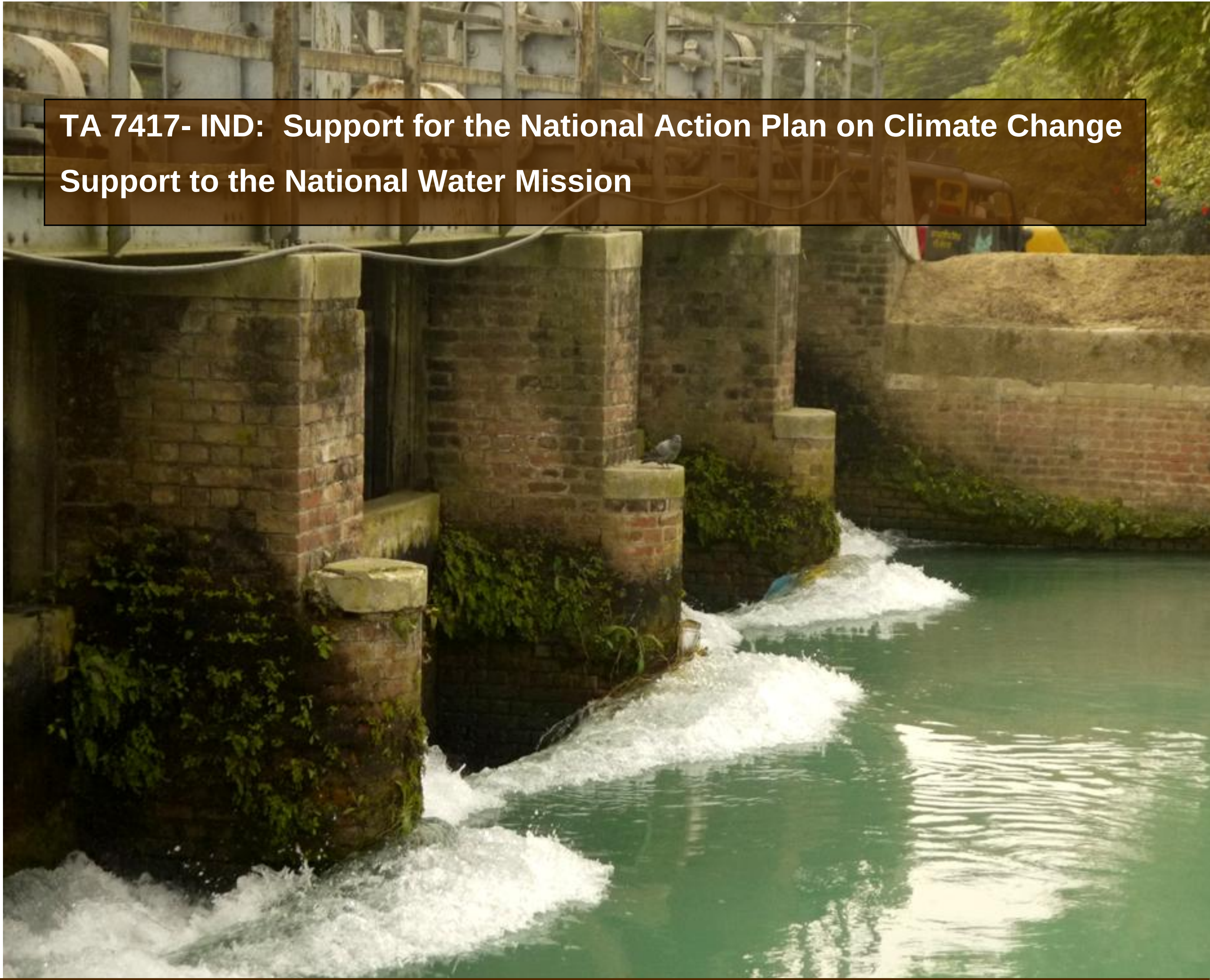

TA 7417- IND: Support for the National Action Plan on Climate Change

Support to the National Water Mission

Final Report September 2011
Appendix 3 Kshipra Sub Basin

PREPARED FOR
Government of India
Governments of Punjab, Madhya Pradesh and Tamil Nadu
Asian Development Bank

Appendix 3

Kshipra Sub Basin Madhya Pradesh

SUMMARY OF ABBREVIATIONS

A1B	IPCC Climate Change Scenario A1 assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B).
A2	IPCC climate change Scenario A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change.
ADB	Asian Development Bank
AGTC	Agriculture Technocrats Action Committee of Punjab
AOGCM	Atmosphere Ocean Global Circulation Model
APHRODITE	Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources - a observed gridded rainfall dataset developed in Japan
APN	Asian Pacific Network for Global Change Research
AR	Artificial Recharge
AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
AWM	Adaptive Water Management
B1	IPCC climate change Scenario B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy.
B2	IPCC climate change Scenario B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability.
BBMB	Bhakra Beas Management Board
BCM	Billion Cubic Metres
BML	Bhakra Main Line Canal
BPL	Below the Poverty Line
BPMO	Basin Planning and Management Organisation of the CWC
CAD	Command Area Development
CADA	Command Area Development Authority
CBO	Community Based Organisation
CCA	Command Control Area
CCIP	Climate Change Implementation Plan
CDM	Clean Development Mechanism
CDMR	Cauvery Delta Modernisation Report
CESER	Centre for Earth Systems Engineering Research, Newcastle University, UK
CGIAR	Consultative Group on International Agricultural Research
CGWA	Central Ground Water Authority
CGWB	Central Ground Water Board
CMIP	Coupled Model Intercomparison Project - an IPCC initiative to compare climate models
CMR	Cauvery Modernization Report
CNES	French Centre National d'Etudes Spatiales
CPCB	Central Pollution Control Board
CSK HPAU	CSK Himachal Pradesh Agricultural University
CUSECS	Cubic feet per second
CWC	Central Water Commission
CWPRS	Central Water and Power Research Station
DEA	Department of Economic Affairs
DEM	Digital Elevation Model
DJF	December-January-February
DMC	Developing Member Country
DMR	Delta Management Report
DSS	Decision Support System
DSSAT	Decision Support System for Agricultural Technology
DTR	Diurnal Temperature Range
EC	Electrical Conductivity
ED&MM	Exploratory Drilling and Materials Management
EIA	Environmental Impact Assessment
EMC	Environmental Monitoring Committee
EMP	Environmental Management Plan
ESSP	Earth System Science Programme
ETo	Evapotranspiration
FAO	Food and Agriculture Organisation of the United Nations
FASS	Farmers Advisory Services Schemes

FPARP	Farmer's Participatory Action Research Programme
FYP	Five Year Plan
GCM	Global Circulation or Climate Model
GIS	Geographic Information Systems
GLOF	Glacial Lake Outburst Flood
GOI	Government of India
GRBMP	Ganga River Basin Management Plan
GSI	Geological Survey of India
GW	Groundwater
HAM	Hectare Metres
HIS	Hydrological Information System
HP	Himachal Pradesh
HP2	Hydrology Project 2
I&D	Irrigation and Drainage
ICIMOD	International Centre for Integrated Mountain Development
ICT	Information and Communication Technologies
IITM	Indian Institute for Tropical Meteorology
IMD	Indian Meteorological Department
IMTI	Irrigation Management Training Institute
INCCA	Indian Network of Climate Change Assessment
IPCC	International Panel on Climate Change
IRBM	Integrated River Basin Management
IS	Institutional Strengthening
ISRO	Indian Space Research Organisation
IWRM	Integrated Water Resources Management
JF	January-February
JJAS	June-July-August-September
KVK	Krishi Vigyan Kendras
LBC	Lateral Boundary Conditions
l/s/ha	litre per second per hectare
LBC	Lateral Boundary Conditions
LIS	Legal Information System
MAM	March-April-May
MCM	Million Cubic Meters
MODFLOW	Three-dimensional finite-difference groundwater flow model developed by the US Geological Survey
MoEF	Ministry of Environment and Forests
MOHC	Met Office Hadley Centre (UK)
MOU	Memorandum of Understanding
MoWR	Ministry of Water Resources
MP	Madhya Pradesh
msl	Mean Sea Level
MSP	Minimum Support Price
MTM	Megha-Tropiques Mission
NAPCC	National Action Plan for Climate Change
NARBO	Network of Asian River Basin Organisations
NCDS	National Committee on Dam Safety
NCIWRD	National Commission for Water Resources Development
NCMRFF	National Centre for Medium Range Weather Forecasting
NDC	National Data Centre, India
NDMA	National Disaster Management Agency
NGO	Non-Governmental Organisation
NIH	National Institute of Hydrology
NMSKCC	National Mission on Strategic Knowledge for Climate Change
NREGA	National Rural Employment Guarantee Act
NRSA	National Remote Sensing Agency
NSRC	National Remote Sensing Centre
NWH	North-western Himalayan Region
NWM	National Water Mission of the NAPCC
ON	October-November
OND	October-November-December
PAFC	Punjab Agro Foods Corporation
PAO	Project Appraisal Organisation

PATA	Policy Advisory Technical Assistance
PAU	Punjab Agricultural University
PES	Payment for Environmental Services
PIM	Participatory Irrigation Management
PPE	Perturbed Physics Ensemble
PPP	Public Private Partnerships
PRA	Participatory Rural Appraisal
PRECIS	Providing Regional Climates for Impacts Studies
PRI	Panchayati Raj Institutions
PWD	Public Works Department
Q14, Q1 Q0	Identifiers for runs with different perturbations
QUMP	Quantifying Uncertainty in Model Predictions is an approach which aims to provide probabilistic projections of future climate.
RegCM	Regional Climate Model system RegCM
R&R	Rehabilitation and Resettlement
RBO	River Basin Organisation
RCM	Regional Circulation or Climate Model
RCP	Representative Concentration Pathways
RGNGT&RI	Rajiv Gandhi National Ground Water Training and Research Institute
RSC	Residual Sodium Carbonate
RTDSS	Real Time Data Support Systems
SAM	Survey Assessment and Monitoring
SAPCC	State Action Plans for Climate Change
SD&MA	Service Delivery and Management Alternatives
SGWA	State Ground Water Authority
SML	Sustainable Management and Liaison
S-NWM	ADB Support TA to the National Water Mission of the NAPCC
SRES	Special Report on Emission Scenario (IPCC SRES November 2000
SRI	System of Rice Intensification
SRTM90	A DEM with 90m resolution developed by the Shuttle Radar Topography Mission
START	Global change system for analysis, research and training coordinated by IIT Mumbai
SWAP	Soil-Water-Atmosphere-Plant
SWAT	Soil and Water Assessment Tool
T&TT	Training and Technology Transfer
TA	Technical Assistance
TERI	The Energy and Resources Institute
TN	Tamil Nadu
TNRRI	Tamil Nadu Rice Research Institute
TNSEB	Tamil Nadu State Electricity Board
UKIERI	UK India Education and Research Initiative
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USDA	United States Department of Agriculture
UT	Union Territory
WC	Conveyance efficiency
WD	Drainage efficiency
WEAP	Water Evaluation and Planning System- planning tool from Stockholm Environment Institute
WF	On-farm application efficiency
WHS	Water Harvesting Structures
WP	Water use efficiency at the project level
WQAA	Water Quality Assessment Authority
WR	Reservoir or weir efficiency
WRCRC	Water Resources Control and Review Council
WRD	Water Resources Department
WRIS	Water Resources Information System
WRO	Water Resources Organisation
WUA	Water Users Association
WWF	World Wildlife Fund

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Appendix 3A: Kshipra Sub Basin, Madhya Pradesh

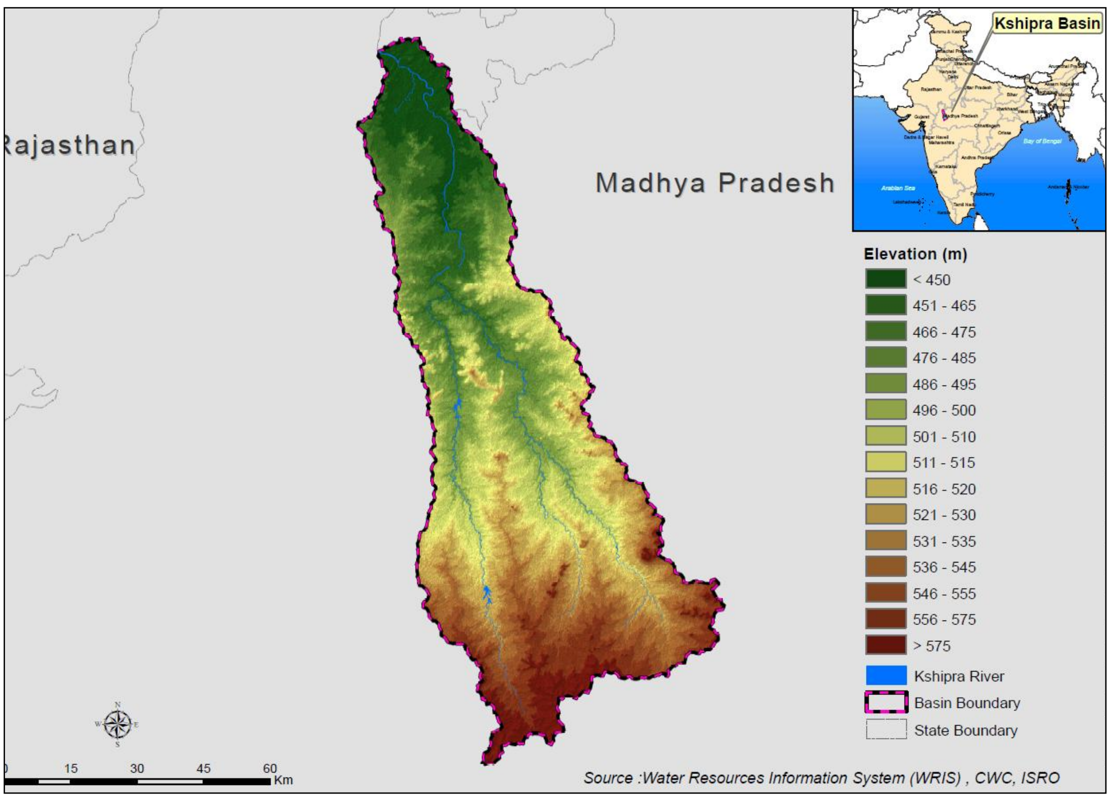
Sub Basin Profile

I. SURFACE WATER RESOURCES

A. Kshipra Sub Basin Characteristics

1. The Kshipra is a river of Central India, also called Kshipra or Avanti nadi. The Kshipra river originates in the Vindhya Range and flows in a northerly direction across the Malwa plateau to join the Chambal River. Upstream of its confluence with the Chambal, the Kshipra has a catchment area of 5600 km^2. Its nominal source is on the Kokri Bardi hill, 20km south-east of Indore near the small village of Ujeni (22° 31' N. and 76° E.). It is considered as sacred as the Ganga river by the Hindus. The holy city of Ujjain is located on the right bank of the Kshipra river. The river flows in a general north-westerly direction and has a very sinuous course. The total course of about 190km flows through Indore, Dewas and Gwalior districts of the state; it finally joins the Chambal near Kalu-Kher village (23° 53' N. and 75° 31''). The main tributaries of Kshipra include the Khan river near Ujjain and the Ghambir river near Mahidpur. The main course of the Kshipra lies over the grassy plains of Malwa between low banks and from Mahidpur and it is characterised by high rocky banks. Over the years the river has lost its perennial nature and now runs dry for a period of 5 to 6 months per year. The water of the Kshipra is used for drinking, industrial and lift irrigation purposes. The main land use along the river is agriculture. The basin location and key topographic and drainage details are shown in Figure 1.

Figure 1: Kshipra sub-basin



B. The Hydrometric Network

2. The hydrometric network in the basin consists six rain gauges and four meteorological stations maintained by the Indian Meteorological Department (IMD) as shown in Figure 2 and Figure 3 .

