joint meetings and dissemination of information				
		2.1 Improving sectoral coordination in water resources management			**M-5**: Expanding and Empowering the District Level Water Utilization Committee and State Level Water Utilization Committee for information on current and future state of small water related infrastructure	+	+++	
		2.2 Increasing WUAs participation in management of water resources			**M-6**: Transferring management of minor water resources assets to WUAs - Irrigation Management Transfer (IMT)	+++	++	

Obj 3. Supply of suitable quality water as per designated best use within the basin to ensure health of citizens and to sustain ecosystem:

Water is essential to sustain life, and adequate safe and accessible supply must be available to all. Improving access to safe drinking-water can result in tangible benefits to health. Major uses of water within Sind sub-basin are domestic, irrigation and environmental use. Quality of water is therefore an essential parameter in ensuring human health, crop production and sustainable ecosystem.

In India, the Central Pollution Control Board (CPCB), an apex body in the field of water quality management, has developed a concept of "designated best use". According to which, out of several uses a particular water body is put to, the use which demands highest quality of water is called its "designated best use", and accordingly the water body is designated. The water quality data of Sind sub-basin as analyzed in situation analysis shows no major contamination within the basin. However, the water at the two stations has degraded from class A to B within a period of 3 years. The reason for this might be disposal of untreated sewage from nearby towns into the river. In most small towns, villages there are no sanitation facilities. Sewage flowing in open drains is discharged directly into river bodies. Open defecation, disposal of solid waste near the river bank are other reasons for pollution of water bodies. Therefore it is essential to restore the water quality by improving it to class A.

The measures proposed for achieving the objective of supply of suitable quality water are listed in Table 60 and are discussed below:

M-7 Educating /sensitizing people on environment and conducting awareness programs in nearby villages:

It is important to educate and sensitize people on, environment, hygiene, river conservation & pollution. Awareness generation is one of the basic steps towards achievement of 100 percent access to sanitation. Changing of existing mindsets through awareness of health and hygiene issues is the key towards achievement of complete sanitation.

M-8 Timely completion of infrastructural measures as envisaged in city development plans.

Timely completion of infrastructural measures such as construction of Sewage treatment plants, new sewerage network and maintenance of sewer lines as envisaged in city development plans will help in achieving better water quality. Construction of flush toilets and drains arrest open defecation near reservoirs and water bodies is a measure to control pollution.

M-9 Assessment of minimum environmental flow for ecological and environmental sustenance based on comprehensive approaches like building block methodology, DRIFT or equivalent

Sind is not a perennial river. There is very little to no flow in the river during summer. Sind sub-basin is home to a variety of flora and fauna. The Madhav National park and Karera Sanctuary lie within the sub-basin. Survival of the river ecosystem during lean season becomes very difficult. Therefore it is essential to maintain a minimum flow in the river. To protect freshwater biodiversity and maintain the essential goods and services provided by rivers, there is a need to mimic components of natural flow variability, taking into consideration the magnitude, frequency, timing, duration, and rate of change and predictability of flow events.

"Flow regime capable of sustaining a complex set of aquatic habitats and ecosystem processes and are referred to as “environmental flow”. The Guidelines for sustainable water resources development and management from the Central Water Commission (CWC) of Government of India in 1992 suggested that the minimum flow in the river should not be less than the average of 10 days minimum flow of the river in its natural state. In 2001, Government of India constituted the Water Quality Assessment Authority (WQAA) which in turn constituted in 2003, a working group to advice the WQAA on ‘the minimum flow in the rivers’ to conserve the ecosystem.

The assessment of minimum environmental flow requires specialized knowledge of ecology and therefore this proposed study would have to be conducted by an agency equipped with such skills. The Forest department or the department of Environment could lead such study through Environmental Planning and Coordination Organization (EPCO) or Madhya Pradesh State Forest Research Institute (MPSFRI). The study should be based on currently acceptable methodologies such as BBM, DRIFT or equivalent for assessment of environmental flows.

Other measures:

Two more measures for achieving Objective 3 are

(1) Establishing 5 additional monitoring stations within the basin and samples from these stations be tested at regular intervals and

(2) WRD to take initiative in forming a web based platform where WQ data from all institutions is compiled;

These measures are similar to those proposed and discussed under Objective 1 and hence are not progressively numbered here.

Table 60: Showing Objective 3 and its Sub objective, Criteria, Indicators, Proposed measures and Impact

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of		
						C-1	C-2	C-3
3	Supply of suitable quality of water as per designated best use within the basin to ensure health of citizens and to sustain ecosystem		C-1 Improvement in Class of river water quality as per CPCB classification	1. Compliance to acceptable levels of water quality paramters				
			C-2 Improved water quality monitoring network	2. Standard set of parameters monitored at important stations at regular intervals and no data gaps				
			C-3 Minimum Environmental Flow	3. No. of days river flow more than minimum environmental flow at existing GD sites				
		3.1 Improving Water quality of River Sank at Tighra and River Sind at Dabra from class B to Class A			**M-7**: Educating /sensitizing people on environment and conducting awareness programs in nearby villages.	++		
					M-8: Timely completion of infrastructural measures as envisaged in city development plans.	+++		+/-
		3.2 Strengthening the existing water quality monitoring network			(Establishing 5 monitoring stations) Described in **M-2**	+	+++	+
					(Forming a web based platform for WQ data from all institutions) Described in **M-3**	+	+++	+/-
		3.3 Providing adequate stream flows to ensure sustenance of wildlife and ecosystem			**M-9**: Assessment of minimum environmental flow for ecological and environmental sustenance based on comprehensive approaches like building block methodology, DRIFT or equivalent	+	+	+++

Obj. 4. Reliable and adequate supply of water especially to the water scarce and drought prone regions of the sub-basin:

This objective of the plan aims to tackle the problem of unbalanced supply and demand identified in the outline and confirmed in the system analysis and limited stakeholder consultation. The proposed measures belong to both demand and supply side management of water resource. The sub-objectives, criteria and indicators for the proposed measures are given in Table 61, and the sub-objectives and the proposed measures are discussed below:

M-10 Continuation and intensification of Khet-talab and Balram Talab programmes in Gwalior, Morena and Bhind districts

In Sind sub- basin, agriculture is the major water user. To ensure that adequate water for irrigation purposes is available without thwarting the sustainability of groundwater system, a combination of demand and supply side interventions are required. Under the ongoing programmes of the Government of Madhya Pradesh - Khet Talaab Yojana and Balram Taal Yojana, on-farm conservation of rain water by digging small/ large ponds have been well received.

Farmers are incentivized in the form of 25-50% subsidies for adopting conservation measures. Such water conservation measures are not new in the state, but had fallen out of practice as cultivators need to set aside a portion of their farm-holding for the pond. Water conservation practices like these need to be in vogue for a long time to become traditions.

To ensure that valuable practices in water conservation are engrained inseparably in the basin's agriculture practice, continuation and intensification of ongoing programmes is essential.

M-11 Completion of series of stop dams in Upper Sind and other ongoing works

Apart from the regular maintenance and rehabilitation of existing irrigation projects, quite a few schemes are currently ongoing in the Sind sub-basin. For example, a series of cascading small stop dams are under construction near Sonera-Khamkheda in Upper Sind in Ashoknagar district. Completion of these schemes would add at least 2500 hectares of unirrigated farms into productive irrigated area without negative impacts of environment harm and resettlement. The completion of other ongoing schemes in the basin would add to the prosperity of the cultivators in the basin.

Including the above projects, 45 minor projects for the benefit of nearly 17,800 hectares are ongoing whilst another 12,050 hectares is proposed to be benefitted by 70 small irrigation schemes in the pipeline. The list of these projects is appended as Appendix-3 and Appendix-4.

A very obvious spinoff from such developments is lower dependence on groundwater and lower groundwater abstractions.

M-12 Scoping studies for water resources development on Kunwari and Sind rivers

Pursuant to the situation and system analysis, there exists some scope of developing the water resources in the sub-basin. Such development within the existing environmental framework is possible after detailed scoping studies. Kunwari and lower Sind sub-basins have much of the water resources yet unharnessed. For example, based on desk reconnaissance, a potential benefit zone is identified in Sind River as a possible water resources development area.

Figure 144 : Map showing potential development zone on Sind river

The catchment area of the possible sites of the potential zones is 12900 Sq Km, corresponding to average yield of 1.5 BCM. This zone is detailed in Appendix-5

A suite of such potential development zones can be evaluated for their environmental feasibility and techno-economic feasibility, which is the norm in WRD, before selection of best options in the sub-basin.

M-13 Completion of ongoing Sind Ramowa link project and other proposals

As discussed in System Analysis, although the sub-basin has sufficient amount of water for its needs, shortages occur for the users' demand due to spatial as well as temporal mismatch of availability and demand. Spatial disparity of availability can be bridged by transfer of excess water to areas with deficit water. The ongoing link projects like Sind-Ramowa and scoping for other small scale intra-basin transfers would help in ensuring sufficient and equitable water for the users in the sub-basin.

Table 61: Showing Objective 4 and its Sub objective, Criteria, Indicators, Proposed measures and Impact

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of		
						C-1	C-2	C-3
4	Reliable and adequate supply of water especially to the water scarce regions of Sind basin for agricultural use.		C-1 Sufficient irrigation waterings received	1. No. of irrigation waterings				
			C-2 Area receiving irrigation service	2. % of net sown area receiving irrigation service				
			C-3 Reduced groundwater dependence	3. Reduction of stage of GW development (%)				
		4.1 On-field rainwater harvesting and conservation			**M-10**: Continuation and intensification of Khet-talab and Balram Talab programmes in Gwalior, Morena and Bhind districts	+	+	+++
		4.2 Creation of additional storage/ availability with the completion of ongoing WRD schemes			**M-11**: Completion of series of stop dams (Sonera Khamkheda) in Upper Sind and other ongoing works	++	+++	++
		4.3 To develop possible new storages			**M-12:** Scoping studies for water resources development on Kunwari and Sind Rivers	++	+++	++
		4.4 Expansion of irrigation service from intra-basin transfers			**M-13**: Completion of ongoing Sind Ramowa link project and other proposals	++	++	+

Obj. 5 Improvement of water use efficiency in agriculture use:

Pursuant to the discussion on the status of water use efficiency in the chapter on situation analysis, it was found that the project level efficiency of the two old irrigation projects was nearly 40% which is close to the CWC estimate of 38% for projects in India. It is construed that these levels of water use efficiencies only refer to the surface water use. The water use efficiency levels of groundwater application would be much higher due to quasi private ownership.

Low water use efficiency was one of the issues identified during framing of outline of the plan and subsequent field visits and stakeholder consultations. This issue got maximum approval from the farmers during the stakeholder consultation. The National Water Mission and GoMP vision document 2018 aim at 10% increase in the water use efficiency.

From expert judgment it is known that most of the losses occur at the field level due to improper irrigation practices like over tillage, flood irrigation method, unleveled fields etc. Considerable losses also occur due to evaporation and seepages at the reservoir and conveyance level. The measures proposed (Table 62) for achieving improvement of water use efficiency in agriculture by addressing some of the causes indicated in the problem tree are discussed below:

M-14 Asset modernization measures to minimize seepage within tolerance level specified in MPWRD Technical Circular and BIS standards

Most of the dams in the sub-basin are earthen dams in which seepage contributes to the dam stability. Yet the seepage should be restricted to the permissible levels so that the soil particles are not removed along with the seepage flow. Depending upon the location, content and quantity of the seepage, rehabilitation measures like cut-offs, internal filters and drainage provisions may be adopted.

M-15 Improving seepage measurement system like installation of piezometers in dams, V-notches in seepage drains

Regular monitoring for seepage detection and prevention of dam failure is necessary. Pre and post monsoon inspection of dams is a regular feature in the sub-basin which is conducted by the Directorate of Dam Safety, WRD. Yet, continuous records of surveillance of the embankment and seepage drains are essential to detect the changes in seepage pattern. For this, necessary measuring devices like V-notch weirs and piezometers should be installed.

M-16 Restructuring of complete conveyance system (structural measures like re-sectioning, lining, repair of structures etc.)

Estimates of conveyance losses in canal systems in different countries of the world reveal that about one third of all the water diverted for irrigation is lost in conveyance from the head works to the farm fields [30]. Irrigation commission 1972 also brings out that conveyance losses (for canal systems in alluvial plains of north India) in main and branch canals are 17%

[30] Irrigation : Theory and Practice, A.M. Michael, 2008, pg.212

of the head discharge and that at the distributaries and minors are 8% of the head discharge. The losses in water courses are 20% of the head discharge.

The practice of lining of canals in the sub-basin has been initiated in recent years in view of the value of water lost in unlined canals despite the cost of lining being 3 to 4 times more than that of conventional unlined canal. While new projects are designed for lined or partially lined canal systems, old canal systems require concurrent re-sectioning and lining to achieve full coverage of designed command area. Due to such remodeling of some canal systems in the sub-basin, benefits of irrigation could be expanded till the tail end of the command, with water reaching the disadvantaged tail users after decades in some cases. Such restructuring also provides the opportunity to modernize the canal system with regulatory and measuring structures.

M-17 Switching from conventional flood irrigation methods to sprinkler/drip

K Palasimani et al[31] have used data from Raman (2010) and Indiastat 2010 to demonstrate the low adoption of micro-irrigation in Madhya Pradesh among others despite the promise of high water use efficiency and returns on investment. For the State and the sub-basin, the ratios of actual area under micro-irrigation to the potential area for drip and sprinkler irrigation are 1.48% and 2.35% respectively. Despite the low adoption, the state has picked up on the rate of adoption (800%) of micro-irrigation after the introduction of centrally sponsored scheme (CSS) for its adoption in 2005-06. Sweet orange, banana and vegetables are the major crops under the CSS and implemented through the Department of Horticulture.

The adoption of micro-irrigation among farmers leads to voluntary diversification of cropping pattern and better market linkages. While the sub-basin tries to gain benefit from the CSS, it is also necessary to promote micro-irrigation by coupling its adoption to new irrigation projects. The need for designing low-cost drip (like introduction of Chapin tubes, paired row planting) and micro-irrigation systems to suit small farmers and farm sizes, clarity and timeliness of the subsidy schemes and technical support like method of *fertigation* (fertilizer injection through water) can give the needed impetus to its adoption.

M-18 Creating awareness among farmers to adopt improved agricultural practices

Much of the field losses occur due to poor agricultural practices like flood irrigation, over-tillage, low weed control and unleveled fields. The departments of Agriculture and Horticulture have a considerable say in spreading awareness among farmers to adopt new and improved agricultural practices. The outreach of the ongoing awareness programs on adoption of Systemic Crop/ Rice Intensification (SCI/ SRI), zero-till method, raised-bed cultivation, ridge & furrow irrigation, sprinkler and drip irrigation etc. may be enhanced

[31] Spread and Economics of Micro-irrigation in India: K. Palasimani, Kadiri Mohan, K.R. Kakumanu, S. Raman: Economic and Political Weekly Supplement June 25, 2011 Vol. XLVI nos. 26 & 27

through collaboration between WRD, Agriculture and Horticulture Departments, and other institutions such as DLWUC, Krishi Vigyan Kendras (KVK), agriculture universities and NGOs.

Table 62: Showing Objective 5 and its Sub objective, Criteria, Indicators, Proposed measures and Impact

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of		
						C-1	C-2	C-3
5	Improvement of water use efficiency in Agriculture use		C-1 Increase in irrigated area serviced per unit volume of stored water	Area serviced in hectares per unit storage (Ha/MCM)				
			C-2 Increase in crop yield of indicator crops- wheat, mustard and soybean	Crop yield per unit farm areaTonnes/Ha				
		5.1 Improving Reservoir (tank) efficiency in dams			**M-14**: Asset modernization measures to minimize seepage within tolerance level specified in WRD T.C. and BIS standards	++	+	
					M-15: Improving seepage measurement system like installation of piezo- meters in dams ,V-notches in seepage drains	+	+	
		5.2 Improving conveyance efficiency in projects			**M-16**: Restructuring of complete conveyance system (structural measures like re-sectioning, lining, repair of structures etc.)	+++	++	
		5.3 Improving Field application efficiency			**M-17:** Switching from conventional flood irrigation methods to sprinkler/drip	+++	+++	
					M-18: Creating awareness among farmers to adopt improved agricultural practices, micro-irrigation techniques and adopting high yielding crops	++	++	

Obj. 6 Promote sustainable ground water use:

Groundwater is one of the sub-basin's most important water resources as it provides more than 60% of agricultural use as well as water for domestic use for majority of domestic users. It is the principal reserve of fresh water and the potential of future water supply. As has been put forth in the analysis of status of groundwater 7of the 24 blocks spread over the sub-basin are in semi-critical state meaning that these regions are potentially vulnerable to fall under criticality and over-abstraction with increase in population, urban agglomeration and lack of access to surface water sources. The remaining blocks have the potential for groundwater development under a regulatory framework.

The proposed measures to achieve this objective are listed in Table 63 and discussed below:

M-19 Adoption of artificial recharge measures like roof top water harvesting in urban areas, contour bunding, percolation tanks etc. in rural areas

Artificial recharge is the process by which the ground water reservoir is augmented at a rate exceeding that under natural conditions of replenishment. Any man made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system. Artificial recharge of groundwater by harvesting excess monsoon runoff, otherwise being lost to sea, is one of the best supply side water management options for providing sustainability to GW sources.

To fully utilize the available surplus monsoon runoff in rural areas, it is recommended for adoption of artificial recharge techniques based on surface spreading like percolation tanks, check dams, contour bunds, gully plugs, gabion structures etc. and sub surface techniques of recharge shaft, well recharge, etc. In urban areas, roof top rainwater harvesting is proposed both by augmenting the ground water storage as well as by storing it in specially built tanks. Roof top rainwater harvesting in urban areas can be made mandatory by the respective municipalities within the sub-basin for roof area more than 100 sqm.

These artificial recharge practices can be implemented with the participatory approach of State and Central Government agencies, industries, NGO's, community and research Institutions. The District level Water Utilization Committee under District Collector, and implementing agency such as Rural Development department as members, is recommended to have an overall monitoring of the artificial recharge programs in the sub -basin.

M-20 Conducting mass awareness programs and training on groundwater management

In the seven identified semi-critical blocks, the drafts from ground water are mainly to meet irrigation demands of local farmers. It has been observed that it is very difficult to change the current farming practices that envisages shift from water intensive crops to less water consuming crops. The agriculture department should continue its efforts in creating awareness amongst farmers of the tangible short and long term benefits that may be accrued by using water efficient crops such as better crop remuneration, better marketing of agriculture produce, minimum support price etc. Adopting water saving on-farm techniques can reduce demand for ground water by 35 %. It is important to educate the community about its groundwater resources and the need to manage it sustainably.

Sustainable management of groundwater is feasible only if users understand its occurrence, cycle, and limited availability. Community based approach for groundwater management should therefore be encouraged as has been the experience in Andhra Pradesh, where there has been a participation and involvement of farmers in groundwater management under the Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS). The key aspect of this project is capacity building of local communities who then take care of protecting their precious resources.

M-21 Construction of hand pump , dug wells & tube wells by the Rural Development department, PHED, Panchayats, Municipalities and farmers in safe blocks

As discussed in the system analysis of the groundwater status of the sub-basin, 17 of the 24 blocks may be categorized as safe based on the stage of groundwater development. In these blocks there remains scope for groundwater development without thwarting sustainability. However such development would require regulation by the district administration and implementation by the department of Rural Development, PHED, Municipalities and Panchayats. Such development of groundwater would promote a balanced and conjunctive use of water.

Table 63: Showing Objective 6 and its Sub objective, Criteria, Indicators, Proposed measures and Impact

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of		
						C-1	C-2	C-3
6	Promote sustainable ground water use		C-1 Stage of groundwater development in safe category	Ratio of annual groundwater draft and annual replenishable groundwater availability (in %)				
		6.1 Stabilization of declining GW table in 7 blocks (semi-critical units) of Datia, Guna, Gwalior, Morena & Shivpuri districts			**M-19**: Adoption of artificial recharge measures like roof top water harvesting in urban areas, contour bunding, percolation tanks etc. in rural areas	+++		
					M-20: Conducting mass awareness programs and training on groundwater management	+++		
		6.2 GW development in Seventeen blocks (safe units) of Ashoknagar, Bhind, Datia, Guna, Gwalior, Morena, Sheopur, Shivpuri & Vidisha districts			**M-21**: Construction of hand pumps , dug wells & tube wells by the Agriculture department, PHED, Panchayats, Municipalities and farmers	++		

OVERALL STRATEGY

Overall Strategy

IWRM approach underpinning the strategy

Water is a vulnerable resource, essential for sustaining life, environment and development. The management, development, use and protection of water resources should therefore be planned in an integrated manner. There are several challenges which constitute the basis for future action. These need to be overcome by developing water resource in an equitable, reasonable and optimal way. Integrated approach for water resources management has been emphasized in the National Water Policy 2012, State Water Policy and National Water Mission. This planning document is prepared in line with these policies and the IWRM principles.

After analyzing the data collected from various sources, the major problems related to water resources within the basin were identified. The problems were also discussed and substantiated in stakeholders' meeting during field visit. Based on the issues and challenges identified within the basin, six primary objectives of the plan are defined keeping in mind the principles of IWRM. These include but not limited to improved stakeholder participation, conjunctive use of surface and groundwater resources, integrated monitoring and evaluation and management of both water quantity and quality, consideration of water uses in urban, industrial, agriculture and environment sectors, though water uses other than agriculture are not directly linked to the functions of WRD. But an attempt is made to address water needs and emerging issues in these sectors as a part of integrated plan. A number of possible measures have been proposed to achieve the defined objectives. The basic strategies proposed include infrastructure development, promoting participation, environmental protection, sustainability and awareness generation. The implementation of proposed measures, discussed in previous section and summarized in Table 64 for the optimal utilization of water resources is essential for achieving the objectives and overall goal. As indicated in Table 64, most of the suggested measures are likely to contribute in achieving the IWRM targets of equity, economic efficiency and environmental sustainability.

Implementation of the measures

The proposed measures can be broadly categorized as Awareness, Environmental, Infrastructural and Institutional. It is practically not feasible to implement all the proposed measures simultaneously or immediately. Some actions are proposed in response to the problems identified, while certain measures would help in achieving the long term goal and objectives. Some measures are such that they need to be implemented in short or medium term. Depending on time required for implementation and practicality; the proposed measures are recommended to be considered for implementation in short term (within next five years, i.e. by 2018), medium term (within next ten years, i.e. by 2025) or long term (within 10-20 years, i.e. by 2035) time horizons.