Figure 2: Hydrometric Network

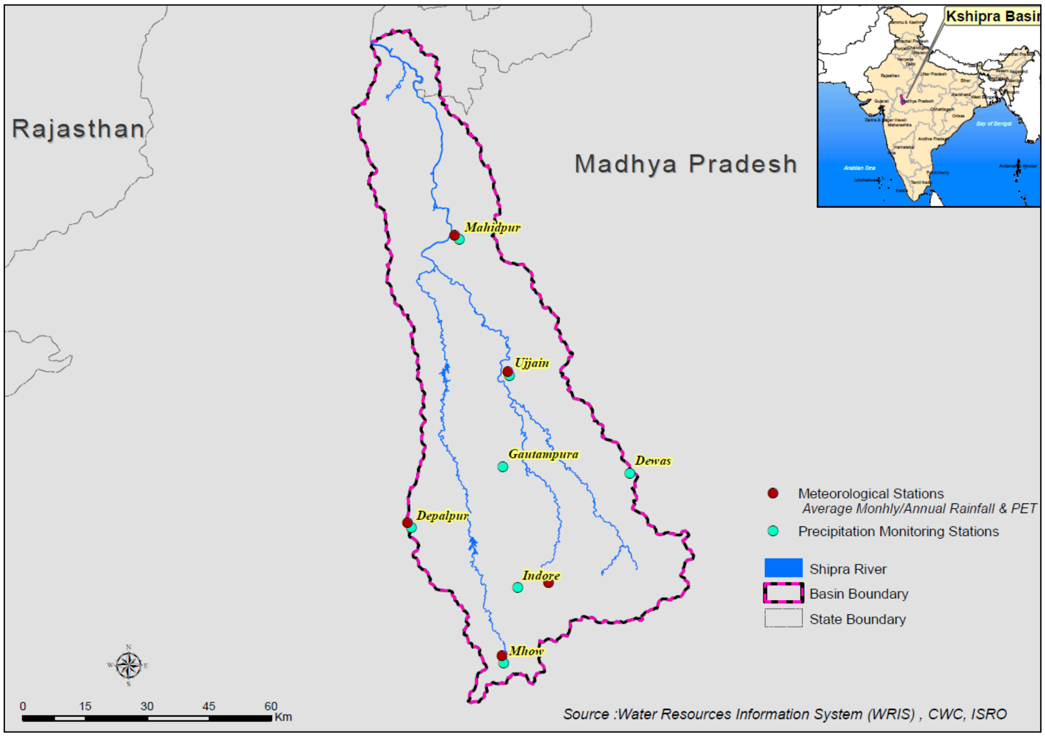
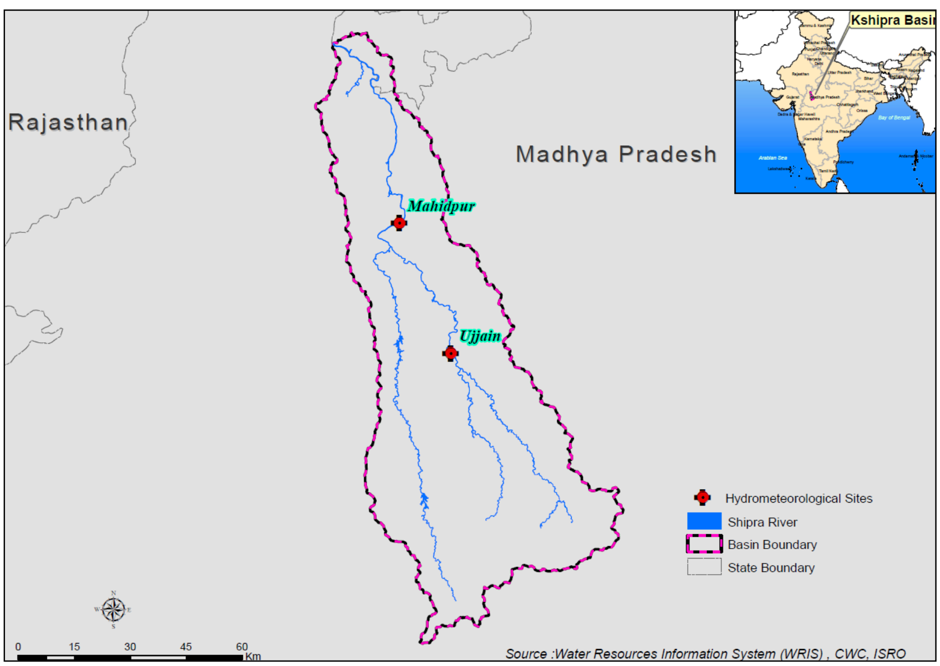


Figure 3: Hydrometeorological Sites



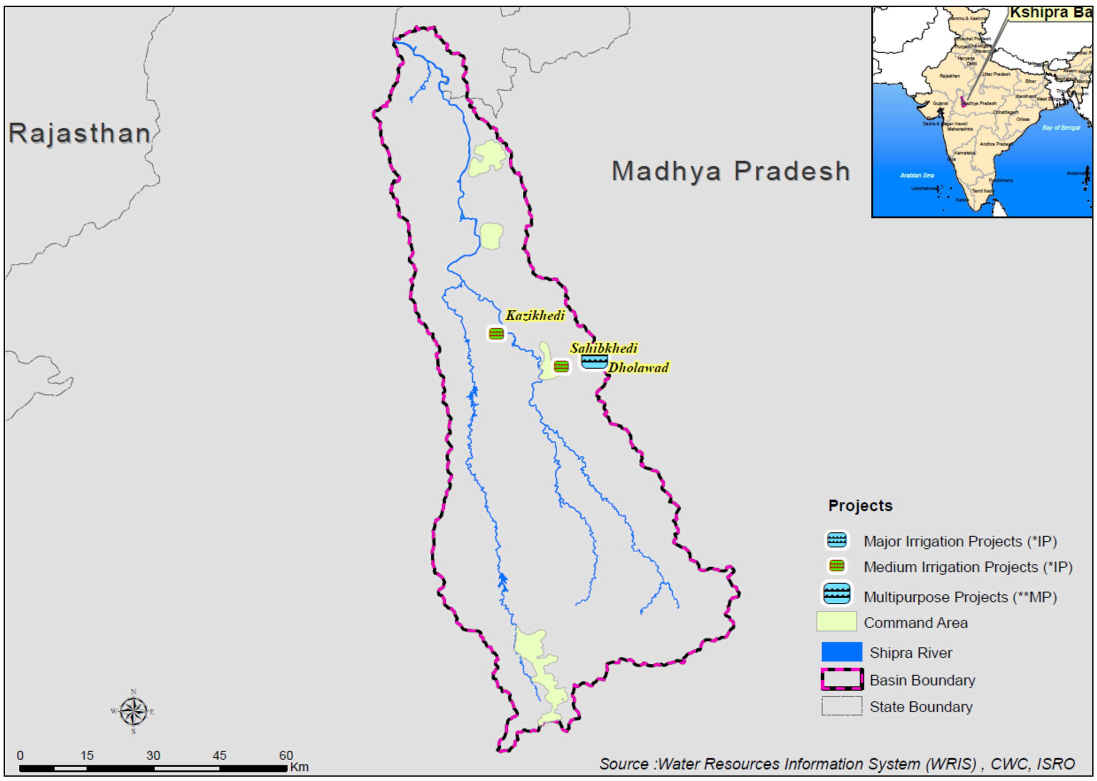
C. Projects

3. There are three small dams on Kshipra as shown in Figure 4 and Table 1 summarises the details of the three medium scale projects

Table 1 Medium Irrigation Projects

Name	District	Potential created	Irrigated Area (ha)	Year of completion
Sahibkhedi	Ujjain	1440	984	1983
Kazikhedi	Ujjain	1240	1366	1990
Dholavar	Ratlam	6440	1353	
Total		9120	3703	

Figure 4: Project Locations



D. Climatic Norms, Kshipra Basin

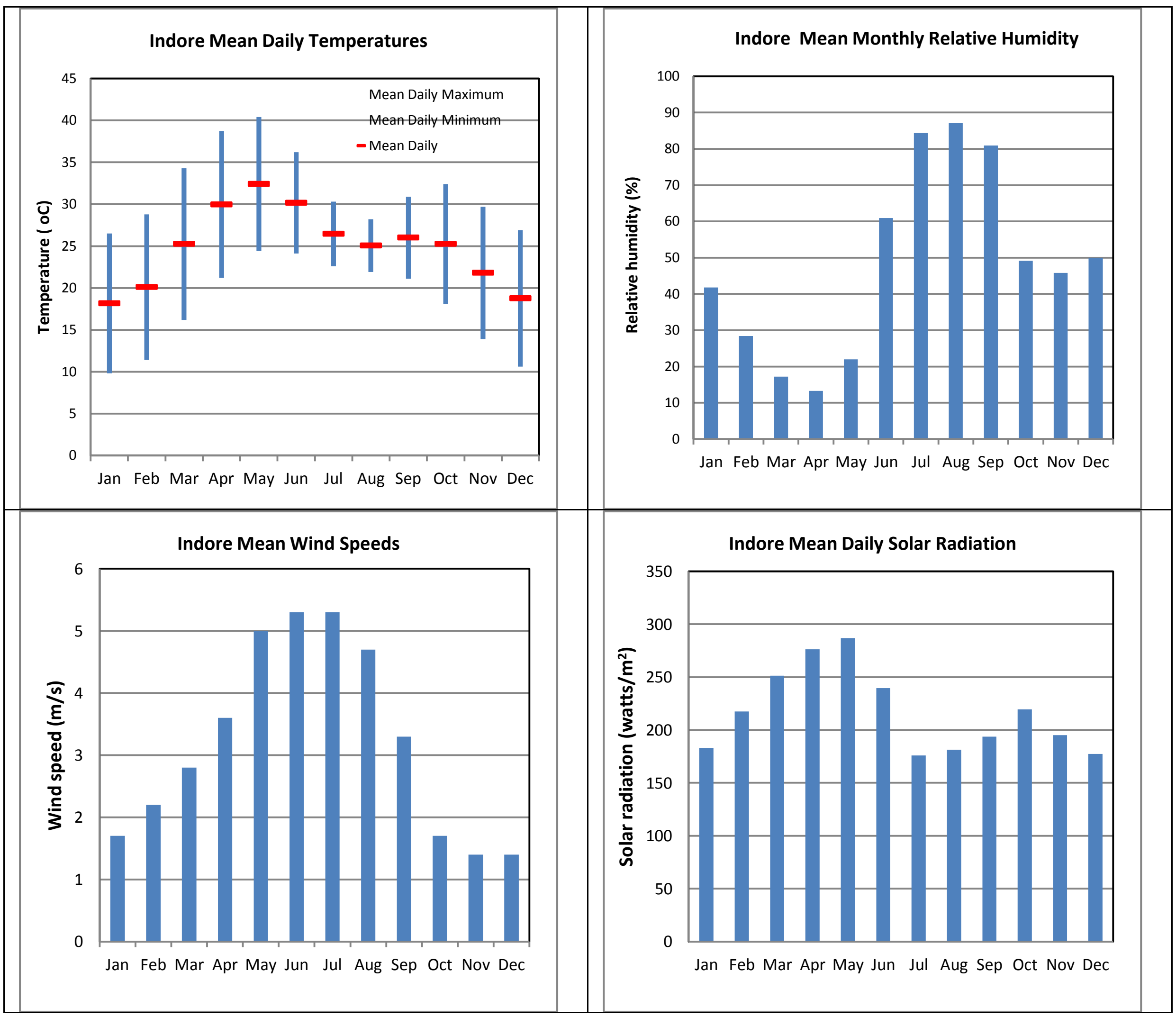
4. An assessment has been made of climatic norms in the Kshipra Basin using data for the station at Indore. The location of the stations is shown in Figure 2. In absence of meteorological data from the IMD at time for the preparation of this report, use was therefore made of the FAO CLIMWAT database1 which includes mean monthly meteorological data for over 5000 stations worldwide.

[1] http://www.fao.org/nr/water/infores_databases_climwat.html

5. Figure 5 shows climatic norms for Indore and includes potential evapotranspiration and effective rainfall calculated using the FAO CROPWAT 8 package[2]. CROPWAT 8 uses the FAO Penman method in the calculation of ETo, and calculates effective rainfall using the USDA S.C. method.

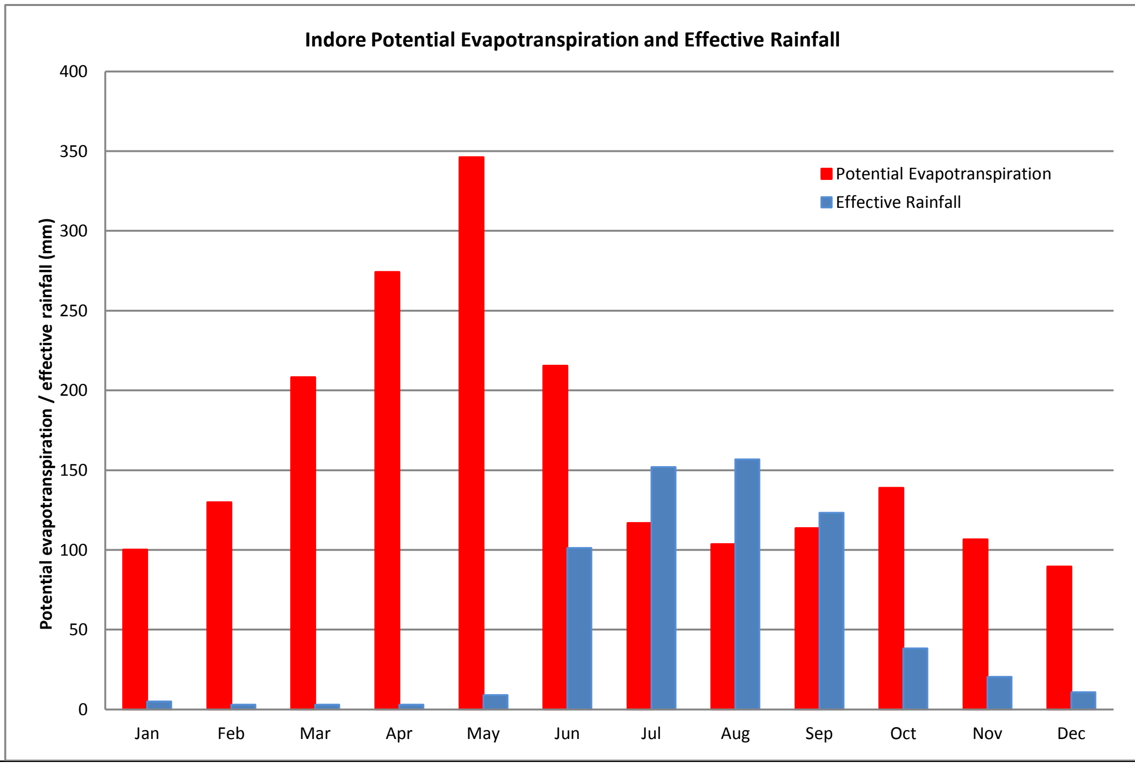
6. Mean daily temperatures at Indore ranges from a low of about 18^{o}C in January to a high of about 32^{o}C in May. May and June are the hottest months with mean daily maximums close to 40^{o}C. The mean daily temperature range is typically about 15^{o}C. A maximum range of 15.5^{o}C occurs in May. The minimum range of about 8^{o}C occurs in July and August. Relative humidity is at its lowest in April, averaging 13%, and peaks in August at 87%. Wind speeds are generally in the range of 1.4 to 5.3 m/s, and are highest in May to June, when solar radiation is also at a its peak. The climatic parameters combine to give an annual potential evapotranspiration at Indore of 1943mm, with peak evapotranspiration in April, May and June. The peak daily rates of evapotranspiration occur in May with a mean of 11.2 mm/day. It is clear from Figure 6 that with the exception of the months of July, August and September, the effective precipitation is far short of potential evapotranspiration. Mean annual rainfall at Indore is 980mm, and the computed mean annual effective rainfall is 625mm.

Figure 5: Climatic Norms Indore



[2] http://www.fao.org/nr/water/infores_databases_cropwat.html

Figure 6: Potential Evapotranspiration and Effective Rainfall



E. Precipitation in the Kshipra Basin

7. At the time of preparing this report, precipitation data had not been received from IMD, and it has not therefore been possible to carry out any meaningful analysis for the detection of long term trends or analysis of rainfall extreme maximum events. The analysis presented here is based on the IMD gridded $0.5^o \times 0.5^o$ data that covers the 35 year period (1971-2005).

1. Annual Precipitation

8. Figure 7 presents isohyets of mean annual precipitation over the Kshipra Basin. About 93% of the total annual rainfall takes place during the southwest monsoon period (June to September). The maximum monthly rainfall takes place during the months of July and August. Season-wise distribution of the annual rainfall is about 6% in winter and 1% in summer prior to the monsoon, giving about 7% of the annual rainfall from October to about the first week of June. The very small amount of rainfall between November and the first week of June is insufficient to build up the soil-moisture and thus it does not contribute to the groundwater potential of the area. It is only during the monsoon period that surplus water for deep percolation can be available. Annual precipitation varies from about 984mm in the southeast to 865mm in the northwest.

9. Coefficients of variation in annual rainfall are shown in Figure 8. Inter annual variability is more or less spatially uniform across the basin, with marginally higher variability in the north western part

Figure 7: Mean Annual Precipitation

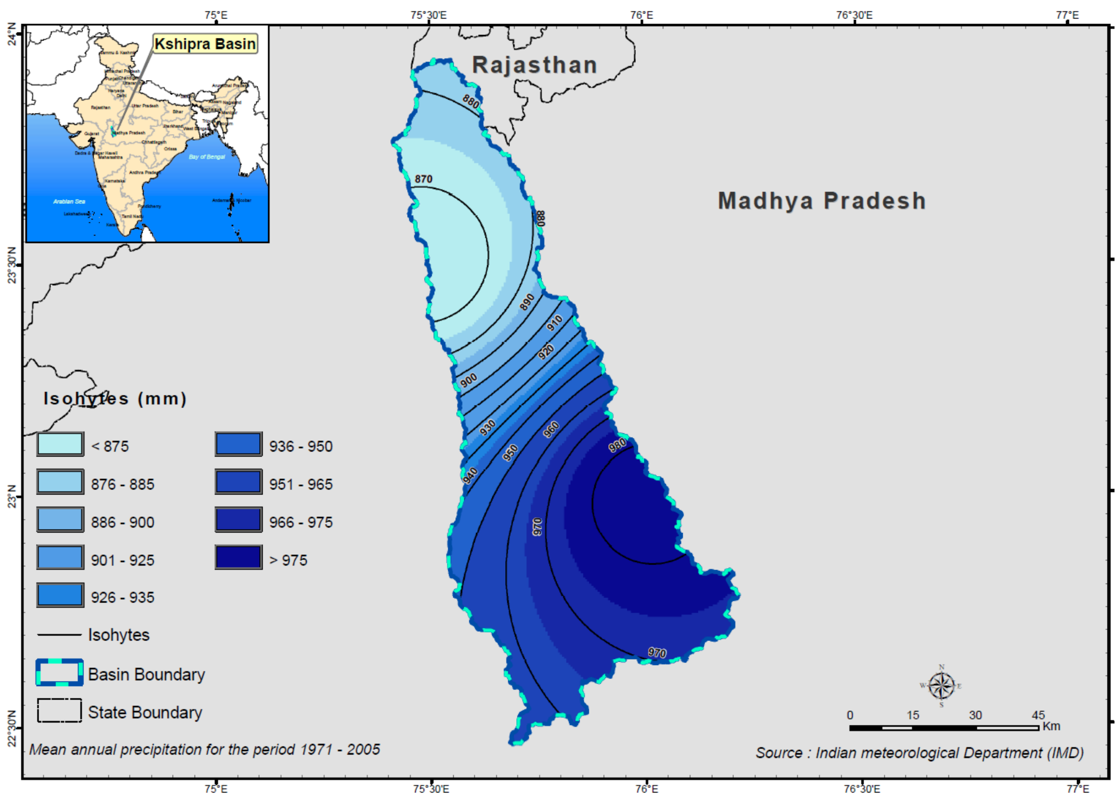


Figure 8: Coefficients of Variation of Annual Rainfall

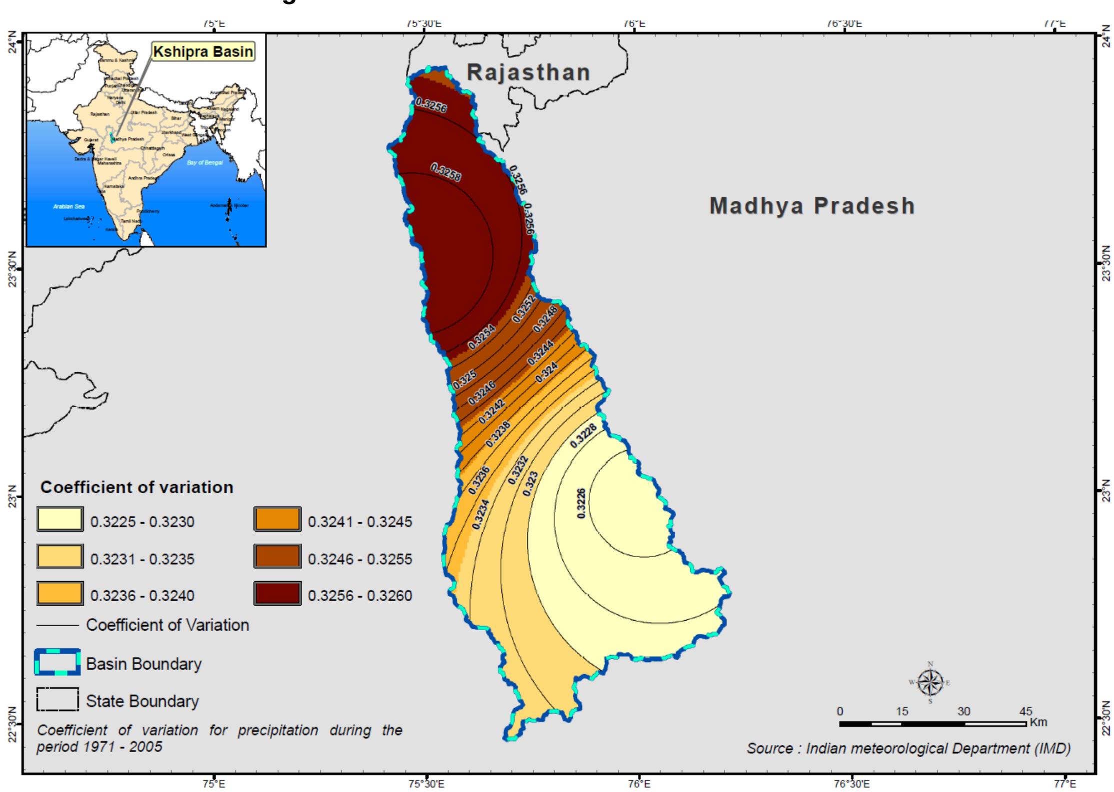
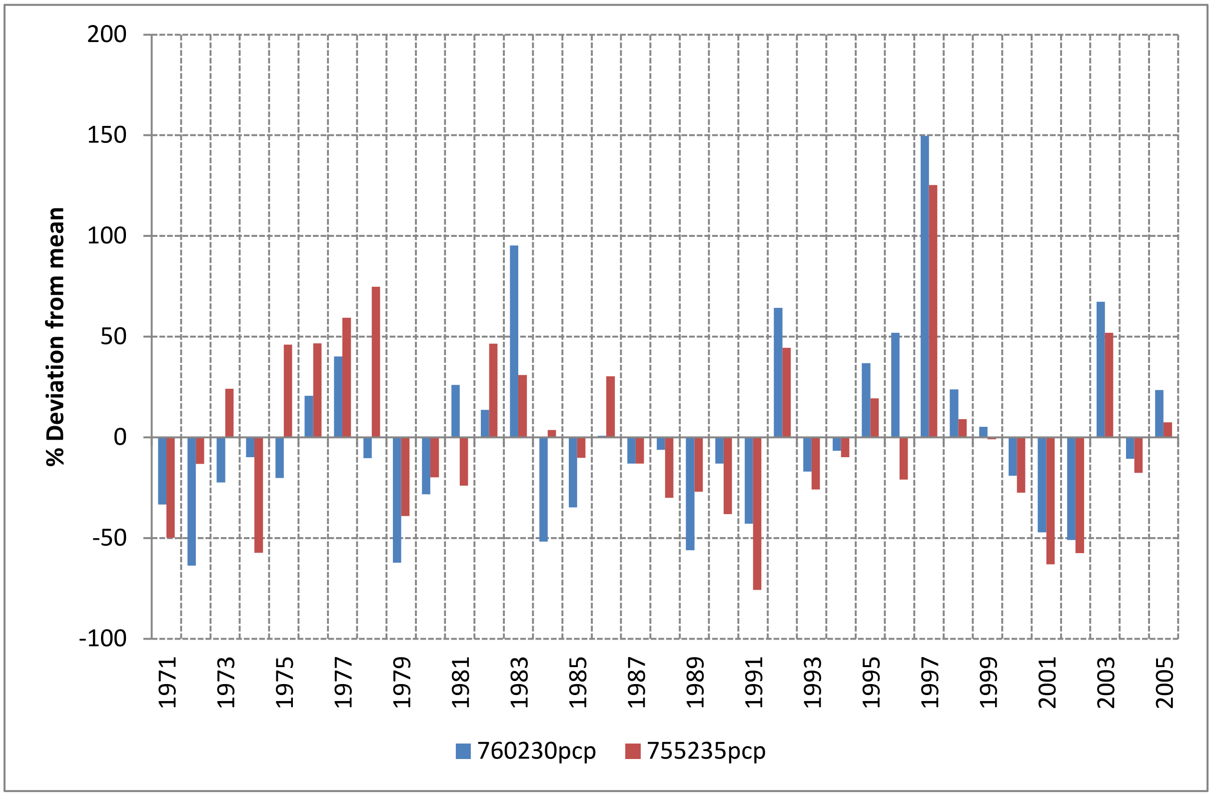


Figure 9: Deviation from Mean Annual Rainfall at IMD Grids



10. Figure 9 shows deviations from the mean of annual precipitation in the Kshipra basin in the period from 1971 to 2005. Precipitation is variable in space and time, and there is no evidence of trend in the data.

2. Seasonal Precipitation

11. Seasonal precipitation has been analysed in a similar way to that of annual precipitation. For the purposes of analysis, seasons were defined as; March, April, May (MAM) June, July, August, September (JJAS); October, November, December (OND); January, February (JF).

12. Figure 10 shows mean annual precipitation for the four seasons and Figure 11 the coefficients of variation. During MAM precipitation is generally negligible and coefficients of variation are thus high, and increase from southeast to northwest. During JJAS season approximately 93% of the annual rainfall in the Kshipra basin occurs, coefficients of variation are significantly lower than in MAM, and the data are less skewed. During OND there is little variation precipitation across the basin, with mean values of approximately 50mm. January-February (JF) is the driest season, with such low rainfall there is significant inter-annual variability and coefficients of variation are high. variations higher in the northwest than in the southeast.