Each of the suggested measure is also ranked by considering the likely impact on the plan objectives and IWRM target. This may facilitate prioritization of measures. For instance, the most promising top ten measures with highest scores are noted below:

1. M6 (score: 18): IMT (institutional), recommended for short, medium and long term strategies
2. M8 (score: 17): completion of city development works (infrastructural), recommended for short term strategy
3. M9 (score: 16): assessment of EFR (environmental), recommended for medium term
4. M5 (score: 16): expanding district and state level water committees (institutional), recommended for short term strategy
5. M19 (score: 16): Artificial recharge (infrastructure), recommended for short and medium term strategies
6. M 18 (score: 15): efficient irrigation technology/practices adoption (environmental), recommended for short, medium and long term strategies
7. M3 (score: 14): common data portal (infrastructural): recommended for short and medium term strategies
8. M10 (score: 14): continuation of Khet and Balram Talab programmes (infrastructural), recommended for short, medium and long term strategies
9. M 11 (score: 13): completion of stop dams (infrastructural), recommended for short term strategy
10. M 12 (score: 13): scoping studies for water resources development for Kunwari and Sind rivers (infrastructural), recommended for short term strategy

Table 64: Overall Strategy

S.No.	Proposed Measures	Qualitative Impact of measures			Measure category	Objective type - Qualitative						IWRM Targets			Score	Suitable for		
		C-1	C-2	C-3		Obj 1 (Data ..)	Obj 2 (Coord..)	Obj 3 (Env..)	Obj 4 (Reliable..)	Obj 5 (WUE..)	Obj 6 (GW)	Economic efficiency	Equity	Environmental sustainability	Simple	Short term	Medium term	Long term
1	**M-1**: Re-structuring of State Water Resources Data Analysis Center (SWaRDAC) of MP Water Resources Department, Hydrometeorology and Ground water wing of the department with responsibility for data collection, analysis	++	+++	+/-	Institutional	+++	+	+				++		+	8	√		
2	**M-2**: Installing new field stations for hydrological and water quality data at strategic locations	+++	++	+/-	Infrastructural	+++	+	+	+/-		+/-	++	++	++	11	√	√	
3	**M-3**: Initiate a common portal, for data archival and disclosure, as has been done by the GOI *data.gov.in*	+++	++	+++	Infrastructural	+++	+++	+	+/-		+/-	+++	+++	+	14	√	√	
4	**M-4**: Use of departmental websites for data dissemination with 'public data' and 'Data for departmental use' sections		++	+++	Institutional	+++	+	+			+/-	+	+++	+	10	√		
5	**M-5**: Expanding and Empowering the District Level Water Utilization Committee and State Level Water Utilization Committee for information on current and future state of small water related infrastructure	+	+++		Institutional	+++	+++	+	+	+	++	++	++	+	16	√		

S.No.	Proposed Measures	Qualitative Impact of measures			Measure category	Objective type - Qualitative						IWRM Targets			Score	Suitable for		
		C-1	C-2	C-3		Obj 1 (Data ..)	Obj 2 (Coord..)	Obj 3 (Env..)	Obj 4 (Reliable..)	Obj 5 (WUE..)	Obj 6 (GW)	Economic efficiency	Equity	Environmental sustainability	Simple	Short term	Medium term	Long term
6	**M-6**: Transferring management of minor water resources assets to WUAs - Irrigation Management Transfer (IMT)	+++	++		Institutional	+/-	+++	+/-	+++	+++	++	+++	+++	+	18	√	√	√
7	**M-7**: Educating /sensitizing people on environment and conducting awareness programs in nearby villages.	++			Environmental		++	+++				++	+	+++	11	√	√	√
8	**M-8**: Timely completion of infrastructural measures as envisaged in city development plans.	+++		+/-	Infrastructural		++	+++	++		++	++	+++	+++	17	√		
	*(Establishing 5 monitoring stations) Described in **M-2***	+	+++	+	Infrastructural	+++	+	+++			+/-	++	+	+++	13	√		
	*(Forming a web based platform for WQ data from all institutions) Described in **M-3***	+	+++	+/-	Infrastructural	+++	+++	++	+/-		+/-	+++	+++	+	15	√	√	
9	**M-9**: Assessment of minimum environmental flow for ecological and environmental sustenance based on comprehensive approaches like building block methodology, DRIFT or equivalent	+	+	+++	Environmental	++	++	+++	++		+	+	++	+++	16		√	

S.No.	Proposed Measures	Qualitative Impact of measures			Measure category	Objective type - Qualitative						IWRM Targets			Score	Suitable for		
		C-1	C-2	C-3		Obj 1 (Data ..)	Obj 2 (Coord..)	Obj 3 (Env..)	Obj 4 (Reliable..)	Obj 5 (WUE..)	Obj 6 (GW)	Economic efficiency	Equity	Environmental sustainability	Simple	Short term	Medium term	Long term
10	**M-10**: Continuation and intensification of Khet-talab and Balram Talab programmes in Gwalior, Morena and Bhind districts	+	+	+++	Environmental		+/-	++	+++	+	++	++	++	++	14	√	√	√
11	**M-11**: Completion of series of stop dams (Sonera Khamkheda) in Upper Sind and other ongoing works	++	+++	++	Infrastructural		+	+/-	+++	++	++	++	+++	+/-	13	√		
12	**M-12:** Scoping studies for water resources development on Kunwari and Sind Rivers	++	+++	++	Infrastructural		+	+/-	+++	++	++	++	+++	+/-	13	√		
13	**M-13**: Completion of ongoing Sind Ramowa link project and other proposals	++	++	+	Infrastructural		++	-	+++	+	+/-	++	+++	+/-	10			
14	**M-14**: Asset modernization measures to minimize seepage within tolerance level specified in WRD T.C. and BIS standards	++	+		Infrastructural				+++	+++		+++	+		10	√	√	
15	**M-15**: Improving seepage measurement system like installation of piezo- meters in dams ,V-notches in seepage drains	+	+		Infrastructural	++			++	+++		+++	+		11	√		

S.No.	Proposed Measures	Qualitative Impact of measures			Measure category	Objective type - Qualitative						IWRM Targets			Score	Suitable for		
		C-1	C-2	C-3		Obj 1 (Data ..)	Obj 2 (Coord..)	Obj 3 (Env..)	Obj 4 (Reliable..)	Obj 5 (WUE..)	Obj 6 (GW)	Economic efficiency	Equity	Environmental sustainability	Simple	Short term	Medium term	Long term
16	**M-16**: Restructuring of complete conveyance system (structural measures like re-sectioning, lining, repair of structures etc.)	+++	++		Infrastructural			+/-	+++	+++	+/-	+++	+++	+/-	12	√	√	
17	**M-17:** Switching from conventional flood irrigation methods to sprinkler/drip	+++	+++		Infrastructural			+	+++	+++	+/-	++	+	++	12	√	√	√
18	**M-18**: Creating awareness among farmers to adopt improved agricultural practices, micro-irrigation techniques and adopting high yielding crops	++	++		Environmental		++	+	++	+++	+	+++	+	++	15	√	√	√
19	**M-19**: Adoption of artificial recharge measures like roof top water harvesting in urban areas, contour bunding, percolation tanks etc. in rural areas	+++			Infrastructural			++	+++	+	+++	++	+++	++	16	√	√	
20	**M-20**: Conducting mass awareness programs and training on groundwater management	+++			Awareness		+	++	+	+	+++	+	++	++	13	√	√	√
21	**M-21**: Construction of hand pumps , dug wells & tube wells by the Agriculture department, PHED, Panchayats, Municipalities and farmers	++			Infrastructural			-	+++	++	+++	++	++	-	10	√	√	

LIMITATIONS

Limitations

The study is limited in its scope and accuracy mainly due to limited data availability which was further constrained by quality issues. Some of the information available is mostly for the districts and where the districts fall partially in the Sind sub-basin, assumptions were required to derive such information for the sub-basin.

The study had aimed to include a flood simulation model for dam operation. The prepared model needs to be further tested with hourly precipitation and flow data to ensure its satisfactory calibration.

Similarly the allocation model requires more accurate inputs like inflows and user demands. Industrial demands and allocations in particular have been difficult to assess and have higher chances of inaccuracy. In the available data from the State agencies, lack of geo-spatial information makes the analysis become difficult and cumbersome.

The study has involved limited stakeholder consultation in the sub-basin. With formulation of actions, stakeholders' opinions need to be incorporated in the plan.

Due to paucity of relevant data and time, the plan has not included detailed economic analysis or finance required for implementation. However, it is seen as a work in hand in the future version of the plan.

Furthermore, it is important to note that this plan is made as part of the training and capacity building program which also had limitations such as limited time of about 6 months and limited availability of human and other resources. However, despite above mentioned limitations, the proposed plan is expected to be a very valuable document providing a good foundation for integrated river basin planning and management in the Sind sub-basin.

THE WAY FORWARD

The Way Forward

The Sind river basin plan will be sent for external and peer review. The first step would be to finalize the plan by accommodating all possible suggestions and comments received from these reviews. This would be followed by a workshop proposed to be conducted in Madhya Pradesh, India where the final plan will be presented to officers and decision makers of WRD as well as other related departments.

There are several initiatives going on in the sub basin that are closely related to the some of the proposed measures such as interventions mentioned in city development plans. Proposed strategies can therefore be merged or scheduled with the ongoing activities of stakeholder departments. The workshop will help in prioritizing and deciding on choice of strategy in consultation with other stakeholder departments. A number of implementable measures could then be shortlisted after evaluating and ranking the options against technical, financial, social, ecological, economic and institutional criteria.

The next step is obtaining approval from competent authorities for the shortlisted strategies that are to be implemented by WRD. Formulation of projects and detailed project specific economic and financial analysis will then be carried out. A road map can be prepared for execution of the projects and its monitoring and evaluation.

However, the strategy will not remain static. It needs to be reviewed as new data and information becomes available that may necessitate a review of the sub-basin dynamics, sub-basin needs and potential and the national policies. A review of the strategy should be conducted at regular interval (every five years?) to know how the sub-basin behaves under evolving circumstances and changing social, economic and environmental conditions. Periodic review and updating /revising the sub objectives are an important step towards achieving the long term policy objectives.

In this way, each successive basin development strategy can be updated in an informed manner, adjusting as necessary to ensure that the policy goals and planning goals are met.

Monitoring and Evaluation:

The selection of promising strategy and measures for implementation depend upon administrative, financial and political decision making through an established consultative process among the stakeholder institutions. The basin plan has therefore to take into account the actual implementation process and be subjected to periodic reviews and corrections.

A format as indicated below shall be used to monitor the annual progress made.

Measures listed in Strategy	Office in control	Start date	End date	Cost	Expenditure	Expected Impact as per criteria/ indicator	Actual Impact as per criteria/ indicator
1.							
2.							
3.							
4.							

Appendix-1

Establishing Rainfall-Runoff Relationships for Upper Sind sub-Basin upto Amola GD station

Brief Overview:

For accurate prediction of stream flow it is important to know the actual amount of rainfall reaching to ground. We estimate the runoff from the recorded rainfall. However, there is not much rain gauges station in a catchment to cover the spatial and temporal variation of rainfall in watershed.

Problem Statement:

Due to non availability of continuous rainfall and discharge data it is difficult to calculate the future flood and also it is not easy to calculate the runoff with change in physical characteristics of the catchment like change in vegetation cover, surface depression, increase in urbanization, depletion of ground water ,soil erosion etc.

Objective:

In view of the above future circumstances there is necessity of development of Event Based and Continuous Model.

Necessity of Modeling:

Data series of climatic variables are often longer than the runoff series. In such cases a model can be calibrated with existing runoff data and the calibrated model can be used to compute runoff series from the climatic data. In a similar way, models can be used to fill gaps in runoff records. Conceptual models are used to obtain both short-term (a few days) and long-term (a number of weeks or months) forecasts of runoff (or other variables). Predictions needed in planning are questions such as the magnitude of the probable maximum flood, the average runoff from an un-gauged catchment or the hydroelectric potential.

What is HEC-HMS and its role?

a. It is a numerical model that includes a large set of methods to simulate watersheds, channel and water control structures behavior, thus predicting flow, stage and timing.
b. HEC-HMS can provide information about runoff from historical/hypothetical event, with and without water control or other flood damage reduction measures in the watershed, with fine / coarse temporal and spatial resolution, for single event or for long period of records.
c. Can be applied to a variety of watersheds with different shapes, sizes and characteristics
d. Graphical User Interface makes the program user friendly
e. Software is public domain- Can be downloaded from HEC website at no cost

Application:

Flood frequencies, Flood-loss reduction, Flood warning systems, Reservoir design, urban flooding and other environmental studies

Methods and Model Development:

Due to non availability of hourly data it is not possible to develop event model, and due to the availability of daily data continuous model is develop. The Soil -Moisture accounting method (SMA) is selected in this study. Basically, SMA in HEC-HMS is a lumped bucket-type model that represents a sub basin with well-linked storage layers/buckets accounting for canopy interception, surface depression storage, infiltration, evapotranspiration, as well as soil water and groundwater percolation

According to the SMA method in HEC-HMS, rainfall contributes first to the canopy interception storage. Then, rain water available for infiltration, which is determined by infiltration capacity and soil storage. Any excess rainwater sequentially fills the surface depression storage and eventually becomes surface runoff.

With the help of HEC-GeoHMS create the basin model which contains all hydrologic elements and their hydrologic conductivity. It includes sub basin area, physical characteristics of streams and watersheds which are directly used in HEC-HMS. The basin model is shown in Figure 145.