Figure 10: Mean Annual Precipitation in the Kshipra

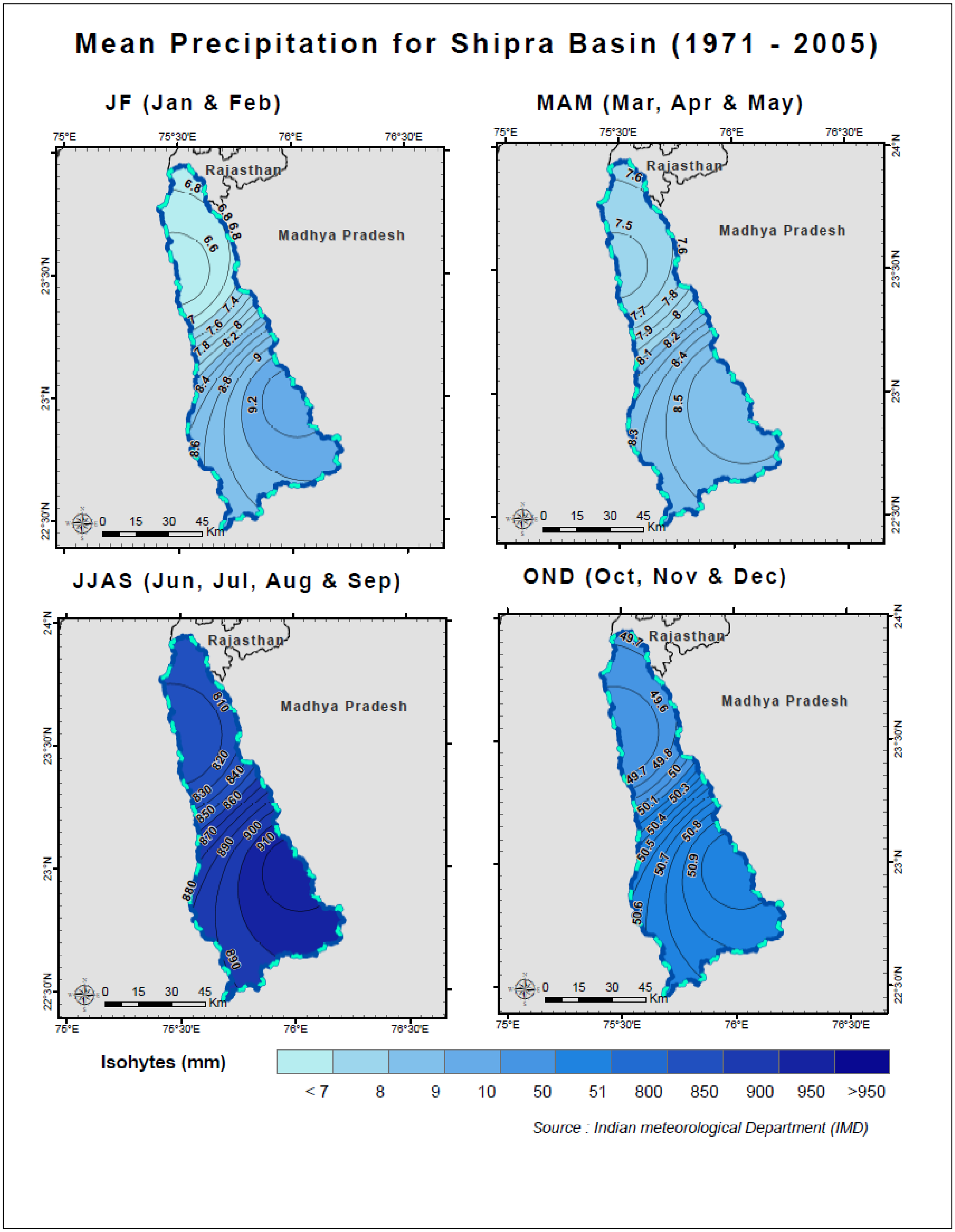


Figure 11: Coefficient of Variation in Mean Precipitation

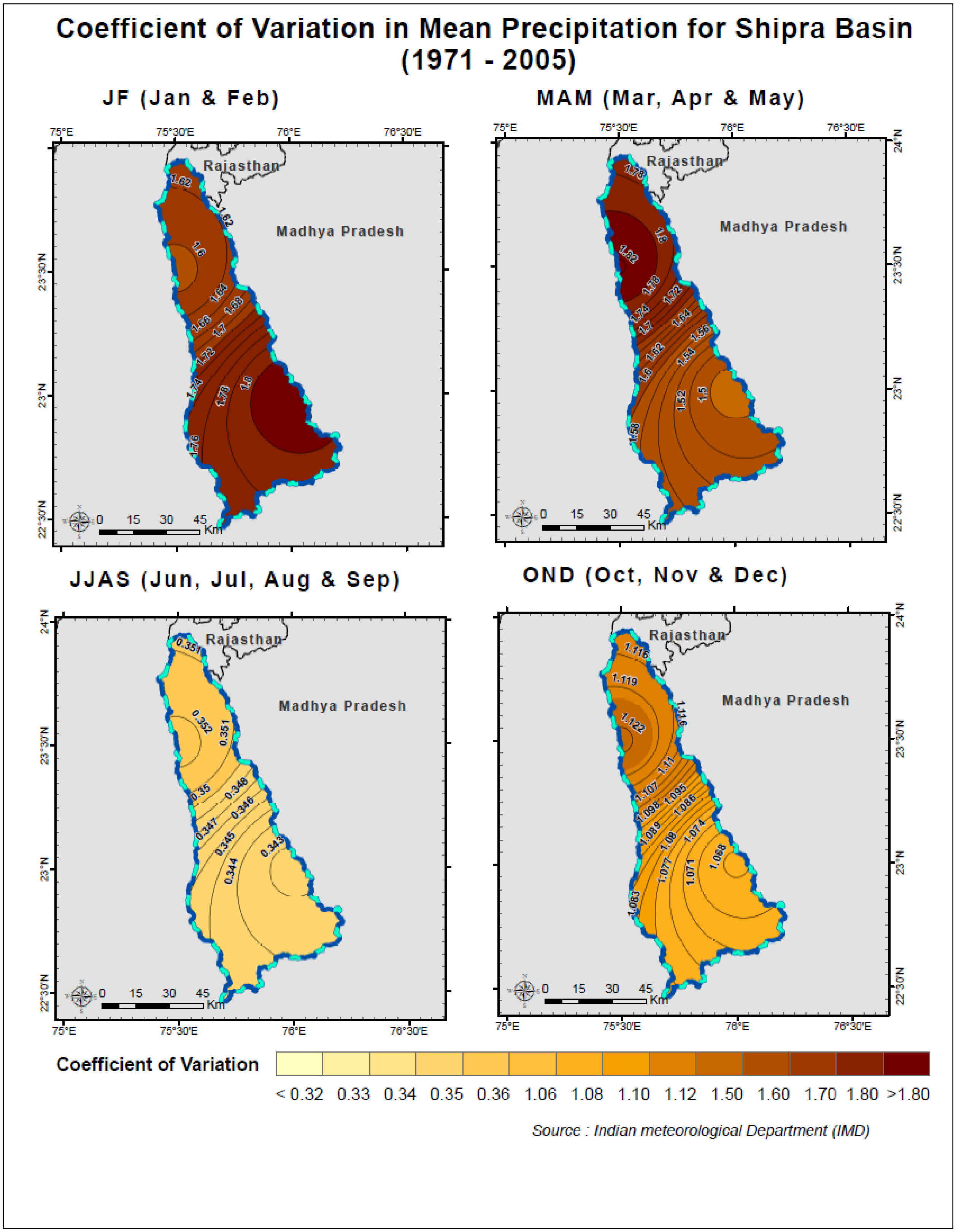


Figure 12: Coefficients of Variation in JJAS Rainfall

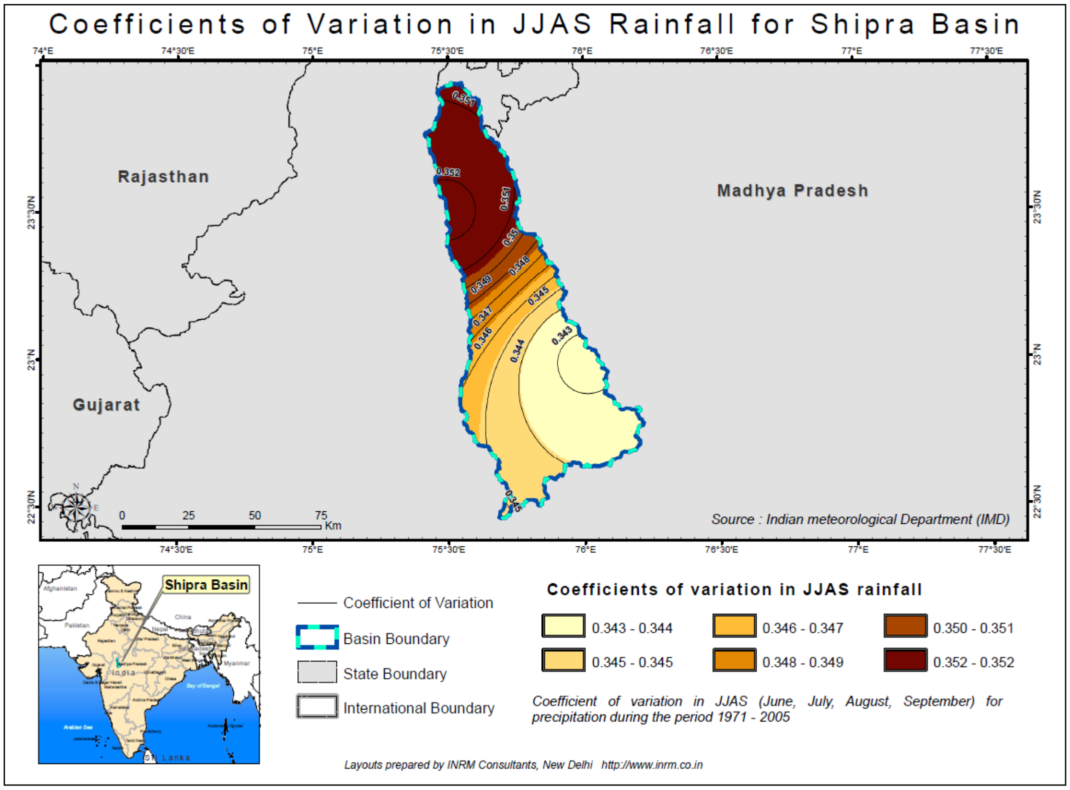


Figure 13: Mean JJAS Precipitation

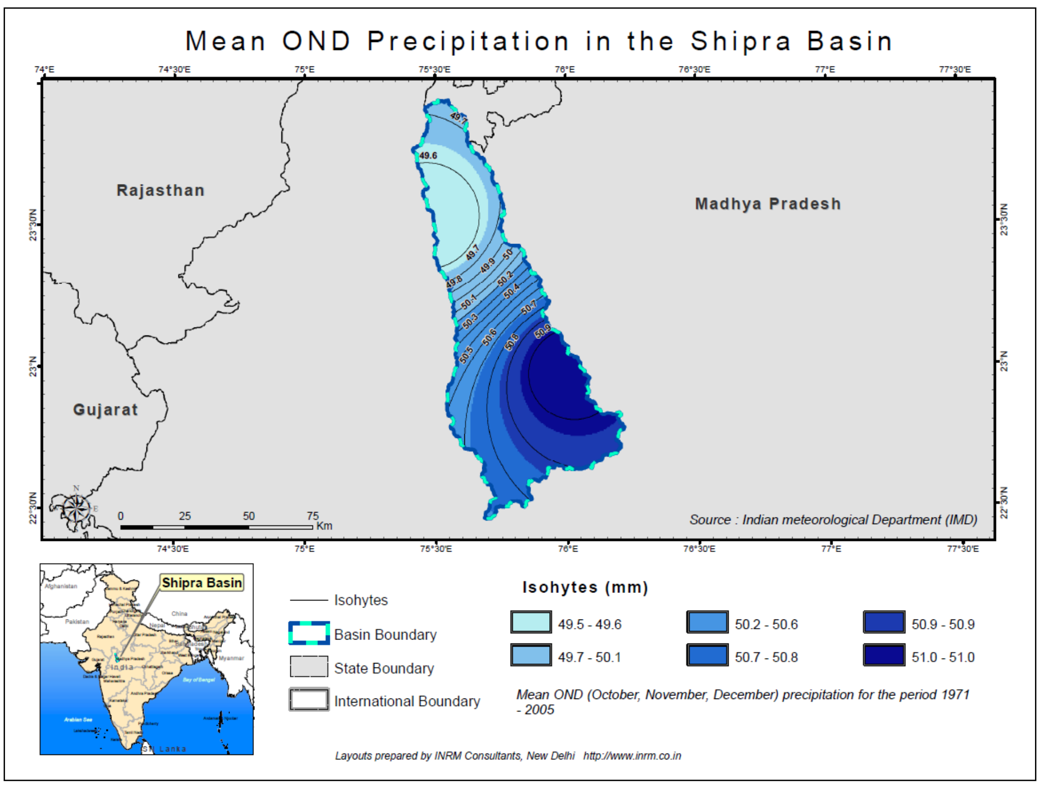


Figure 14: Coefficients of Variation in OND Rainfall

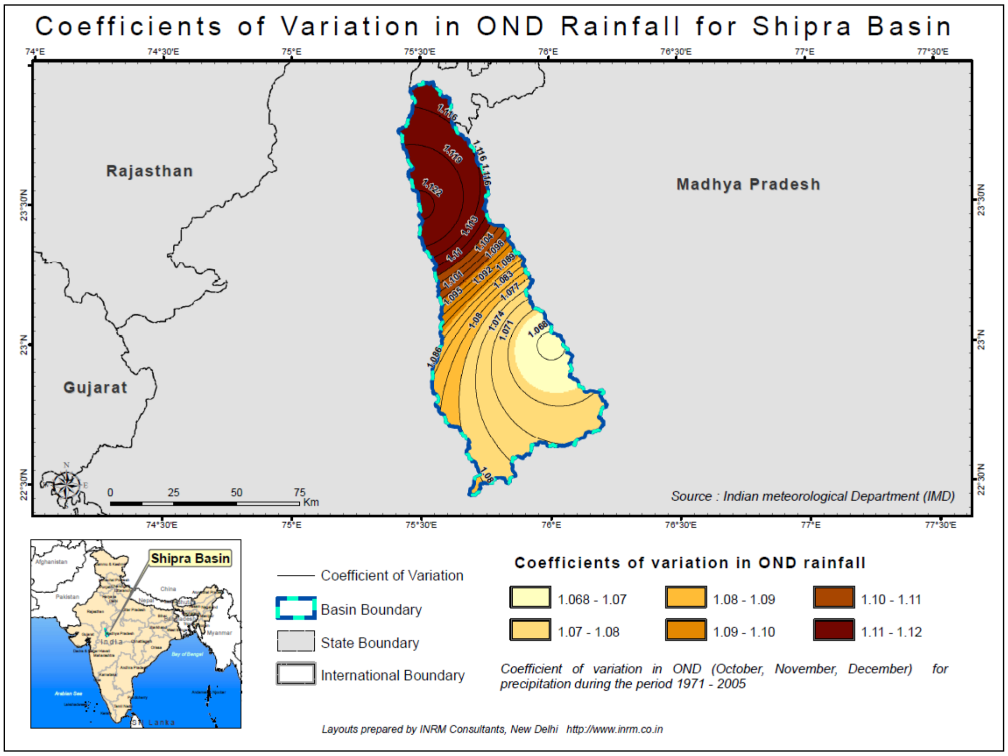


Figure 15: Mean JF Precipitation

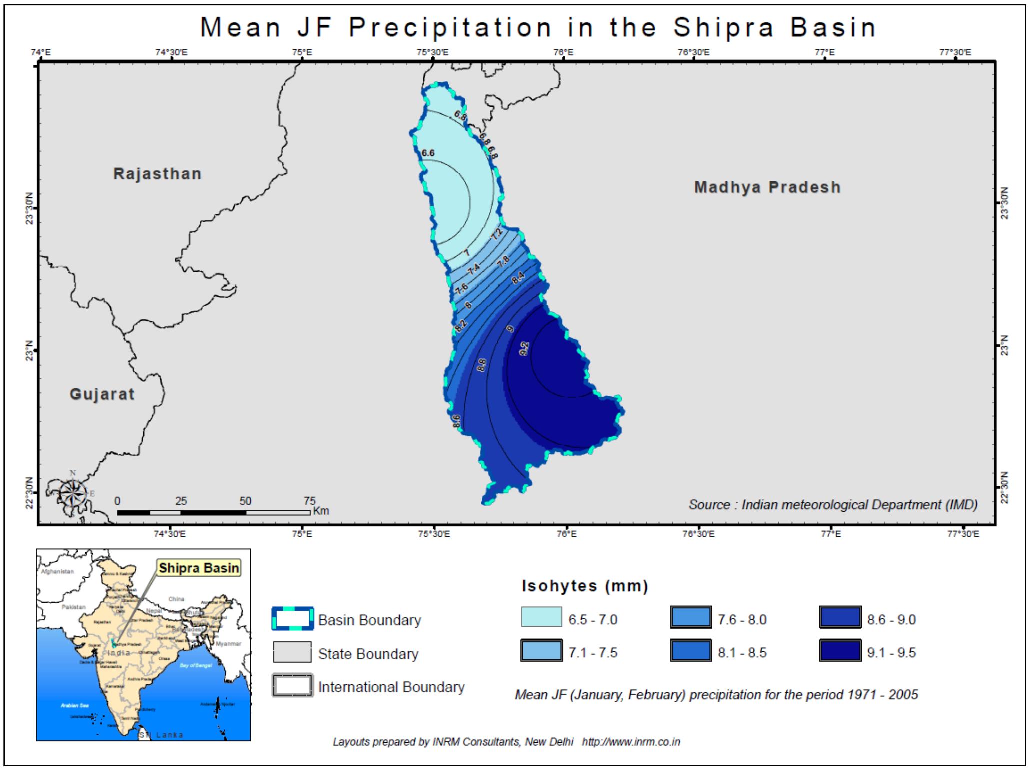
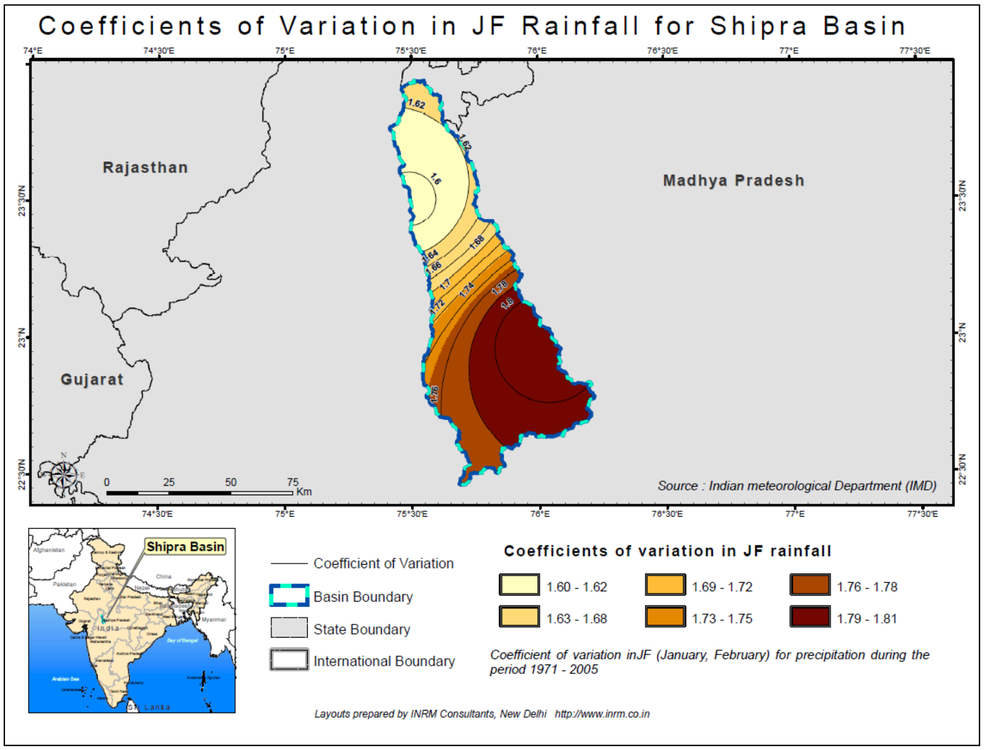


Figure 16: Coefficient of Variation in JJAS Rainfall



3. Drought Characteristics

13. An analysis has been made of drought durations with a 10 mm precipitation threshold in the Kharif (JJAS) and Rabi (ONDJF) seasons. The mean annual drought durations are shown in Figure 17 and Figure 18 respectively. This analysis is of most interest as it is indicative of agricultural risk and irrigation needs. In the Kharif season, mean annual drought durations vary from 20 to 23 days in the basin. The range in drought durations during the Rabi season is less significant, and clearly periods of over 3 months with virtually no precipitation in the Rabi season are common throughout the basin.

Figure 17: Kharif Season Drought with 10mm threshold

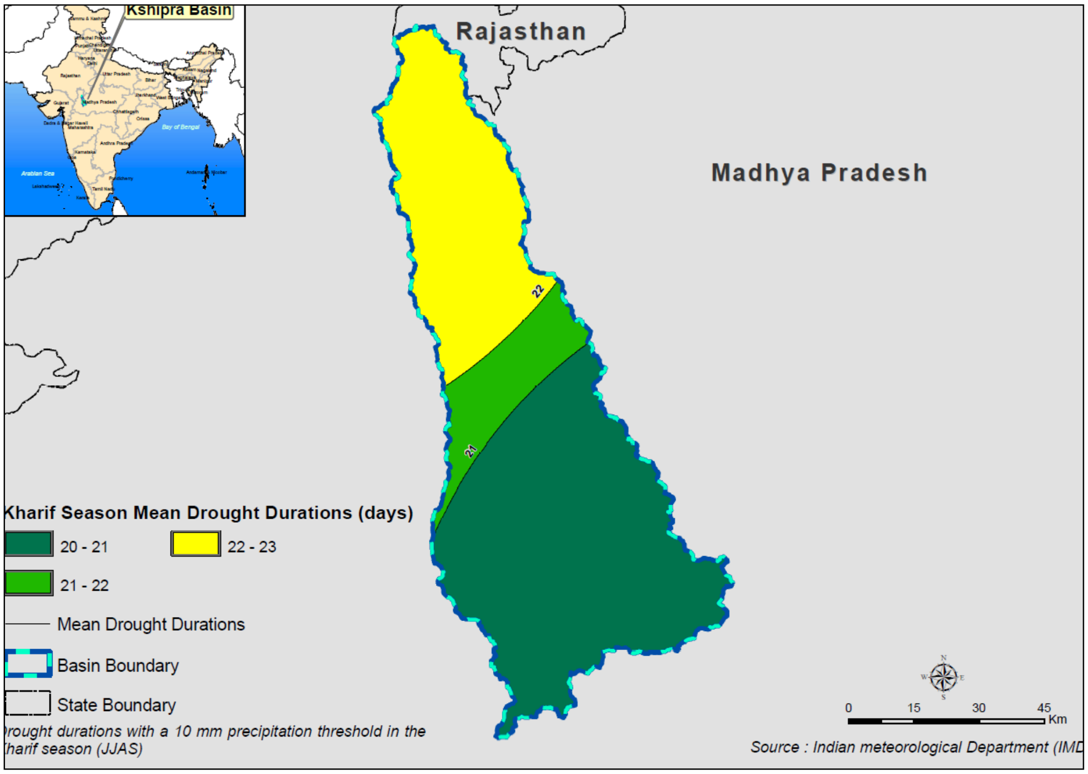


Figure 18: Rabi Season Drought Durations with 10mm threshold

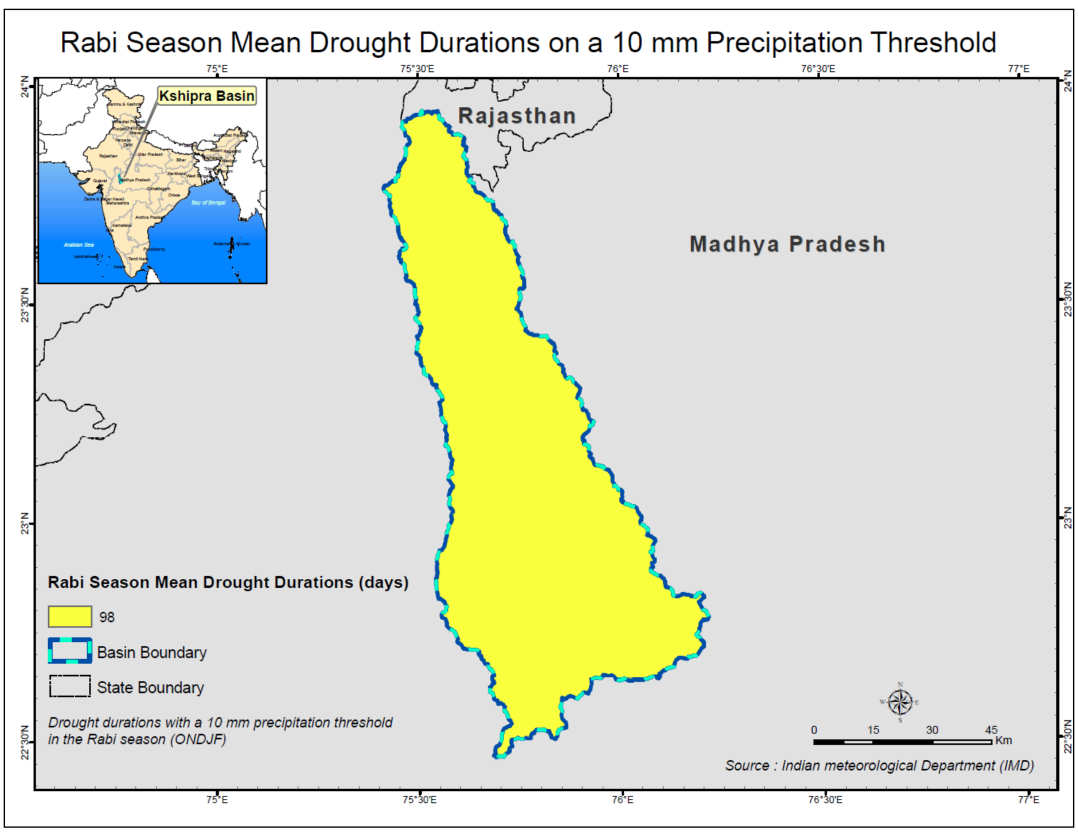
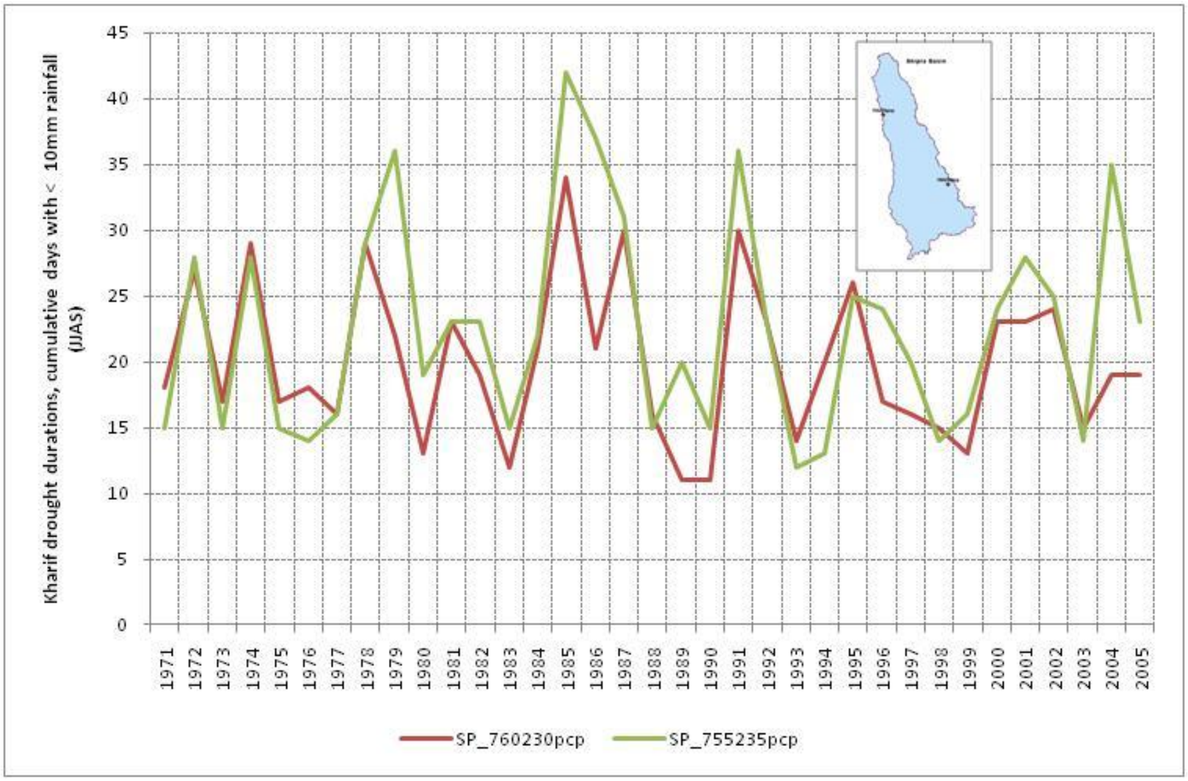


Figure 19: Time Series of Annual Droughts with 10mm threshold in Kharif Season



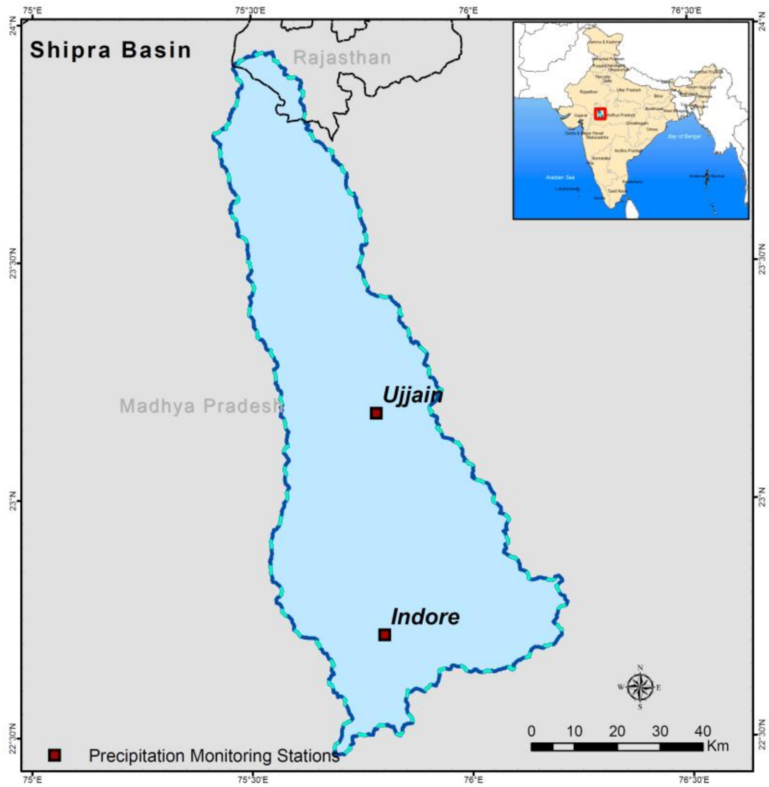
14. The time series of annual droughts with a 10 mm threshold in the Kharif season on IMD grids in the Kshipra basin are shown in Figure 19. There is no evidence changes in drought characteristics, and generally similar conditions are experienced across the whole catchment. The records analysed are not considered long enough to establish the existence of long term trend, and for this reason statistical tests have not been carried out.

F. Trends in Annual and Seasonal Rainfall

15. Tests for trend have been made with two IMD raingauges in the Kshipra basin. ImD made data available for the period from 1971 to 2005. The stations used were Indore and Ujjain. There locations are shown in Figure 20. Thirty five years of data would generally be considered rather short for long term trend analysis, and it was possible to create composite records at both sites dating from 1901 using data archived by GHCN (GHCN precipitation[3]).

[3] http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/

Figure 20: Locations of IMD Observed Raingauge Stations in the Kshipra basins



1. Mann-Kendall Analysis

16. The Mann-Kendall test has been used in trend analysis. The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves (Gilbert, 1987[4]). One benefit of this test is that the data need not conform to any particular distribution.

17. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S.

Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

where: x_1, x_2,….x_n represent n data points, where x_j represents the data point at time j.
sign(k_j-x_k) = 1 if k_j - X_k >0
= 0 if if k_j - $X_{k=}$ 0
= -1 if if k_j - X_k < 0

4 Gilbert, R.O., 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York. Kendall, M.G., 1975. Rank correlation methods, 4th ed. Charles Griffin, London

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend.

2. Data Quality

18. A large number of missing values were found in the IMD records of both stations. Each station had almost three complete years of missing data, and several years in which 10-20% of data were missing. This would be a concern for many types of analysis. In the long term GHCBN record there were only two missing records at Indore, but 1107 missing records at Ujjain.

3. Test Results

19. The results of the Mann-Kendall trend analysis at Indore and Ujjain, using the composite records from 1901 are summarised in Table 2, Table 3 and Table 4. Generally in the evaluation of these tests, a significance level of less than 0.05 would indicate the existence of trend, or there would be 95% confidence in the existence of trend.

20. There is evidence of a slight trend of increasing annual rainfall at Indore, that has a significance level of 0.06. The trend is most evident in southwest monsoon rainfall, for which the significance level is 0.03. The increase in monsoon rainfall amounts to 194 mm over a 102 year period (22%). The time series southwest monsoon rainfall at Indore is shown in Figure 21. There is a mild decreasing trend in northeast monsoon rainfall.

21. At Ujjain, where it will be noted there more missing records, there is no statistically significant trend in annual or seasonal rainfall, although the regressions fitted to the data are similar to those at Indore. The time series for southwest monsoon rainfall at Ujjain is shown in Figure 22..

Table 2: Annual rainfall trends

Stations	Basin	Linear equations	Mann-Kendall test statistics (Calculated z)	Significance level
Indore	Kshipra	y = 2.0019x + 868.19	1.88	>0.05
Ujjain	Kshipra	y = 2.0107x + 802.12	1.45	>0.10

Table 3: Seasonal rainfall trends, southeast monsoon (June-September)

Stations	Basin	Linear equations	Mann-Kendall test statistics (Calculated z)	Significance level
Indore	Kshipra	y = 1.9x + 783.82	2.19	<0.05
Ujjain	Kshipra	y = 1.9064x + 736.42	1.42	>0.10

Table 4: Seasonal rainfall trends, northeast monsoon (October-December)

Rainfall Stations	Basin	Linear equations	Mann-Kendall test statistics (Calculated z)	Significance level
Indore	Kshipra	y = -0.0013x + 17.541	1.88	>0.05
Ujjain	Kshipra	y = 0.0083x + 15.591	1.45	> 0.10

Figure 21: Time series of southwest monsoon rainfall at Indore

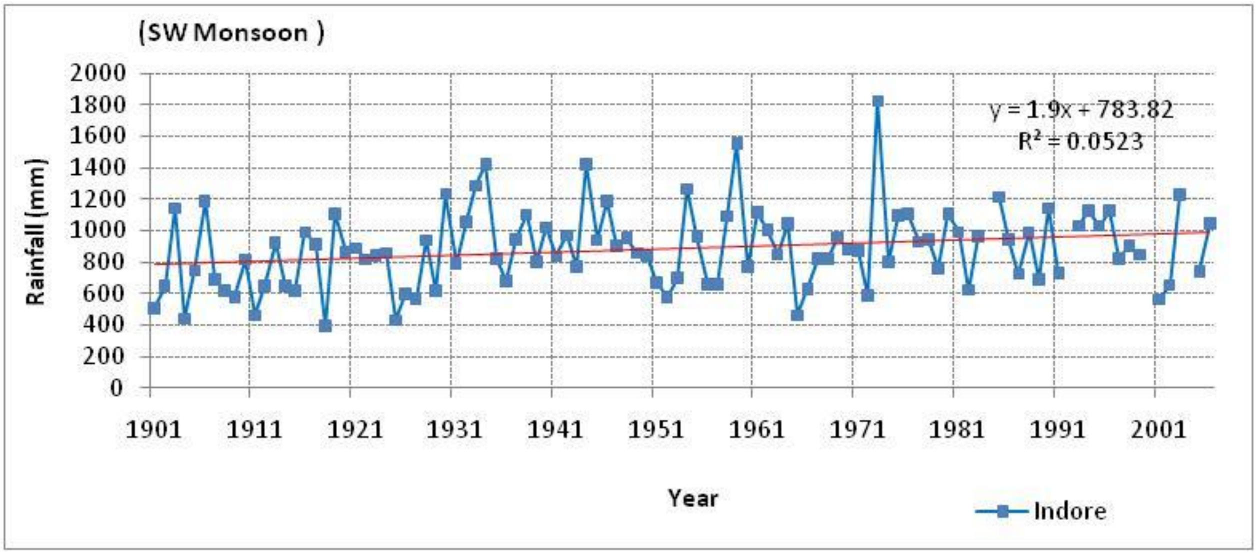
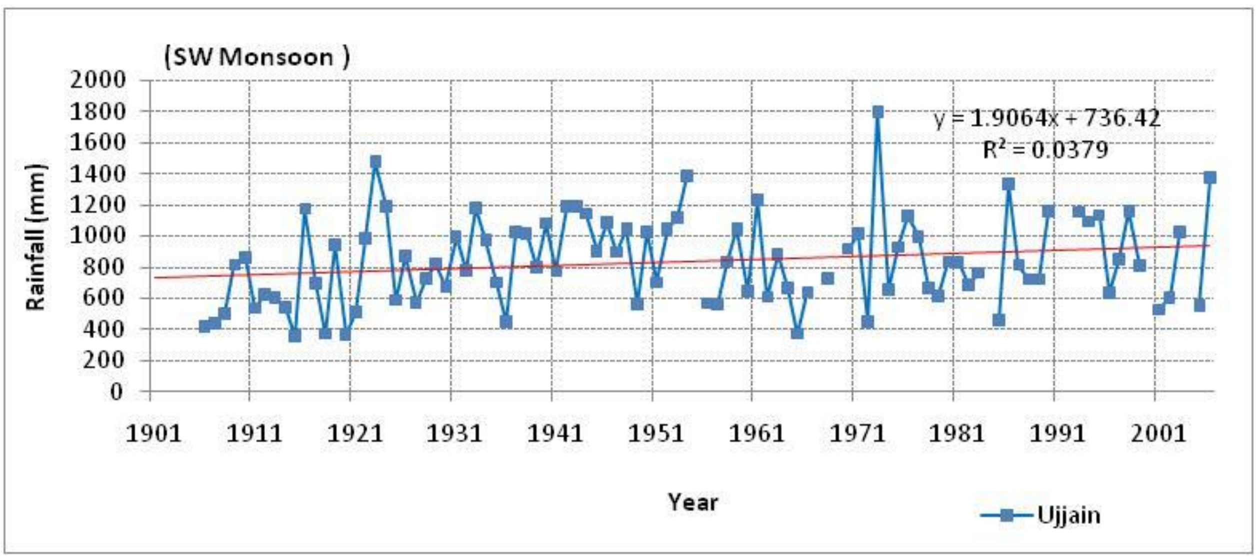


Figure 22: Time series of southwest monsoon rainfall at Ujjain



II. GROUNDWATER

A. Introduction

22. The Chambal river is a tributary of Yamuna river and rises in Vidhyan hill range in western Madhya Pradesh. The Banas, Kali Sindh, Kshipra and Parbati are its tributaries. The Chambal basin lies between latitude 22^0 27' N & 27^0 20' N and longitude $73^0$20'E and $79^0$15' E.. The total area drained upto its confluence with Yamuna is 143,219km^2 and out of which 76,854km^2 lies in state of Madhya Pradesh. This basin is characterized by undulating flood-plain and ravines. River Chambal is utilized for hydro-power generation and for irrigation. The Kshipra tributary of Chambal was a perennial river, however, now it stops flowing a few months after the monsoon. Kshipra originates at 560m (amsl) from a hill near village of Kampell in Indore district. The catchment area of Kshipra is 4751km^2. The rivers Khan and Ghambir are its main tributaries. Kshipra basin intersects the three districts of Dewas, Indore and Ujjain.