Continuous Hydrologic Modelling

In the continuous hydrologic model, the simulation time period ranged from 01January1989 to 31 January 1994 and one day time step was used. After simulation the model is calibrated for time period range from 31January 1994 to 31January 1999 the final parameters obtained from calibration are used on 30 years rainfall data from 1981 to 2012 to obtain the runoff data of missing period:

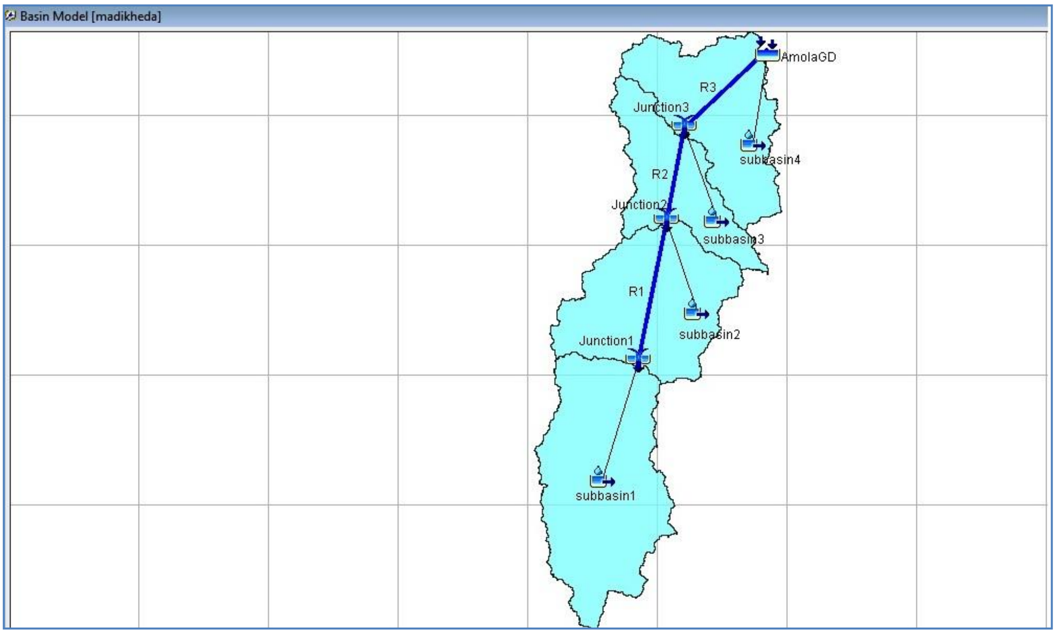


Figure 145: Basin Model Show Hydrological Conductivity

Table 65: Description of Type of Data Available

Type of Data	Spatial Variation	Temporal variation	Remark
Precipitation	5 Rain gauge Station namely Lateri, Sironj, Ashoknagar, Isagarh, Guna, Kolaras and Pichhore	Daily (30 Years)	Manually Operated
Discharge	1 Gauge Discharge Site Amola	Daily (9 Years)	Manually Operated

Analysis of Results

The continuous hydrologic model was calibrated and verified using the observed flow data at the Amola Gauge discharge site. The Comparison between the simulated and observed hydrographs at the Amola gauge site (Sink 1) is shown in Figure 146 to Figure 157.

The Nash Sutcliffe efficiency comes out to be 0.54 near to 1 is acceptable level of performance

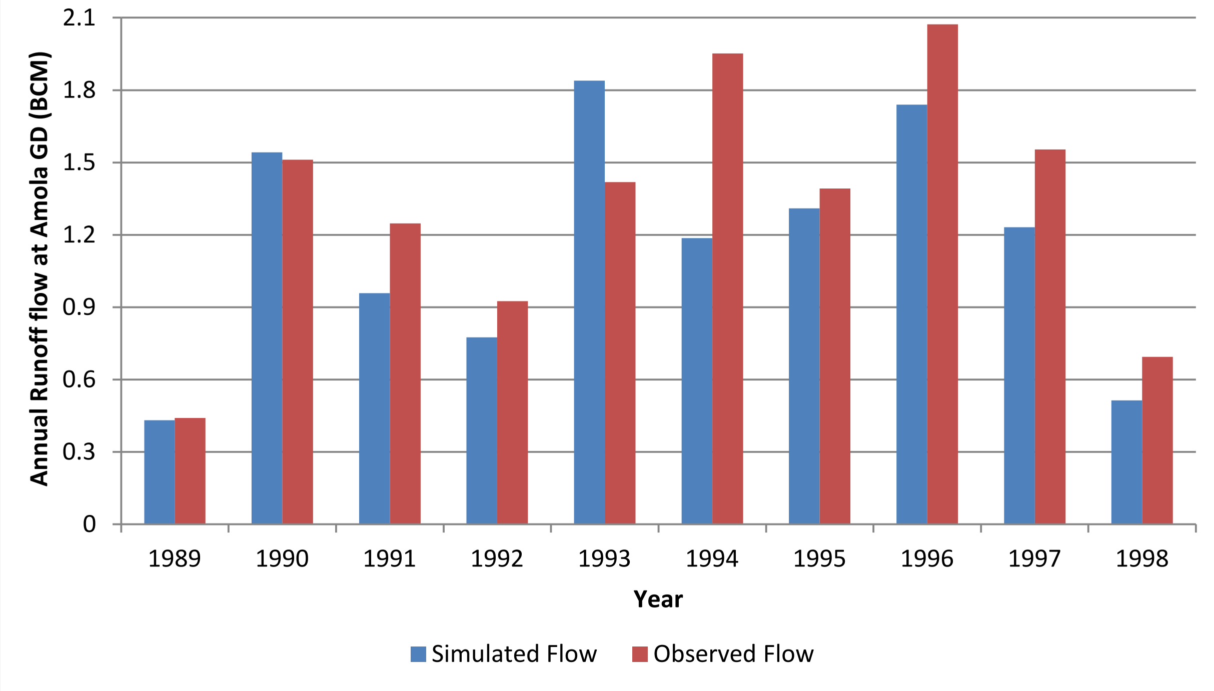


Figure 146: Comparison of Observed and Simulated Flow

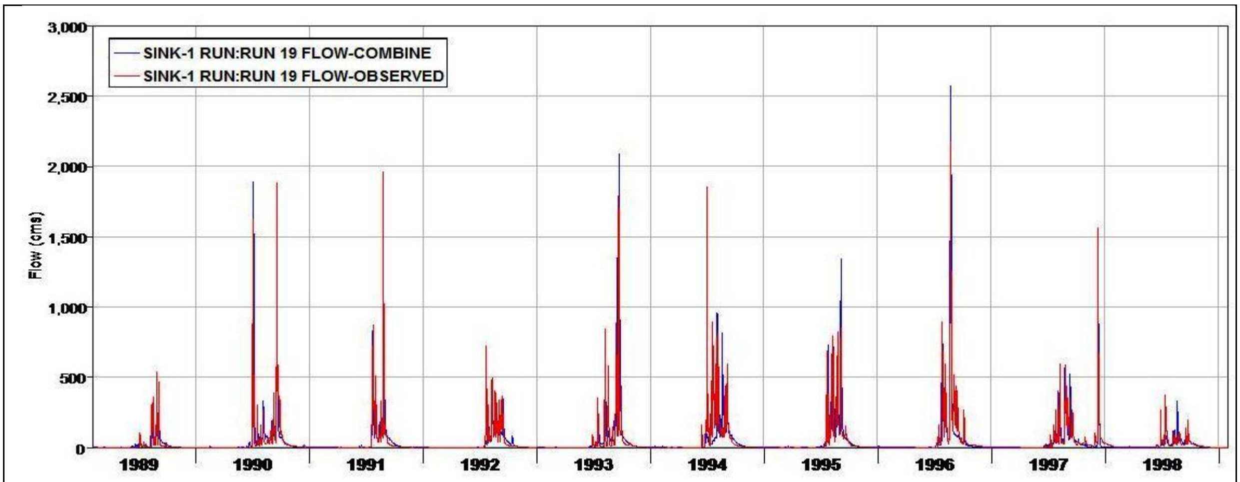


Figure 147: Graph Showing Observed and Simulated Flow

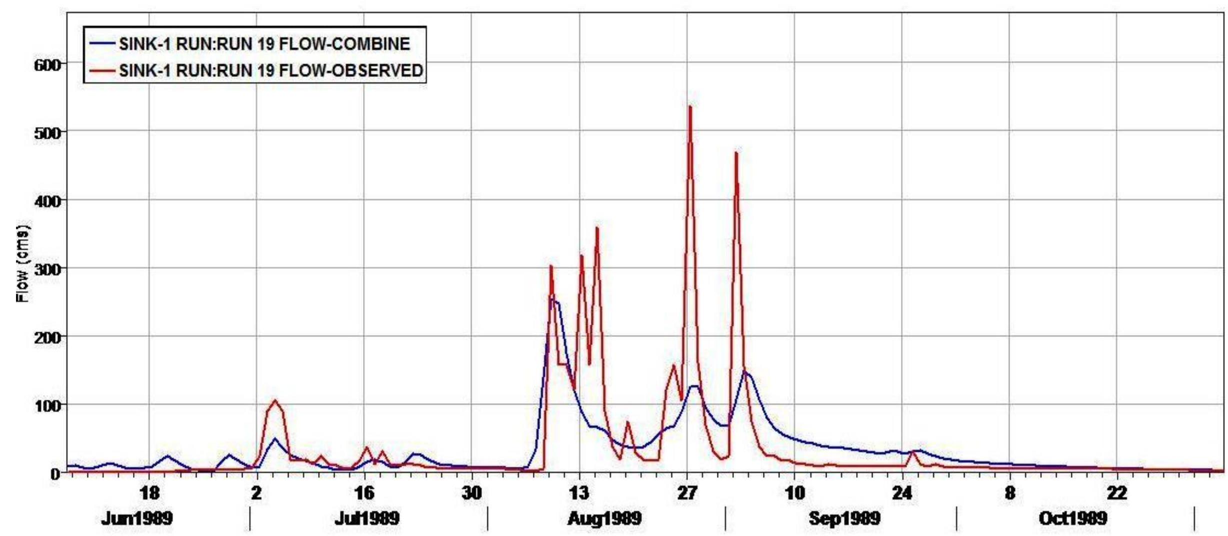


Figure 148: Graph Showing Observed and Simulated Flow (Year1989)

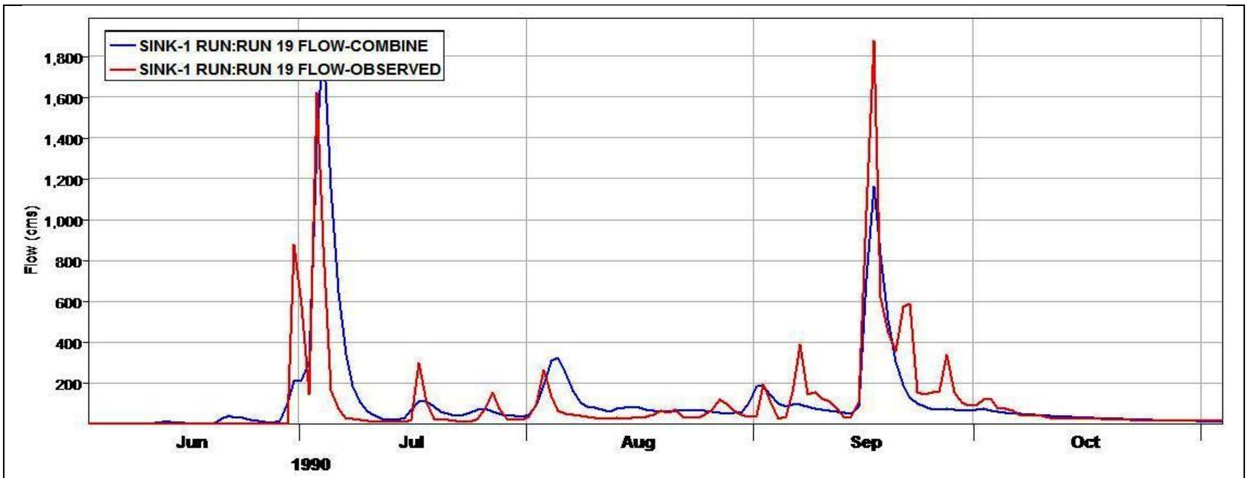


Figure 149: Graph Showing Observed and Simulated Flow(Year1990)