B. Groundwater

1. Aquifers

23. The main aquifer in Indore is made up of a basaltic rock formation, which is unconfined to semi confined in nature. The hydrogeological map of the basin is shown in Figure 24. The borewells tapping basaltic aquifer in the northern and southern part of the district to a depth of 100m have capacity to yield discharge of the order of 6.2 to 14.6 litres per second (lps). In the southern part of the district, the yield capacity of borewells is 1.2 to 3.8 lps.

24. Dewas district is mostly occupied with basaltic rocks except southern part of the district where Vindhyan sandstones and Archean granites form aquifers. The open wells in granite rock aquifer yield 8lps of discharge on an average whereas Vindhyan sandstone aquifer yield upto 11lps. Basalts form extensive aquifer system in the district in which large diameter open wells to a depth of 20m yield 3.5 to 9 lps and borewells to a depth of 200m yield 1 to 3 lps.

25. Basalts also form extensive aquifers in Ujjain district. The open wells to a depth of 20m in weathered zone of basalt yield 1 to 2 lps. Borewells in the depth range of 50-200m yield between 1 and 20 lps, the average being 3.5 for drawdown ranging from 2.85-66m. The static water level in boreholes in the district ranges from 7.14-49m. The groundwater maps of districts of Kishpra basin are given in Figure 25 and Figure 26.

C. Groundwater Levels and Trends

26. Groundwater observation wells Kshipra sub-basin are shown in Figure 27. The mean water level for the year 1980 and 2009 for the Dewas, Indore and Ujjian districts in Kishpra basin are given in Table 5 below for long-term comparison. It may be observed that in the pre-monsoon average water level in general, there is severe decline, however in post monsoon there is not much change. Mean water levels in Kshipra sub-basin are shown in Table 5, with trends iin Table 6 below:

Table 5: Mean Groundwater Levels in Kshipra sub-basin

Sl No	District	Mean GW Depth (m bgl)			
		May-80	Nov-80	May-09	Nov-09
1	Dewas	8.72	6.2	15.64	4.63
2	Indore	7.84	5.37	16.65	6.49
3	Ujjain	7.32	2.65	12.14	7.64

27. The Pre and post monsoon groundwater levels and their trends in three districts of Dewas, Indore and Ujjain falling in Kshipra sub-basin are given in the table below. The pre and post monsoon depth to

water level maps are given in Figure 28 . The hydrographs of select observation stations drawn are given in Figure 29 and Figure 30.

Table 6: Groundwater Levels and Trend

District	Depth to groundwater (Pre-monsoon)	Depth to groundwater (Post-monsoon)	Fall in levels (Premonsoon)	Fall in levels (post-monsoon)
Ujjain	8.96-17.00	1.45-11.90	0.05-0.39	0.01-0.43
Dewas	3.06-24.05	0.55-10.30	0.05-0.33	0.05-0.60
Indore	6.30-15.70	1.40-10.08	0.02-0.28	0.08-0.80

1. Water quality

28. The groundwater quality in general is good in the basin. The EC value of groundwater in entire Kishpra sub-basin is less than 3000 micro Siemens/cm. Water quality map with EC contours is given in Figure 31**.** High levels of nitrate and fluoride have also been reported from some blocks of the district of Dewas, Indore and Ujjain. A table indicating levels of Fluoride and Nitrate is given in Table 7 below:

Table 7: Fluoride and Nitrate Levels of Shallow Groundwater in Kshipra sub-basin

District	**Block**	**Nitrate(mg/l)**	**Block**	**Fluoride(mg/l)**
Dewas	Bagla	52-156	Khategaon	1.5
	Dewas	51-111	-	-
Indore	Depala	139	-	-
	Indore	79-179	-	-
Ujjain	Badnagar	67	-	-
	Mahidpur	48-76	-	-
	Ujjain	67-94	-	-

2. Groundwater resources:

29. The Chambal basin encompasses a large number districts but the present study focuses on the Kshipra sub-basin of Chambal basin. The state government has estimated the availability of groundwater of Kshipra sub-basin as 1100 million cubic meters. The status of groundwater potential of the whole Chambal river basin is given in Table 8 below.

Table 8: Dynamic Groundwater Resources of Chambal Basin (in BCM)

Total replenishable groundwater	Provision for domestic, industrial and other uses	Available groundwater resources for irrigation	Net groundwater draft	Balance groundwater available	Extent of groundwater use (%)
7.19	1.08	6.11	2.45	3.66	49%

30. The district wise position of groundwater availability in the district of Indore, Dewas and Ujjain covering Kshipra sub -basin is given in Table 9. It may be observed that in general the extent of groundwater use in Indore and Ujjain exceeds 100%, whereas in Dewas the stage of development is 66%. By block it can be seen there is some significant differences between the blocks as shown in Table 9.

Table 9: Groundwater Resources by District (MCM))

District	Annual replenishable groundwater	Natural groundwater drainage	Net groundwater availability	Annual groundwater draft	Extent of groundwater use(%)	Number of groundwater over-exploited block
Dewas	92.7	4.6	88.1	58.5	66	0
Indore	59.8	3.0	56.9	59.4	104	2
Ujjain	83.4	4.2	79.3	86.4	109	3

Table 10: Dynamic Groundwater Resources of District and by Block

District/ Block	Type (see notes at bottom of table)	Net Annual Groundwater Availability (MCM)	Existing (MCM)				Future (MCM)	
			Gross Draft for irrigation	Gross Draft for Domestic & Industry	Total gross draft	Stage of GW devpment	Estim draft for domestic & industry over next 25 years	Net avail for future irrig.
Dewas	C							
	NC	164.1	151.3	5.6	156.9	96	10.3	2.5
	BT	164.1	151.3	5.6	156.9	96	10.3	2.5
Sonkutch	C	-	-	-	-		-	-
	NC	100.7	95.1	2.4	97.5	97	2.7	3.0
	BT	100.7	95.1	2.4	97.5	97	2.7	3.0
Tonkkhurd	C	-	-	-	-		-	-
	NC	99.2	63.0	2.5	65.4	66	2.7	33.5
	BT	99.2	63.0	2.5	65.4	66	2.7	33.5
Bagli	C	8.5	0.5	0.1	0.6	7	0.2	7.8
	NC	249.0	123.4	5.0	128.3	52	5.3	120.3
	BT	257.4	123.9	5.1	128.9	50	5.5	128.1
Kannod	C	29.9	1.4	0.5	1.9	6	0.7	27.9
	NC	106.7	59.7	3.8	63.5	59	5.3	41.8
	BT	136.7	61.0	4.3	65.3	48	6.0	69.7
Khategaon	C	-	-	-	-		-	-
	NC	122.6	67.4	3.2	70.6	58	3.7	51.4
	BT	122.6	67.4	3.2	70.6	58	3.7	51.4
DEWAS TOTAL		880.7	561.7	23.0	584.7	66	30.9	288.1
Indore	C	-	-	-	-		-	-
	NC	163.7	211.6	12.1	223.7	137	39.5	-87.4
	BT	163.7	211.6	12.1	223.7	137	39.5	-87.4
Sanwer	C	-	-	-	-		-	
	NC	131.2	170.5	3.7	174.2	133	6.1	-45.3
	BT	131.2	170.5	3.7	174.2	133	6.1	- 45.3
Depalpur	C	4.6	1.2	0.2	1.4	31	0.4	3.0
	NC	124.1	115.8	3.9	119.6	96	6.3	2.0
	BT	128.7	117.0	4.1	121.1	94	6.7	5.0
Mhow	C	19.4	1.6	0.3	1.8	9	0.3	17.5
	NC	126.1	68.9	4.7	73.5	58	7.2	50.1
	BT	145.5	70.4	4.9	75.4	52	7.4	67.6
INDORE TOTAL		569.0	569.4	24.8	594.3	104	59.7	- 60.1
Ujjain	C	4.7	2.6	0.1	2.7	59	0.1	1.9
	NC	101.2	147.5	2.7	150.2	148	3.5	- 49.7
	BT	105.9	150.1	2.8	152.9	144	3.6	- 47.8
Ghatia	C	-	-	-	-		-	-
	NC	82.7	81.0	2.3	83.4	101	2.6	- 1 .0
	BT	82.7	81.0	2.3	83.4	101	2.6	-1.0
Mahidpur	C	13.4	3.6	0.3	4.0	29	0.4	9.4
	NC	142.0	103.1	4.2	107.3	76	5.0	33.9

District/ Block	Type (see notes at bottom of table)	Net Annual Groundwater Availability (MCM)	Existing (MCM)				Future (MCM)	
			Gross Draft for irrigation	Gross Draft for Domestic & Industry	Total gross draft	Stage of GW devpment	Estim draft for domestic & industry over next 25 years	Net avail for future irrig.
	BT	155.5	106.7	4.5	111.2	72	5.4	43.3
Tarana	C	-	-	-	-		-	-
	NC	122.1	96.0	4.4	100.4	82	5.5	20.6
	BT	122.1	96.0	4.4	100.4	82	5.5	20.6
Badnagar	C	-	-	-	-		-	-
	NC	162.7	269.3	4.8	274.1	168	5.4	- 112.0
	BT	162.7	269.3	4.8	274.1	168	5.4	- 112.0
Kachrod	C	-	-	-	-		-	-
	NC	164.0	136.2	6.2	142.4	87	8.0	19.8
	BT	164.0	136.2	6.2	142.4	87	8.0	19.8
UJJAIN TOTAL		792.8	839.3	25.0	864.4	109	30.6	- 77.1
OVERALL TOTAL		2,242.5	1,970.5	72.8	2,043.3	91	121.1	150.9
Notes: Inside Irrigation Command (C), Outside Irrigation Command (NC) BT Block Total								

D. Artificial Recharge:

31. The Central Groundwater Board (CGWB) has worked out preliminary feasibility of recharging groundwater in the state of Madhya Pradesh. The estimates for Chambal, Kshipra and Ghambir tributary basins areas given in table below. The total feasibility for Artificial recharge the Kshipra watershed is estimated to be 14 MCM with Ghambir 32MCM giving a total of 46MCM. Area feasible for artificial recharge in the State of Madhya Pradesh including upper Chambal and Kshipra sub-basin as given in Figure 32 and summarised in Table 11. The National Rural Employment Guarantee Act (NREGA) programmes are very focused on soil and water conservation with 70% of NREGA funds in the state being directed at soil and water conservation

Table 11: Feasibility of Artificial recharge

Basin / Watershed	**Potential Artificial recharge (MCM)**	**Volume (in MCM) of water to be recharged and Type / Number of Water harvesting Structures**							
		Percolation tanks		**Check dams/ Nala bunds**		**Dug well/Tube wells & shafts**		**Gully plugs/ Gabions**	
		Vol. of water	**Nos**	**Vol. of water**	**Nos**	**Vol. of water**	**Nos**	**Vol. of water**	**No**
Upper Chambal	9.58	4.79	24	2.40	80	0.96	96	1.44	287
Middle Chambal	9.31	4.66	23	2.33	78	0.93	93	1.40	279
Siwana	47.88	23.94	120	11.97	399	4.79	479	7.18	1436
Kshipra	14.36	7.18	36	3.59	120	1.44	144	2.15	431
Idar-retan	25.54	12.77	64	6.39	213	2.55	255	3.83	766
Ghambir	31.92	15.96	80	7.98	266	3.19	319	4.79	958
Maten	18.35	9.18	46	4.59	153	1.84	184	2.75	551

E. Groundwater Irrigation

1. Government and Private wells

32. In Kshipra sub-basin the irrigation is mainly from private dug wells and tubewell. These groundwater abstraction units predominantly belongs to individuals or groups of farmers. The Government intervention in groundwater irrigation is limited. The district wise status of irrigation dugwell, shallow and deep tube wells for the Kshipra sub-basin is given in Table 12 to Table 19 below:.

Table 12: Irrigation Dug Wells

District	Government	Cooperative	Panchayat	Group of Farmers	Individual Farmer	Others	Total
Dewas	19	2	5	1274	32173	21	33494
Indore	87	37	4	80	12479	20	12707
Ujjain	398	19	4	1064	39267	129	40881

Table 13: Cultivable Command Area and Irrigation Through Dug Well

District	Cultivable Command	Irrigation Potential created (ha)	Potential utilised (ha)
Dewas	92516	93864	52562
Indore	30198	36406	16963
Ujjain	90654	93790	23406

Table 14: Irrigation from Shallow Tubewells

District	Government	Cooperative	Panchayat	Group of Farmers	Individual Farmer	Others	Total
Dewas	5	2	2	1233	18409	17	19668
Indore	93	22	1	54	29272	24	29466
Ujjain	47	7	1	590	34774	76	35495

Table 15: Distribution of Shallow Tubewells by Type

District	Shallow TW	Bore Wells	Filter Point TW	Others	Total
Dewas	5375	94	14179	20	19668
Indore	26346	254	949	1917	29466
Ujjain	29059	1191	4953	292	35495

Table 16: Cultivable Command Area and Irrigation potential created Through Shallow Tubewell

District	Cultivable Command (ha)	Irrigation Potential created (ha)	Potential utilised (ha)
Dewas	61316	62310	40930
Indore	92406	102453	47500
Ujjain	93897	96680	36921

Table 17 : Deep Tube Wells

District	Govt	Cooperative	Panchayat	Group of Farmers	Others	Total
Dewas	10	14	8	329	1273	1634
Indore	7	4	2	253	1475	1741
Ujjain	0	0	0	1	307	308

Table 18: Cultivable Command Area and Irrigation Potential Through Deep Tubewell

District	Cultivable Command (ha)	Irrigation Potential created (ha)	Potential utilised (ha)
Dewas	4643	4720	2530
Indore	6633	7588	2964
Ujjain	555	566	350

Table 19: Cultivable Command Area and Irrigation Potential created Through Deep Tube Well

District	Cultivable Command (ha)	Irrigation Potential created (ha)	Potential utilised (ha)
Dewas	4643	4720	2530
Indore	6633	7588	2964
Ujjain	555	566	350

2. Power for Tubewells

33. The distribution of the irrigation wells as per average pumping hours in the basin is given in Table 20, Table 21 and Table 22 below. Photographs of micro irrigation being adopted are given in Figure 23.

Table 20: Distribution of Dugwells as Per Average Pumping Hours And Distribution System

District	Average pumping hour during peak season	Water distribution system					Total
		Sprinkler	Drip	Open Channel	Under Ground Channel	Others	
Dewas	33484	388	1271	21904	7382	2549	33494
Indore	12707	110	436	7910	1722	2530	12708
Ujjain	40871	283	138	23157	11919	5374	40871

Table 21: Distribution of Shallow Tubewells

District	Average Pumping Hour (peak season)	Water distribution system					Total
		Sprinkler	Drip	Open Channel	Under Ground Channel	Others	
Dewas	19668	148	203	9878	7505	1934	19668
Indore	29466	178	235	21238	1701	6114	29466
Ujjain	35495	410	722	21010	8240	5113	35495

Table 22: Distribution of Deep Tubewells

District	Average Pumping Hour during peak season	Water distribution system					Total
		Sprinkler	Drip	Open Channel	Underground Channel	Others	
Dewas	1634	2	1	1089	431	51	1634
Indore	1741	621	23	941	124	32	1741
Ujjain	308	1	0	259	28	20	308

Figure 23: Drip Irrigation in Dewas

F. Regulatory Framework Relating to Groundwater

34. The Government of India has circulated to state governments including the Government of Madhya Pradesh (GoMP) a Model for enactment of suitable legislation to setup state government authority for control and regulation of groundwater development. The *MP Peya Jal Parirakshan Adhiniyam, 1986* provides for the preservation of water in water sources and for the regulation of digging of tubewells in order to maintain the water supply for the public for domestic purposes and for matters ancillary thereto. The state of MP vide notification dated 26.6.2006 have made roof top rainwater harvesting mandatory for all types of new buildings having plot size of more than $140km^2$. The CGWB constituted under the Environmental Protection Act have notified Dhar and Manawar blocks of Dhar district, Indore Muncipal Corporation, Mandasuaur and Sitamau blocks of Mandsaur district, Neemuch block of Neemuch district and Jaora block of Ratlam district of MP for regulation of groundwater development.

G. Groundwater Problems and issues

35. The basin has several issues related to groundwater such as:

- Limited availability of groundwater in hard rock aquifer system of Malwa Region.
- Diminishing surface water resources.
- Polluted stream water with untreated urban and industrial wastewater.
- Decline levels of groundwater due to excessive use.
- High levels of fluoride in deep aquifers.
- Parts of the districts of Dewas, Indore and Ujjain are affected with high levels of nitrate in groundwater.
- Inadequate interaction among supply and demand side initiatives and lack of decision making at basin level.
- inadequate knowledge-base and awareness at grass root level.
- The number of districts with falling groundwater levels in the state have increased from 33 in 2001 to 47 in year 2004.

Figure 24: Hydrogeological Map

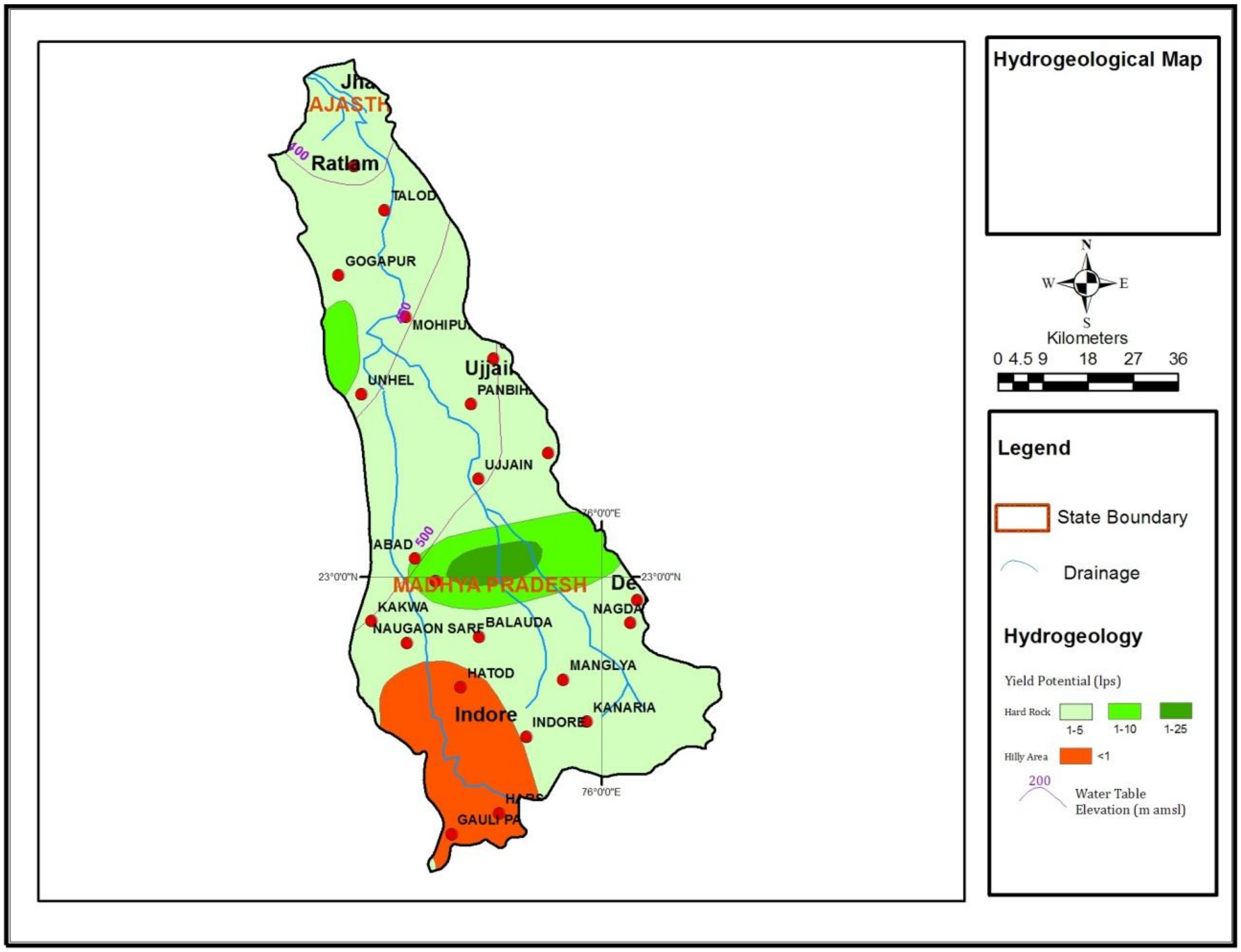


Figure 25: Groundwater Ujjain

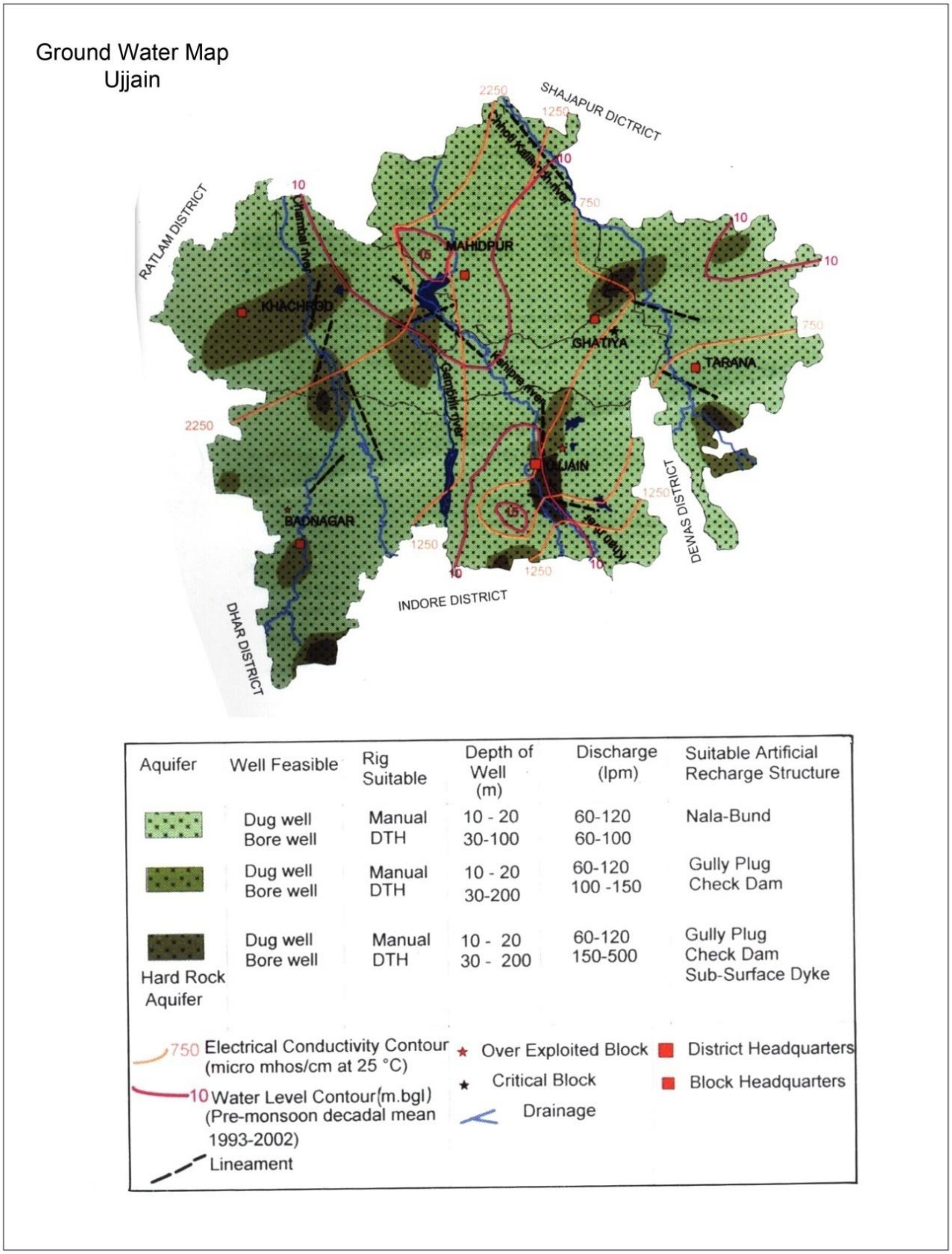
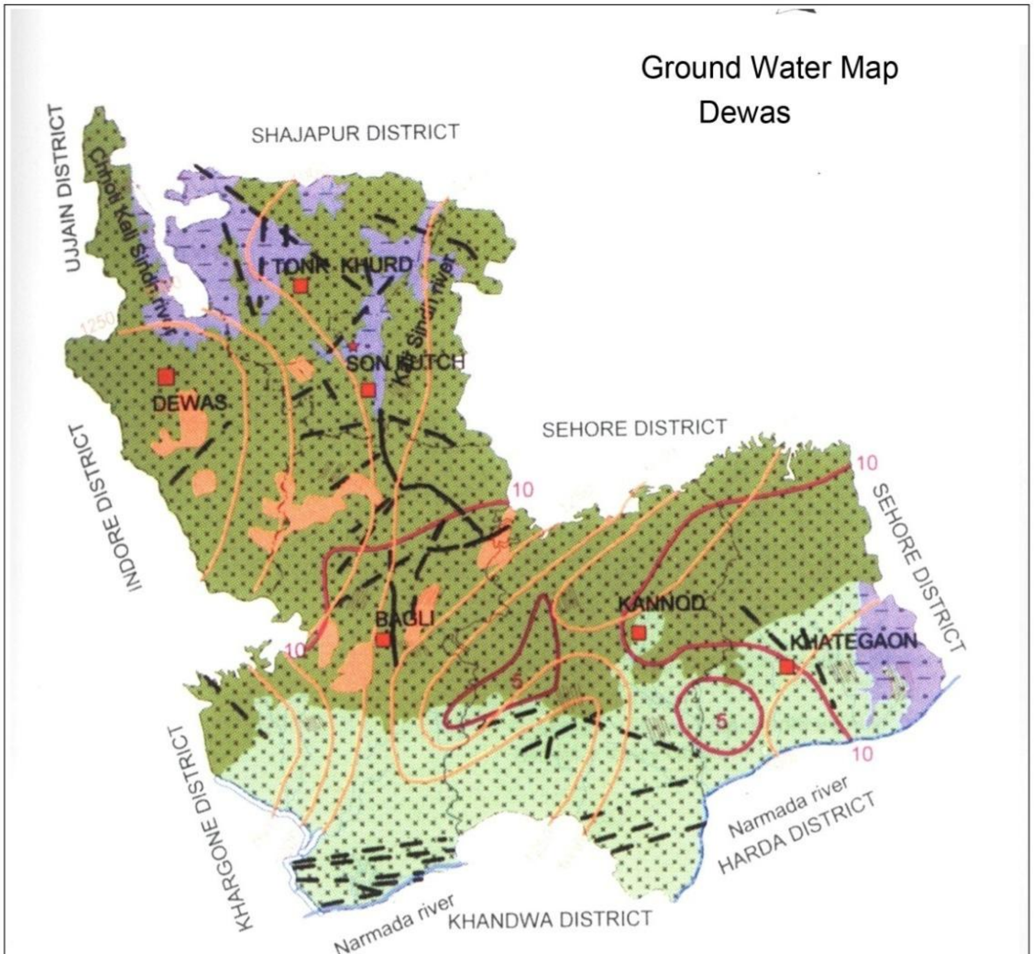


Figure 26: Groundwater Dewas



LEGEND

Aquifer	Well feasible	Rig Suitable	Depth of Well (m)	Discharge (lpm)	Suitable Artificial Recharge Structure
Soft Rock Aquifer	Dug Well Borewell	Manual Rotary	10-15 100-150	60-120 60-120	Recharge Shaft
Hard Rock Aquifer	Dug Well Borewell	Manual DTH	10-15 150-200	60-120 60-180	Nala Bund Gully Plug
	Dug Well Borewell	Manual DTH	10-20 100-150	60-120 60-120	Gully Plug, Check Dam

Electrical Conductivity Contour (micro mhos cm at 25 °C)
Water Level Contour(m.bgl.) (Pre-monsoon decadal mean 1993 - 2002)
Lineament