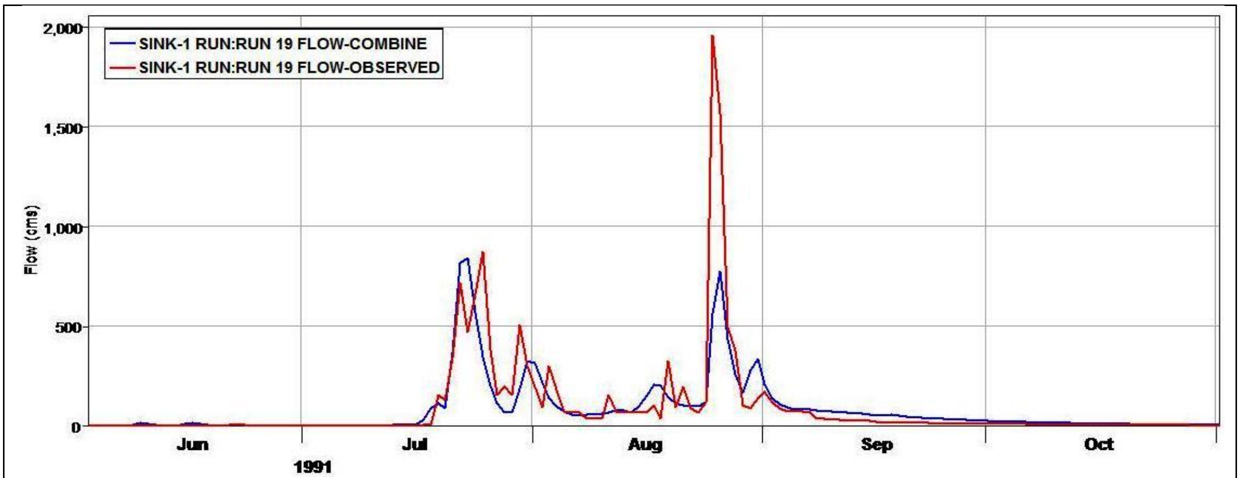


Figure 150: Graph Showing Observed and Simulated Flow(Year1991)

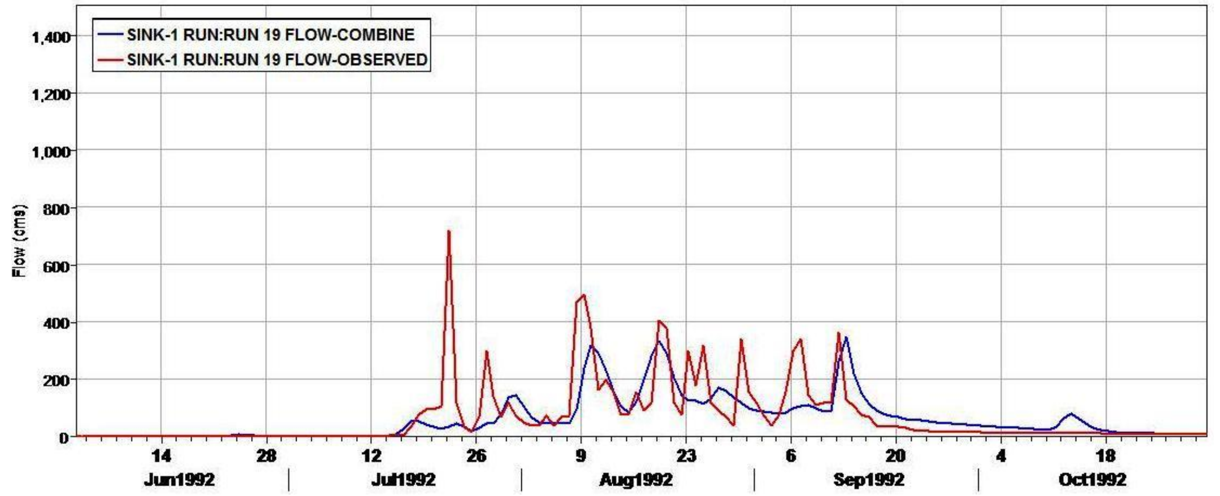


Figure 151: Graph Showing Observed and Simulated Flow(Year1992)

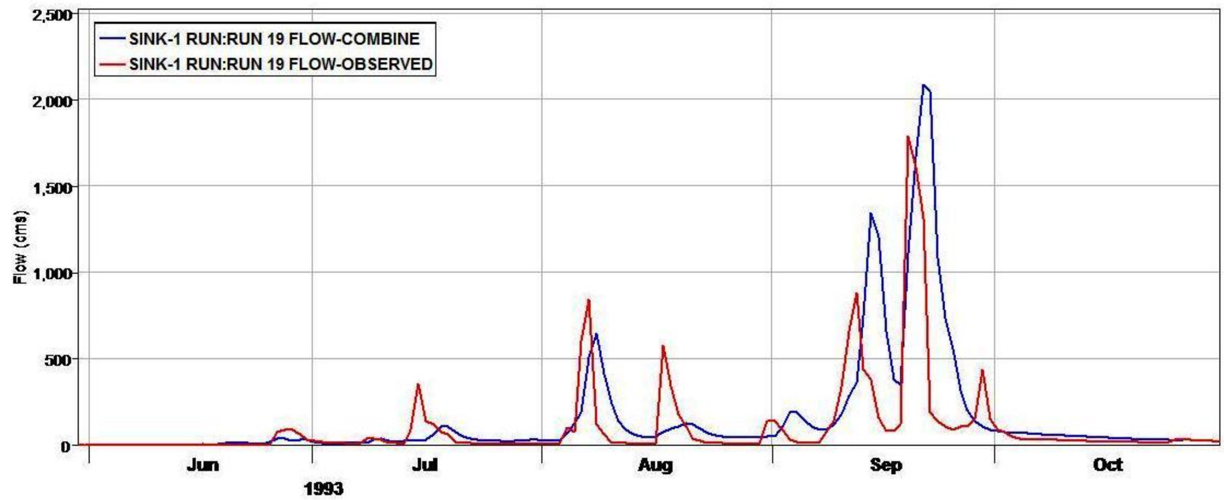


Figure 152: Graph Showing Observed and Simulated Flow(Year1993)

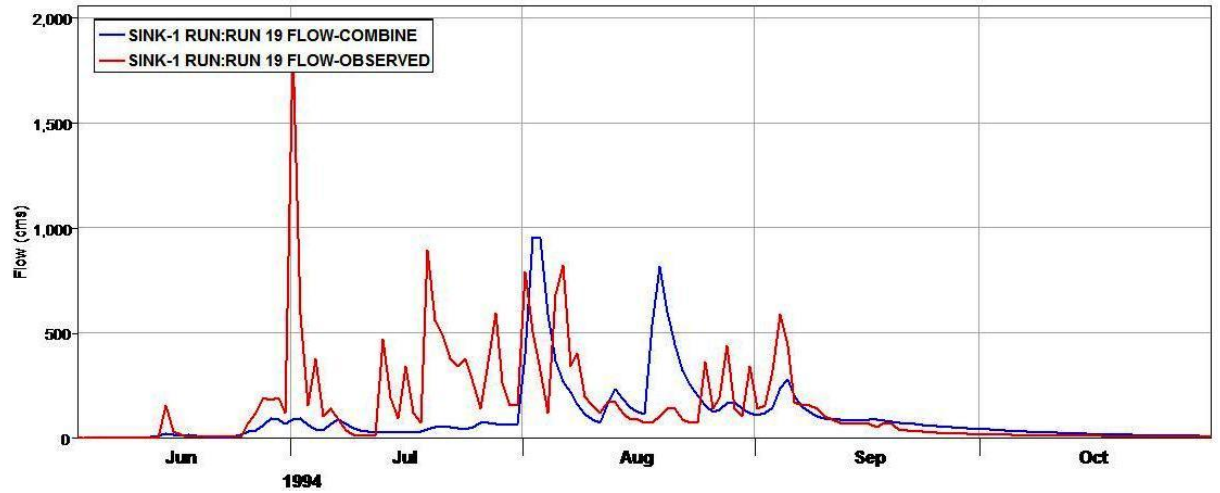


Figure 153: Graph Showing Observed and Simulated Flow(Year1994)

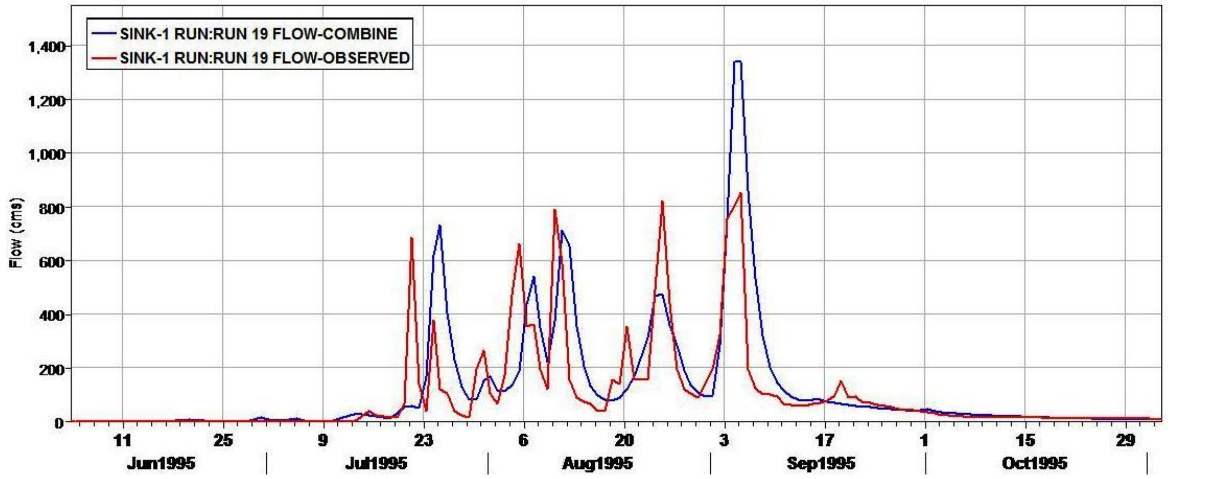


Figure 154: Graph Showing Observed and Simulated Flow(Year1995)

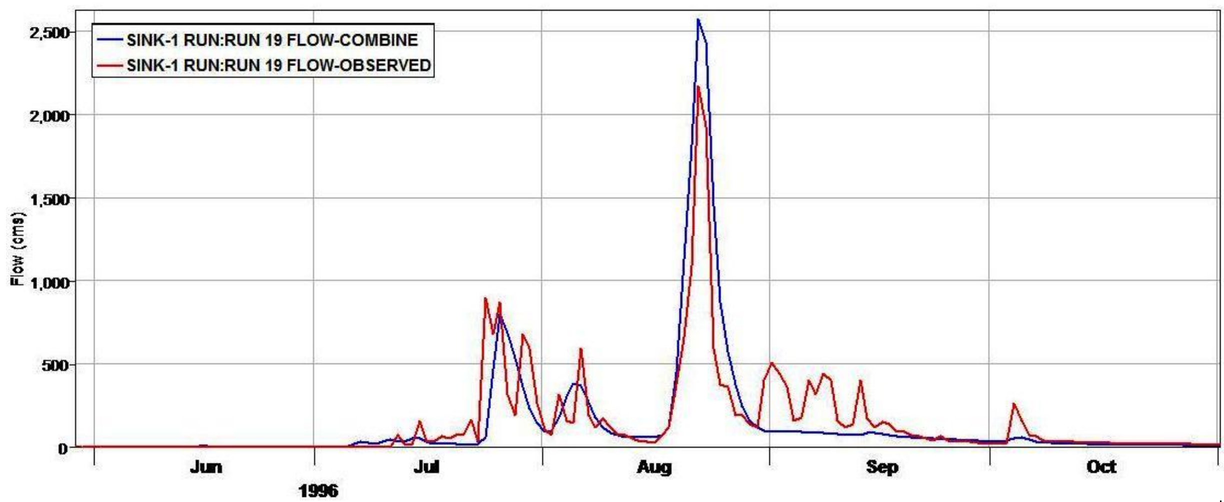


Figure 155: Graph Showing Observed and Simulated Flow(Year1996)

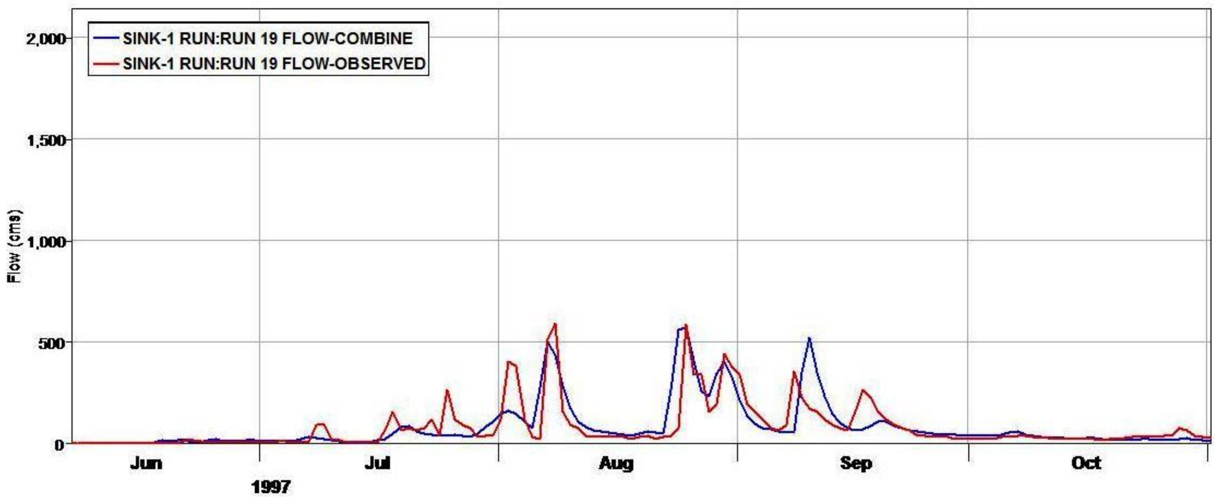


Figure 156: Graph Showing Observed and Simulated Flow(Year1997)

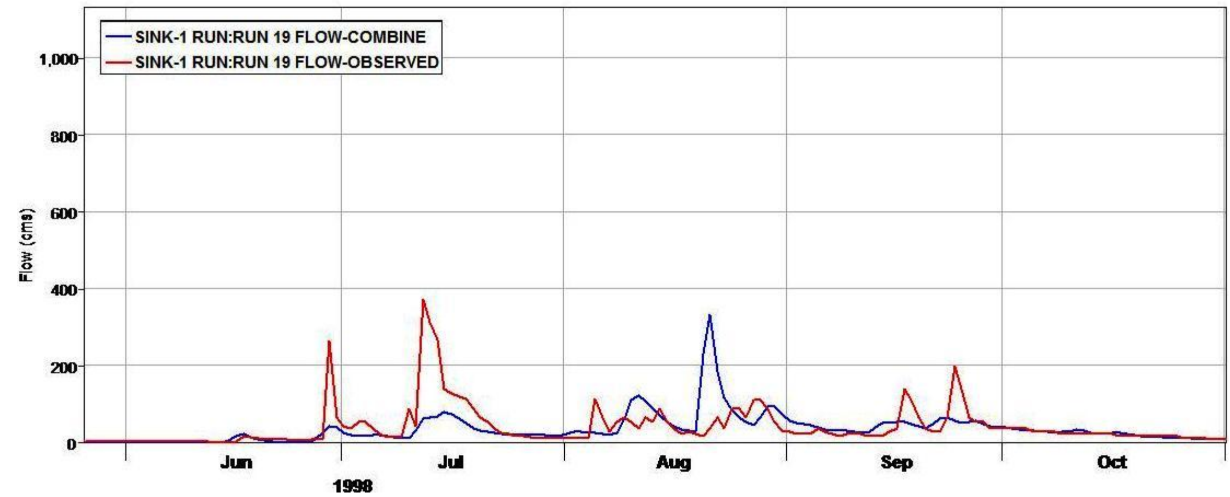


Figure 157: Graph Showing Observed and Simulated Flow(Year1998)

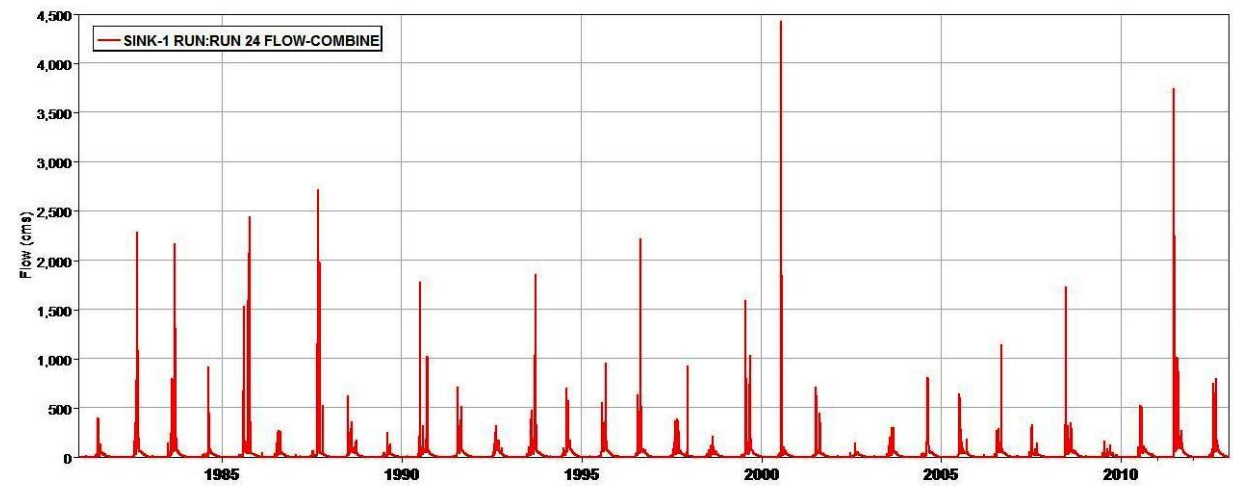


Figure 158: Simulated Hydrograph for the year 1981 to 2011

After Simulation the calibrated parameters are used for determination of missing values of runoff from the period year 1981-1988 and 1999-2011 as shown in Figure14 and the calculated runoff are shown in Table 66.

Table 66: Computed runoff in MCM

Year	Annual runoff in MCM	
1981	485.05	Computed value
1982	2059.39	
1983	1644.41	
1984	673.06	
1985	2648.85	
1986	637.45	
1987	2133.18	
1988	944.12	
1989	431.19	Used for calibration
1990	1542.30	
1991	958.60	
1992	775.06	
1993	1839.73	
1994	1186.61	
1995	1309.41	
1996	1739.86	
1997	1231.30	
1998	513.61	
1999	1402.54	Computed value
2000	1711.56	
2001	918.75	
2002	303.44	
2003	653.01	
2004	927.11	
2005	928.47	
2006	1107.98	
2007	487.22	
2008	1426.90	
2009	400.84	
2010	848.47	
2011	2717.32	

Statistical Analysis:

Flood frequency analyses are used to predict design floods. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability. In this study Peak Flood frequency distributions computed by Gumbel, Log-Pearson Type III and Bulletin 17B by HEC-SSP.The Results are tabulated in Table 67.

Table 67: Result of Statistical analysis

Return Period (In Years)	Discharge by Log Pearson Type III (m^3/sec)	Discharge by Gumbel Distribution (m3/sec)	Disharge by Bulletin 17B HEC-SSP (m3/sec)
50	4475.69	4764.78	5173.95
100	5338.70	5510.19	6546.68
200	6226.99	6252.881	8100.50
500	7434.12	7232.71	10453.39

Conclusion:

In practice short-term hydrologic monitoring data are not always available or they may not always be of sufficient frequency and duration for hydrologic modelling. How to implement effective and accurate hydrologic modelling when faced with such incomplete data is often an issue.. In this study, due to above consequence only continuous hydrologic models were developed for the Upper Sind Sub Basin by using HEC-GeoHMS and the widely used HEC-HMS.

Appendix 2

Water Quality Monitoring System

Surface Water Quality testing of certain important parameters at regular intervals and at crucial locations/points is a must.

There is a need to establish additional monitoring stations at some significant locations. In addition to the existing two stations, 5 important locations have been identified for establishing Water quality monitoring stations as under:

1) One each at downstream of the towns of Gwalior and Morena on Morar and Asan tributaries.
2) One each near major reservoirs Harsi and Madikheda
3) One downstream of Datia town on Pahuj river

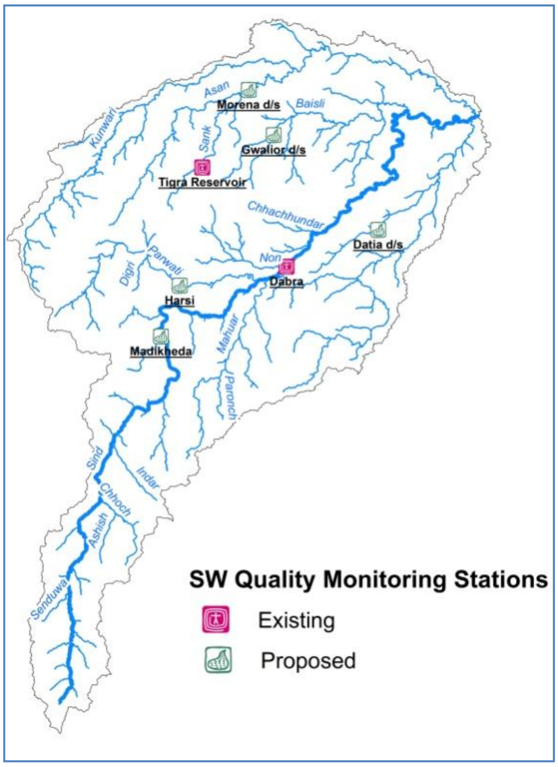


Figure 159: Surface Water Quality Monitoring Stations

The monitoring at these stations should be done for pre and post monsoon period as well as pre and post irrigation (Rabi) period. The basic parameters such as pH, colour, turbidity, DO, BOD, COD, Nitrate, Nitrite, Total coliform, Total dissolved solids, Ammonia and Electrical conductivity are monitored at all stations regularly.

It is known that WQ monitoring is being done by different institutions as per their requirement. The problem however is that data is not easily available. There is no common or easy platform where details such as monitoring stations, parameters tested, frequency of testing and results are available, not even on the website of respective departments/institutions. Information dissemination and sharing of knowledgebase is need of the hour. It is therefore very important to create a common platform where water quality related data of the entire basin is readily available and Water Resources department can take an initiative in this matter and help to form a common web based platform.

Awareness generation is one of the basic steps towards achievement of 100 percent access to sanitation. Changing of existing mindsets through an integrative process of behavioral change through awareness of health and hygiene issues is the key towards achievement of complete sanitation.

Proposed Measure:

At this point it would be ideal to remember that the overall goal of River basin plan is to "protect and develop water resources for present and future needs to ensure the health of the citizens, securing food production through agriculture use and participation in economic development by agriculture, energy and industrial sectors."

This goal can be achieved only through small but significant objectives in every aspect of water resources plan.

Ground Water Quality:

High level of salts in the irrigation water reduces water availability to the crop (because of osmotic pressure) and causes yield reduction. Ground water in affected parts of Bhind and Morena district is therefore unsuitable for irrigation

Reason for presence of high fluoride in ground water may be natural as well as anthropogenic. Anthropogenic sources of fluoride include agricultural fertilisers and combustion of coal. Phosphate fertilisers contribute to fluoride in irrigation lands. To dilute the groundwater contaminated with fluoride, artificial recharging structures can be built in suitable places which will decrease its concentration. Rainwater harvesting through existing wells will prove effective to reduce the groundwater fluoride concentration. Conventional treatment methods like adsorption, ion exchange, reverse osmosis, electrodialysis, coagulation and precipitation etc can be practiced at community level.

Although nitrate occurs naturally in some groundwater, in most cases higher levels are thought to result from human activities. High Nitrate in groundwater within the basin is due to leaching of chemical fertilizers & animal manure, septic and untreated sewage discharges directly on the ground etc. As per the BIS Standard for drinking water the maximum desirable limit of Nitrate concentration in ground water is 45 mg/l with no relaxation. Though Nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern. Proper management of fertilizers, manures, and other nitrogen sources can minimize contamination of drinking water supplies.

The existing status of river water quality within the Sind sub-basin has been discussed in earlier sections of the plan. After situation analysis, it was found that though many organizations are monitoring water quality, the data is not easily available. The numbers of WQ monitoring stations are also inadequate within the basin. CPCB has only two WQM stations in Sind sub-basin in Madhya Pradesh. Hence overall status of water quality of the entire basin is not reflected upon.

Water Resources Department, being the custodian of rivers within its state, has the mandate to monitor the quality of its rivers. Water Resources Department already has water quality testing laboratory at Gwalior within the basin. This was established under Hydrology Project. In order to achieve the water quality objectives mentioned in section on objectives in the report, it is proposed to strengthen the existing water quality monitoring network. There is a need to establish additional stations that would help WRD to monitor water quality at all crucial locations and determine overall health of the river. A full-fledged efficient working network of water quality monitoring is one the most important measures/strategy for achieving water quality related objectives.

Implementation of the proposed measures/ strategies can be done in followings steps:

1) Identification of locations of new monitoring stations.
2) Classifying the WQM stations and determining the parameters to be tested at each of these locations and the frequency of monitoring.
3) Disseminating the information on web portal of Water Resources Department.

Identifying location for new WQM stations:

Central Pollution Control (CPCB) has provided guidelines for establishing new water quality monitoring stations. Location of the additional water quality monitoring stations in the basin is identified based on the following criteria broadly based on CPCB guidelines:

i) Water quality data should be collected at the monitoring stations representing each watershed unit in a river system. Reference station up-stream of all possible discharge points.
ii) Water quality data should be sampled at water treatment facilities or other water intake facilities intended for municipal or industrial use, to support the utilization of water resources. Drinking water intake points, bathing ghats, irrigation canal off-take points.
iii) Water quality samples should be collected in stream sections with degraded water quality.
iv) Monitoring stations should be located on the reaches below pollution discharging facilities and tributaries and on both upper and lower reaches at the point where the point sources flow into the stream. Upstream and downstream of significant pollution outfalls like city sewage drains and industrial effluent outfalls
v) It is appropriate to locate monitoring stations at the confluence of each discharging basin and to observe parameters for both water quality and water quantity.
vi) The physical accessibility of sampling points should also be taken into account, for example, bridges over streams/rivers can provide easy access to water bodies. Availability of sampling facilities such as bridges, boats,

Based on above criteria 5 stations have been identified within Sind sub-basin for WQM. These are shown in GIS map below. If required, the number and locations of these stations can be further modified / improved as per physical or financial constraint during actual implementation.

Classification of WQM stations:

The stations identified above can be classified into different categories as per CPCB and CWC guidelines. This classification is mostly based on previous data analysis. The stations can be grouped as Base station or trend station as below:

i) Baseline Station: Stations should be located in small undisturbed basins with no surface pollutants and no direct human activities. The stations indicating no influence of human activity on water quality are thus classified as the Baseline Station located mostly in upstream of river stretch.

ii) Trend Station: These stations should be located at locations with a range of pollution inducing activities or single dominant activities such as industrial municipal, agricultural mining etc. The network must cover all major human influences upon water quality. Trend station is to be monitored at least once every month.

Based on above definitions, proposed stations can be classified as below:

Baseline Stations:
Trend Stations:
Parameters to be tested at these stations and frequency is as per table below":

Type of Station	Frequency	Parameter
Baseline:	**Perennial rivers and Lakes :** Four times a year **Seasonal rivers :** 3-4 times (at equal spacing) during flow period. **Lake:** 4 times a year	**(A) Pre-monsoon**: Once a year Analyse 25 parameters as listed below : **(a)General** : Colour, odour, temp, pH, EC, DO, turbidity, TDS **(b) Nutrients** : NH_3-N, $NO_2 + NO_3$, Total P **(c)Organic Matter** : BOD, COD **(d)Major ions** : K, Na, Ca, Mg, CO_3, HCO_3, Cl, SO_4, **(e)Other inorganics** : F, B and other location-specific parameter, if any **(f)Microbiological** : Total and Faecal Coliforms **(B)Rest of the year** (after the pre-monsoon sampling) at every three months' interval: Analyse 10 parameters: Colour, Odour, Temp., pH, EC, DO, $NO_2 + NO_3$, BOD, Total and Faecal Coliforms.
Trend:	Once every month starting April-May (pre-monsoon), i.e. 12 times a year	**(A)Pre-monsoon**: Analyse 25 parameters as listed for baseline monitoring **(B)Other months** : Analyse 15 parameters as listed below **(a)General** : Colour, Odour, Temp, pH, EC, DO and Turbidity **(b)Nutrients** : NH_3-N, $NO_2 + NO_3$, Total P **(c)Organic Matter** : BOD, COD **(d)Major ions** : Cl **(e)Microbiological** : Total and Faecal coliforms **(C)Micropollutant** :Once in a year in monsoon season **(i)Pesticides**-Alpha BHC, Beta BHC, Gama BHC (Lindane), OP-DDT, PP-DDT, Alpha Endosulphan, Beta Endosulphan, Aldrin, Dieldrin, 2,4-D, Carboryl (Carbamate), Malathian, Methyl Parathian, Anilophos, Chloropyriphos

Table 68: Quality parameters to be tested

Format for information dissemination:

The most important and often the most neglected part of water quality monitoring is information dissemination. The data related to water quality is generally kept in records within the office and laboratory staff. Lack of sharing and availability of water quality data to decision makers across related sectors defeats the purpose the monitoring. It is therefore important to establish a system where water quality data is shared at a platform easily accessible to the authorities in water resources department as well as other related organizations.

The website of WRD is one such platform (web based) where the data can be disseminated in the following tabular format every month:

WQM station code	WQM Station Name	Date of sampling	Parameters		Remarks
			I	II	

Table 69: Sample Format for data dissemination

This data can be made available to concerned authorities provided with login id and password. Others who need the data can be given a temporary user id and password on request which may be submitted online.

In addition to this, annual reports may be uploaded after analysis of the water quality data which can be available to everyone.

Appendix-3

Ongoing Works to add up New Irrigation Area

S.No.	District	Scheme Name	Project Type	Total Irrigation Potential (ha)	Latest Cost (in Million INR)
1	Ashoknagar	Barkheda chhajju [32089]	Tank	1550	300
2	Ashoknagar	Berkhedi [32363]	Weir	195	15
3	Ashoknagar	Bosra manihari [32091]	Tank	145	29
4	Ashoknagar	Ghat bamuriya stop dam [37477]	Weir	150	11
5	Ashoknagar	Indaur [32092]	Tank	199	40
6	Ashoknagar	Kankda [27751]	Stopdam	534	28
7	Ashoknagar	Kumharra stop dam [33419]	Weir	170	21
8	Ashoknagar	Marhikanoongo [32362]	Tank	700	71
9	Ashoknagar	Pachlana [26881]	Tank	250	29
10	Ashoknagar	Renjhaghat [32364]	Weir	210	16
11	Ashoknagar	Rusalla buzurg stop dam [33421]	Weir	160	15
12	Ashoknagar	Semritanki [32365]	Weir	180	24
13	Ashoknagar	Shahpur [27424]	Tank	386	64
14	Gwalior	Parsen [23533]	Tank	460	100
15	Morena	Budhara [32385]	Weir	332	49
16	Morena	Dimani stop dam [32834]	Weir	324	51
17	Morena	Konthar kala [32387]	Barrage	700	89
18	Morena	Roophati [32388]	Weir	700	89
19	Shivpuri	Bilrau dinara feeder canal [32354]	Weir	260	83
20	Shivpuri	Pachipura [32356]	Tank	1495	270
21	Shivpuri	Sunaj [31190]	Tank	750	133
22	Shivpuri	Teela [32355]	Tank	1225	239
		Total - 22 Works		**11075**	**2747**

Appendix-4

Proposed New Irrigation Schemes

S. No.	District	Scheme Name	Project Type	Proposed Rabi Irrigation Area (in ha)	Total Estimated Cost (in Million INR)
1	Ashoknagar	Bahadurpur weir cum causeway	Weir	140	25
2	Ashoknagar	Barodiya stop dam	Barrage	145	18
3	Ashoknagar	Besra stop dam cum causeway	Barrage	202	30
4	Ashoknagar	Garethi stop dam cum causeway	Weir	190	28
5	Ashoknagar	Kanikhedi stop dam	Weir	110	18
6	Ashoknagar	Kukreta stop dam cum causeway	Barrage	242	30
7	Ashoknagar	Kurmasha stop dam cum causeway	Weir	199	23
8	Ashoknagar	Maholi stop dam	Weir	200	20
9	Ashoknagar	Malaukhedi weir cum causeway	Weir	165	29
10	Ashoknagar	Rampura stop dam ucm causeway	Weir	115	17
11	Ashoknagar	Sanwal heda weir cum causeway	Weir	170	30
12	Bhind	Chandani stop dam	Weir	80	8
13	Bhind	Gahali stop dam	Barrage	41	3
14	Bhind	Gata stop dam	Weir	65	6
15	Bhind	Gugawali stop dam	Weir	51	6
16	Bhind	Kachnav kala boodanpur stop dam cum causeway	Weir	87	17
17	Bhind	Rajpura stop dam	Weir	44	5
18	Datia	Khamroli stop dam	Barrage	250	130
19	Datia	Purana kaserua stop dam	Barrage	270	140
20	Gwalior	Bastarikuitank	Dam	226	34
21	Gwalior	Chandolatank	Dam	666	121
22	Gwalior	Chaparghatstopdam	Dam	120	16
23	Gwalior	Charaidangtank	Dam	118	65
24	Gwalior	Chirolimanpurstopdam	Dam	15	1
25	Gwalior	Dabkatank	Dam	550	37
26	Gwalior	Dadoriphakrpastopdam	Dam	45	1

S. No.	District	Scheme Name	Project Type	Proposed Rabi Irrigation Area (in ha)	Total Estimated Cost (in Million INR)
27	Gwalior	Gadrodlitank	Dam	115	12
28	Gwalior	Ghurraghatstopdam	Dam	130	20
29	Gwalior	Hunpuratank	Dam	85	23
30	Gwalior	Kaimaritank	Dam	51	20
31	Gwalior	Kajirjhoratank	Dam	50	9
32	Gwalior	Lidhoratank	Dam	291	104
33	Gwalior	Pataistopdam	Dam	45	3
34	Gwalior	Raighatstopdam	Dam	120	19
35	Gwalior	Ratinaridhonatank	Dam	65	16
36	Gwalior	Simariya tank no.2	Dam	161	68
37	Gwalior	Tankolitank	Dam	200	7
38	Morena	Bhidosa	Dam	300	45
39	Morena	stop dam accroos kuwari river at bargama	Weir	41.65	8
40	Morena	stop dam across asan river at aino	Weir	61.2	34
41	Morena	stop dam across quari river at sangoli	Weir	95	18
42	Morena	Ekhera	Barrage	20	24
43	Morena	Itora stop dam	Barrage	45	41
44	Morena	Konther kala stop dam cum cause way	Dam	700	89
45	Morena	Konther khurd stopdam cum cause way at kuwari river	Dam	700	95
46	Morena	Mahori stop dam	Barrage	48	43
47	Morena	Mai stop dam	Barrage	52	31
48	Morena	Naharwali stop dam	Barrage	45	64
49	Morena	Sihoniya stop dam	Dam	260	39
50	Shivpuri	Amar pur	Dam	110	20
51	Shivpuri	Golta bahadurpur	Weir	110	17
52	Shivpuri	Jamunia nalla	Weir	250	19
53	Shivpuri	Machhaoli	Weir	140	22
		Total - 53 Works		**8797**	**2360**

Scoping studies for water resources development on Kunwari and Sind rivers:

Pursuant to the situation and system analysis, there exists some scope of developing the water resources in the basin. Such development within the existing environmental and legal framework is possible after detailed scoping studies. Kunwari and lower Sind sub-basins have much of the water resources yet unharnessed. For example, based on desk reconnaissance, a potential benefit zone is identified in lower Sind as a possible water resources development area.

Figure 160 : Index map

The catchment area of the possible sites of the potential zones is 12900 Km^2, corresponding to average yield of 1.5 BCM. The inundation stretch of approximately 30 kms runs along the river on one side where as either side is also closely bounded by the ridge of Pahuj river. With hills on one side and other high lands on the other, there could be a number of possible sites for storage creation, ranging from 10 -25 m high dams.

The assured/perennial storage throughout year could be a boon to nearby human habitation, agriculture and animals. The ongoing mission of shifting the reliance on ground water to surface water especially in rural areas of Datia and Bhind district can be facilitated by such storage.

The elongated and abundant storage along the river stretch could also present an opportunity to ecological and environmental benefit to the nearby Ratangarh forests and could act as an eco-zone or green-zone. Ratangarh temple at the top of hill is the shrine for many pilgrimages and around 1 million people gather twice a year for festivals in the temple and take a holy dip in this river. The cultural importance and nearby forest banks creates an immense potential for tourism and recreation in this zone.

This region is identified in Datia district of lower Sind and is one the districts which are identified as underdeveloped due to recurrent droughts. It witnesses hot summer days in upto 49^{0}C. The storage presents possibilities of diverting water in downstream during dry seasons will serves as mitigation to droughts in a large area.

Another spinoff of such storage creation is its hydro power potential based on some rough estimates:

1) The assured supply in this region with peak discharge of 348 cumecs and minimum base flow discharge 24 cumecs (excluding dry summers April-June).
2) Possibility to create a head of 15-25 metres.
3) Possibility to store 60-100 MCM of water to supplement dry season flows.
4) Adsorption and utilization of upstream environmental and return flows especially vulnerable in dry seasons with assurance of abundant environmental flow to downstream.
5) Possibility to generate 40-60 MW hydropower.

The following points were considered while identifying the site

1) Maximum height
2) Minimum submergence
3) Maximum storage
4) Minimum habitation in submergence area
5) Elongated perennial submergence

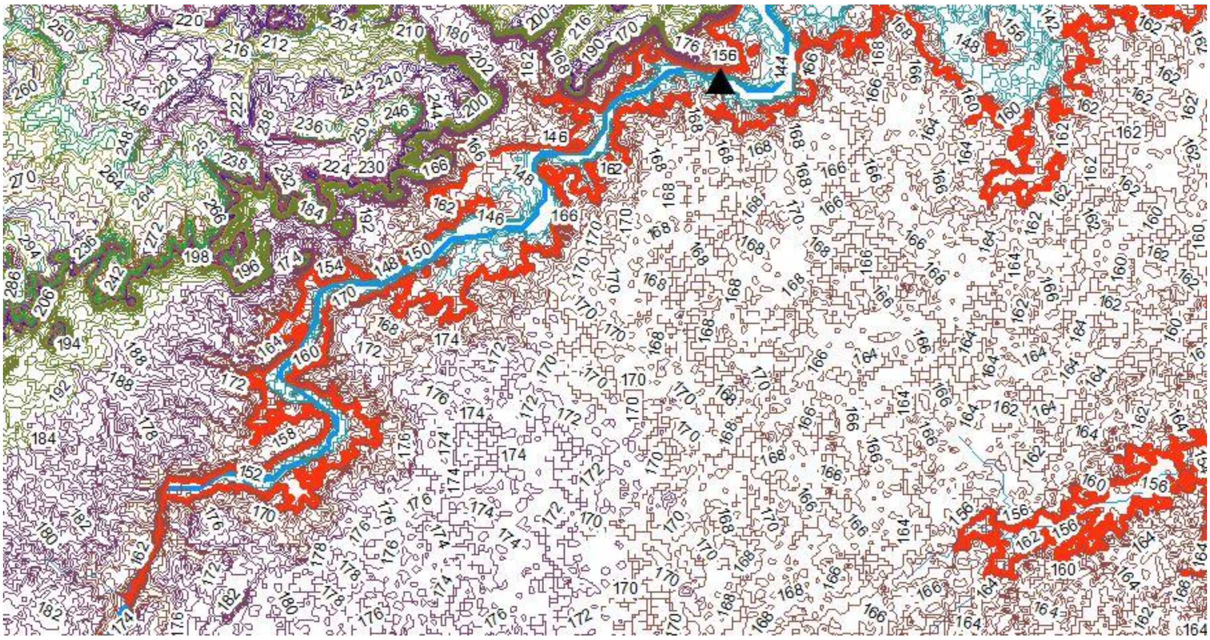


Figure 161: Contour map

The estimated features of proposed dam site could be as below:

Features	
River bed level	138 m
Height of dam	22 m
Top bund level	160 m
Full tank level	158 m
Length of dam	1120 m
Catchment area	12900 km^2
Submergence area	2312 hectares
Storage	78 MCM

The following could be considered broadly for integrated development for the potential zone

1) Identification of Stakeholders
2) Role of stakeholders-existing role in water sector and expected/proposed participation
3) Short term strategy and benefits
4) Long term strategy and benefits

Development of water resources is the multidisciplinary task and has many stakeholders like Water Resources Department, Forests, Fisheries, Agriculture, Energy Companies, Municipal bodies and Gram Panchayats. All the functionaries are integrated at apex level, but the integrated development of water resources in the zone needs active participation of each stakeholder from inception to implementation process. The existing roles and expected participation of some key stakeholders is tabulated below-

S no.	Name of Stakeholder	Existing role in water sector	Expected/proposed participation
1	WRD	Custodian of all SW and GW in state working mainly in domain of providing irrigation facilities through dams and canal.	Co-ordination role amongst different stakeholders
2	Forest	Protecting and developing forest area.	Development of Ratangarh forest by utilizing proposed storage
3	Agriculture	Primarily extension services	Promotion of on farm developments like sprinkler and drip.
4	Horticulture	Extension services	Promotion of demonstration farms and mechanized farming in the benefited areas
5	Fisheries	Development of fisheries	Development of fisheries in storage, creation of fisheries cooperative

S no.	Name of Stakeholder	Existing role in water sector	Expected/proposed participation
6	Energy (Hydel)	Production, distribution of power	Construction of Hydel Power plant and transmission to grid
7	Tourism	Development of tourism	Development of Ratangarh hill and river bank for tourism.
8	Municipal/rural bodies	Responsible for providing potable drinking water	Pitching in for domestic water demand, intake structures, water treatment facilities

The suggestion above is only based on desk calculations (GIS, imageries, Google Earth) and in no way suggestive of its suitability without the prevalent process of field surveys and techno-economic feasibility. Many more sites are available and it is recommended that detailed scoping studies may be conducted to create a shelf of possible projects to be weighed for possible socio-economic benefit.

At a Glance- Objectives, Criteria, Indicator, Proposed Measures and Qualitative impact of measure for Sind sub basin

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
1	Ensure availability of water resources data, to improve scientific database and assessment		C-1 Collection of adequate and reliable hydrological data	1. Repository size with coverage of river network				
			C-2 Processing and analysis of collected data	2. Ready to use in different formats				
			C-3 Dissemination of data	3. Easy availability				
		1.1 Improvement in basic data collection of hydro-meteorological parameters from existing field stations			**M-1**: Re-structuring of State Water Resources Data Analysis Center (SWaRDAC) of MP Water Resources Department, Hydrometeorology and Ground water wing of the department with responsibility for data collection, analysis	++	+++	+/-
		1.2 Improvement in processing and analysis of collected data.			**M-2**: Installing new field stations for hydrological and water quality data at strategic locations	+++	++	+/-

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
		1.3 For cross cutting and historical database, ensure data access to & from CGWB, IMD, CWC, CPCB, SPCB and Agriculture department			**M-3**: Initiate a common portal, for data archival and disclosure, as has been done by the GOI *data.gov.in*	+++	++	+++
		1.4 Improvement in dissemination of processed and analyzed data.			**M-4**: Use of departmental websites for data dissemination with 'public data' and 'Data for departmental use' sections		++	+++
2	Improve coordination in management of water resources		C-1 Users participation	1. Increased and effective participation of user in operation and management				
			C-2 Sectoral coordination	2. Increase in number of joint meetings and dissemination of information				

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
		2.1 Improving sectoral coordination in water resources management			**M-5**: Expanding and Empowering the District Level Water Utilization Committee and State Level Water Utilization Committee for information on current and future state of small water related infrastructure	+	+++	
		2.2 Increasing WUAs participation in management of water resources			**M-6**: Transferring management of minor water resources assets to WUAs - Irrigation Management Transfer (IMT)	+++	++	
3	Supply of suitable quality of water as per designated best use within the basin to ensure health of citizens and to sustain ecosystem		C-1 Improvement in Class of river water quality as per CPCB classification	1. Compliance to acceptable levels of water quality paramters				
			C-2 Improved water quality monitoring network	2. Standard set of parameters monitored at important stations at regular intervals and no data gaps				

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
			C-3 Minimum Environmental Flow	3. No. of days river flow more than minimum environmental flow at existing GD sites				
		3.1 Improving Water quality of River Sank at Tighra and River Sind at Dabra from class B to Class A			**M-7**: Educating /sensitizing people on environment and conducting awareness programs in nearby villages.	++		
					M-8: Timely completion of infrastructural measures as envisaged in city development plans.	+++		+/-
		3.2 Strengthening the existing water quality monitoring network			(Establishing 5 monitoring stations) Described in **M-2**	+	+++	+
					(Forming a web based platform for WQ data from all institutions) Described in **M-3**	+	+++	+/-

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
		3.3 Providing adequate stream flows to ensure sustenance of wildlife and ecosystem			**M-9**: Assessment of minimum environmental flow for ecological and environmental sustenance based on comprehensive approaches like building block methodology, DRIFT or equivalent	+	+	+++
4	Reliable and adequate supply of water especially to the water scarce regions of Sind sub-basin for agricultural use.		C-1 Sufficient irrigation waterings received	1. No. of irrigation waterings				
			C-2 Area receiving irrigation service	2. % of net sown area receiving irrigation service				
			C-3 Reduced groundwater dependence	3. Reduction of stage of GW development (%)				
		4.1 On-field rainwater harvesting and conservation			**M-10**: Continuation and intensification of Khet-talab and Balram Talab programmes in Gwalior, Morena and Bhind districts	+	+	+++

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
		4.2 Creation of additional storage/ availability with the completion of ongoing WRD schemes			**M-11**: Completion of series of stop dams (Sonera Khamkheda) in Upper Sind and other ongoing works	++	+++	++
		4.3 To develop possible new storages			**M-12:** Scoping studies for water resources development on Kunwari and Sind Rivers	++	+++	++
		4.4 Expansion of irrigation service from intra-basin transfers			**M-13**: Completion of ongoing Sind Ramowa link project and other proposals	++	++	+
5	Improvement of water use efficiency in Agriculture use		C-1 Increase in irrigated area serviced per unit volume of stored water	Area serviced in hectares per unit storage (Ha/MCM)				
			C-2 Increase in crop yield of indicator crops-wheat, mustard and soybean	Crop yield per unit farm areaTonnes/Ha				

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
		5.1 Improving Reservoir (tank) efficiency in dams			**M-14**: Asset modernization measures to minimize seepage within tolerance level specified in WRD T.C. and BIS standards	++	+	
					M-15: Improving seepage measurement system like installation of piezo-meters in dams ,V-notches in seepage drains	+	+	
		5.2 Improving conveyance efficiency in projects			**M-16**: Restructuring of complete conveyance system (structural measures like re-sectioning, lining, repair of structures etc.)	+++	++	
		5.3 Improving Field application efficiency			**M-17:** Switching from conventional flood irrigation methods to sprinkler/drip	+++	+++	
					M-18: Creating awareness among farmers to adopt improved agricultural practices, micro-irrigation techniques and adopting high yielding crops	++	++	

S.No.	Objective	Sub objective	Criteria	Indicator	Proposed Measures	Qualitative Impact of measures		
						C-1	C-2	C-3
6	Promote sustainable ground water use		C-1 Stage of groundwater development in safe category	Ratio of annual groundwater draft and annual replenishable groundwater availability (in %)				
		6.1 Stabilization of declining GW table in 7 blocks (semi-critical units) of Datia, Guna, Gwalior, Morena & Shivpuri districts			**M-19**: Adoption of artificial recharge measures like roof top water harvesting in urban areas, contour bunding, percolation tanks etc. in rural areas	+++		
					M-20: Conducting mass awareness programs and training on groundwater management	+++		
		6.2 GW development in Seventeen blocks (safe units) of Ashoknagar, Bhind, Datia, Guna, Gwalior, Morena, Sheopur, Shivpuri & Vidisha districts			**M-21**: Construction of hand pumps , dug wells & tube wells by the Agriculture department, PHED, Panchayats, Municipalities and farmers	++		