Drainage
Hilly Area
Fluoride >1.5 mg/l
Nitrate>45 mg/l

District Headquarters
Block Headquarters
★ Critical Block

Figure 27: Groundwater Observation Wells

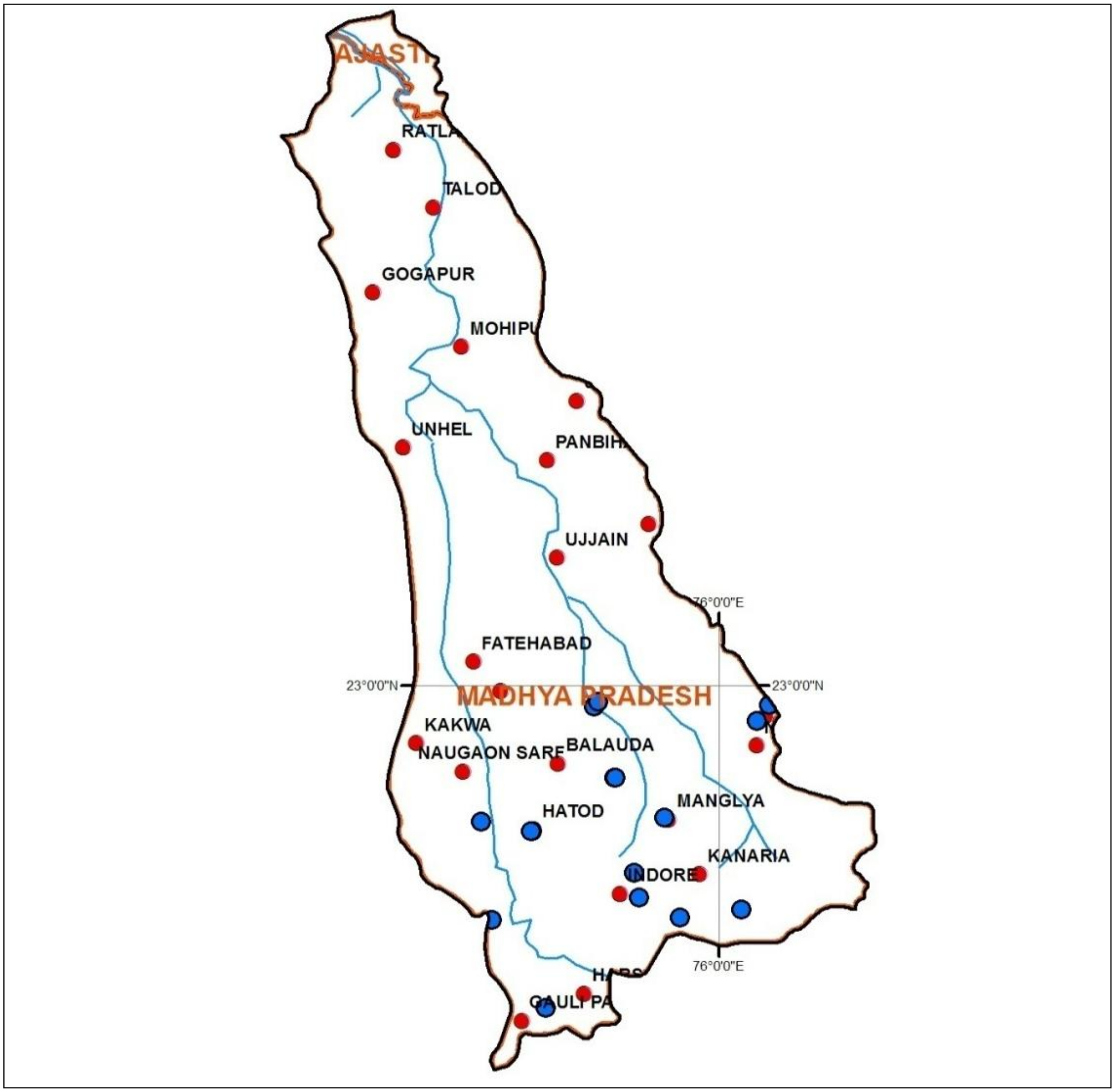
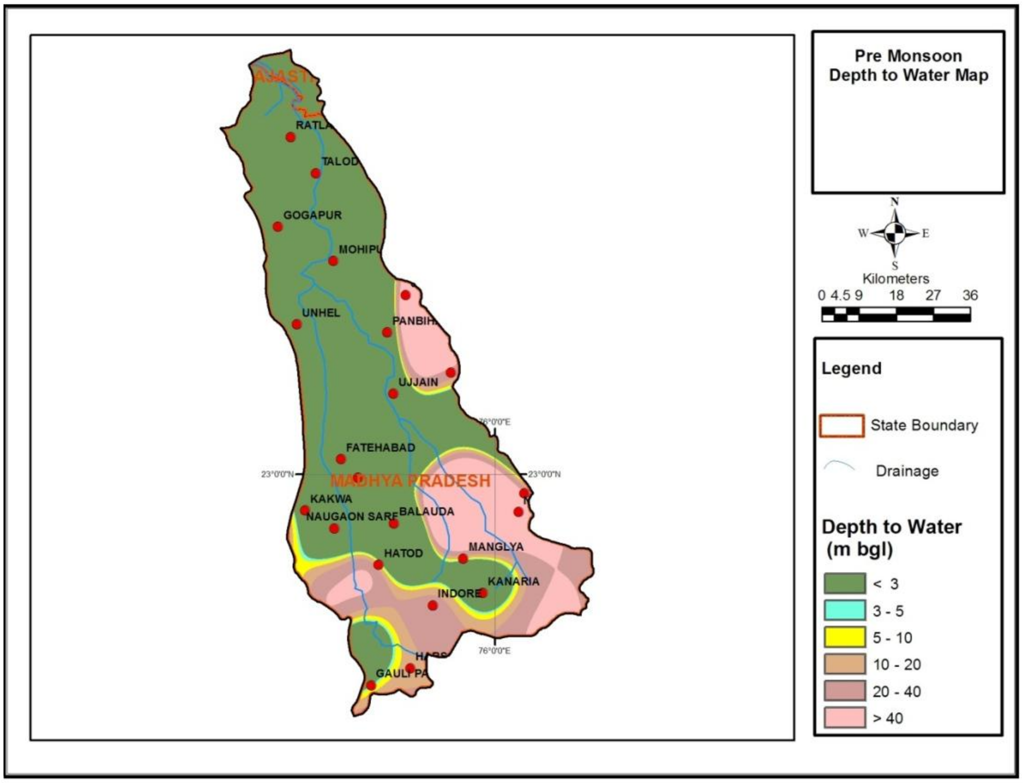


Figure 28: Pre and Post Monsoon Depth to Groundwater



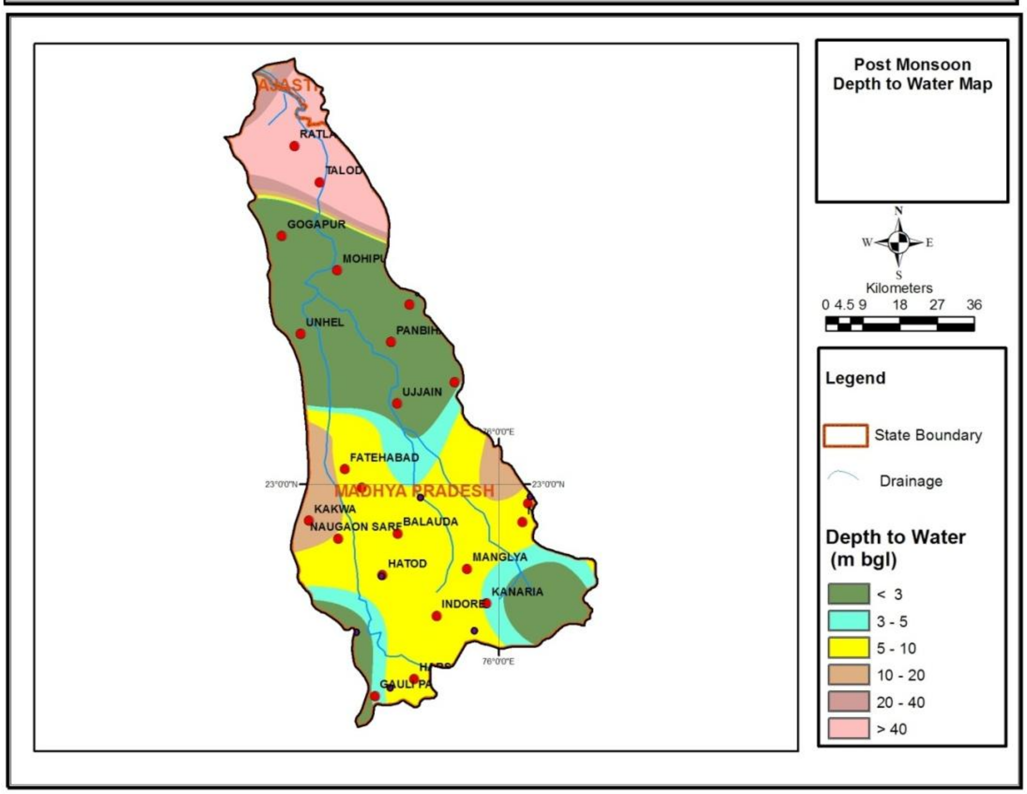
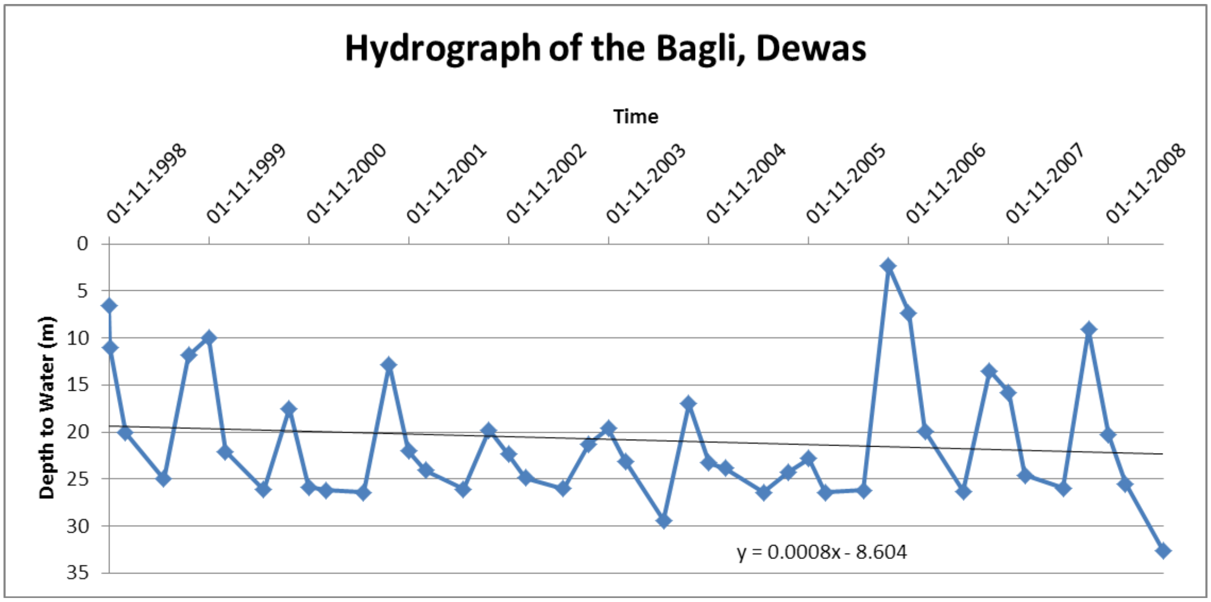


Figure 29: Hydrographs Dewas and Ujjain



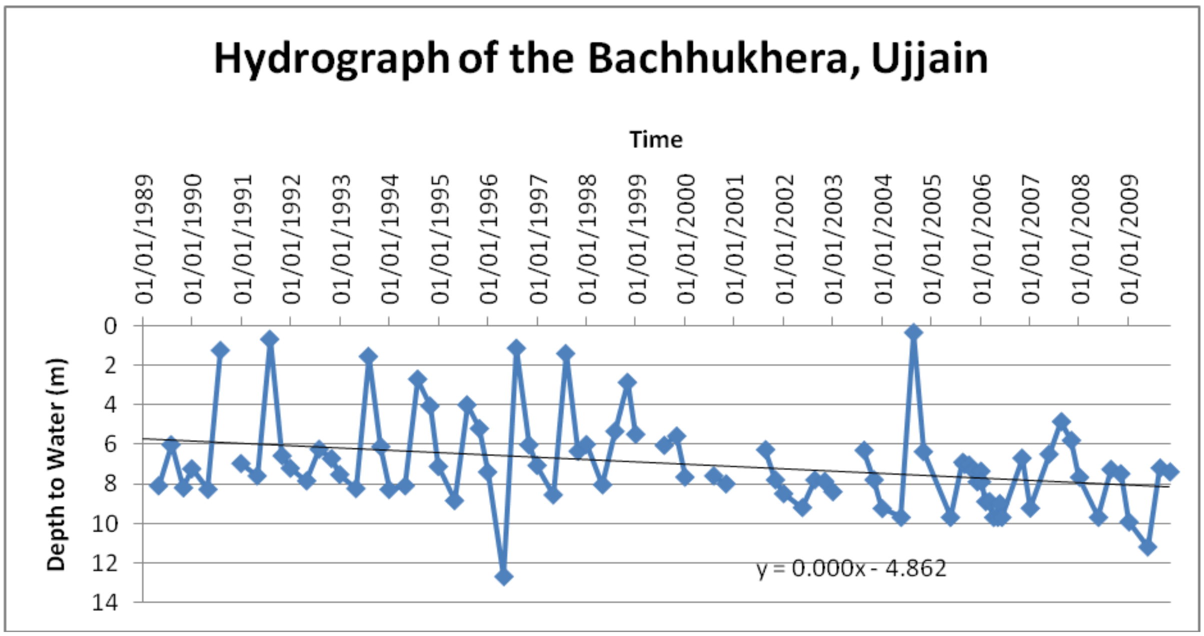
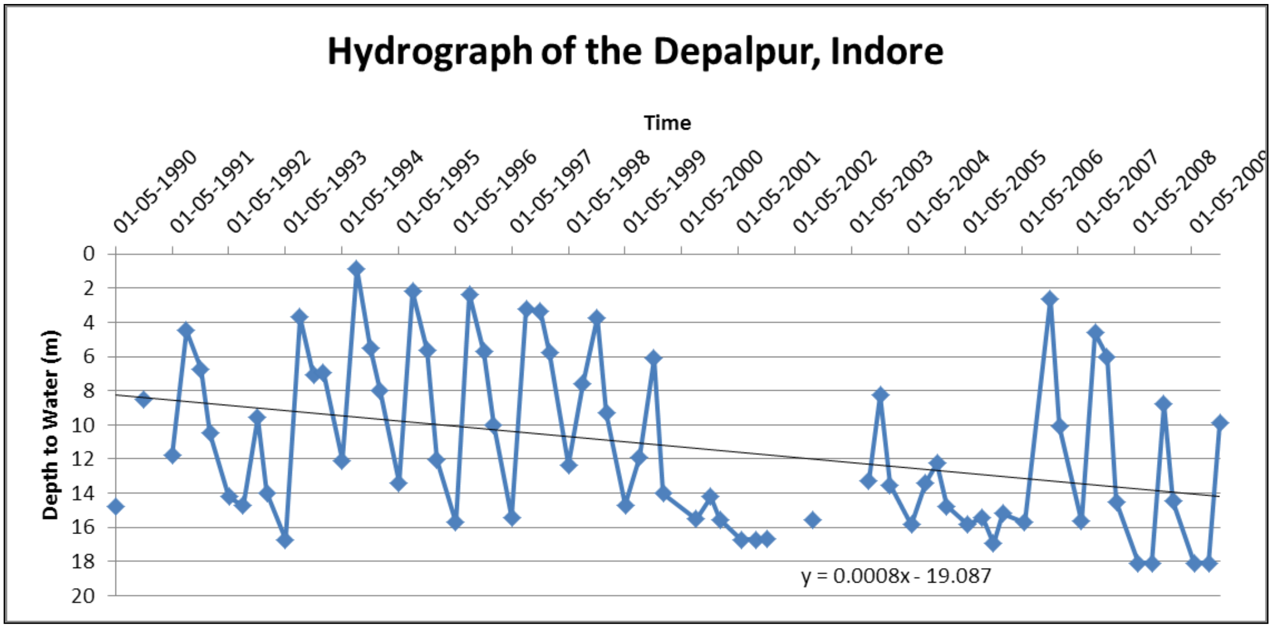


Figure 30: Hydrograph of Indore and Ujjain



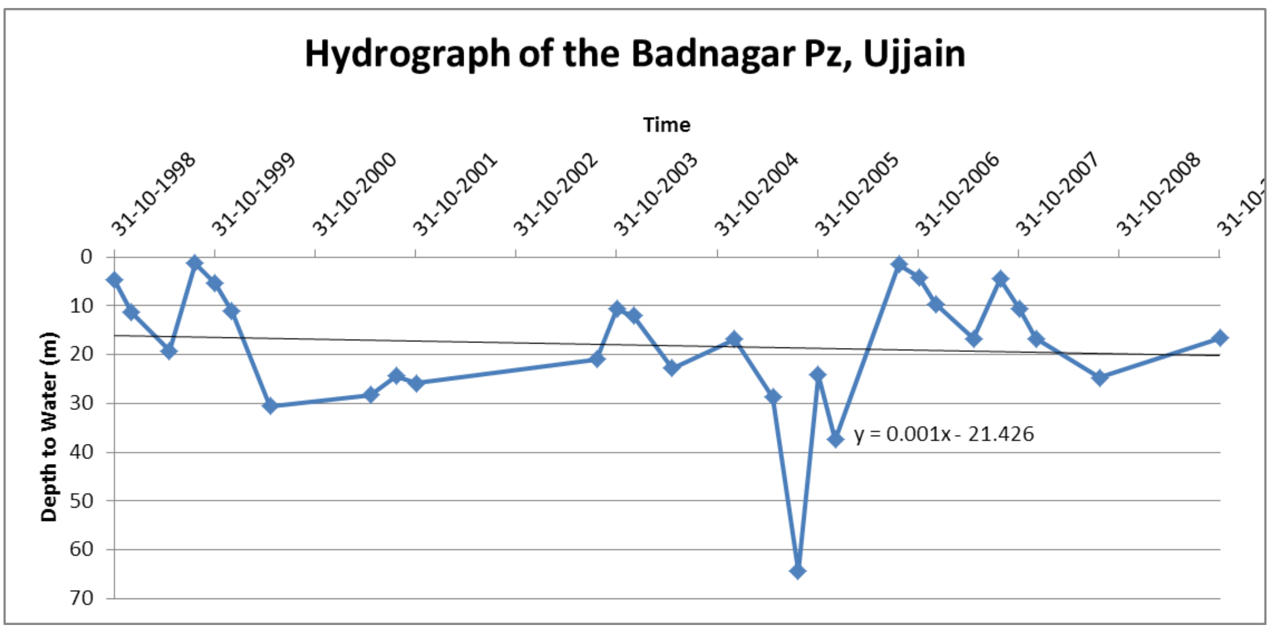


Figure 31: Electrical Conductivity

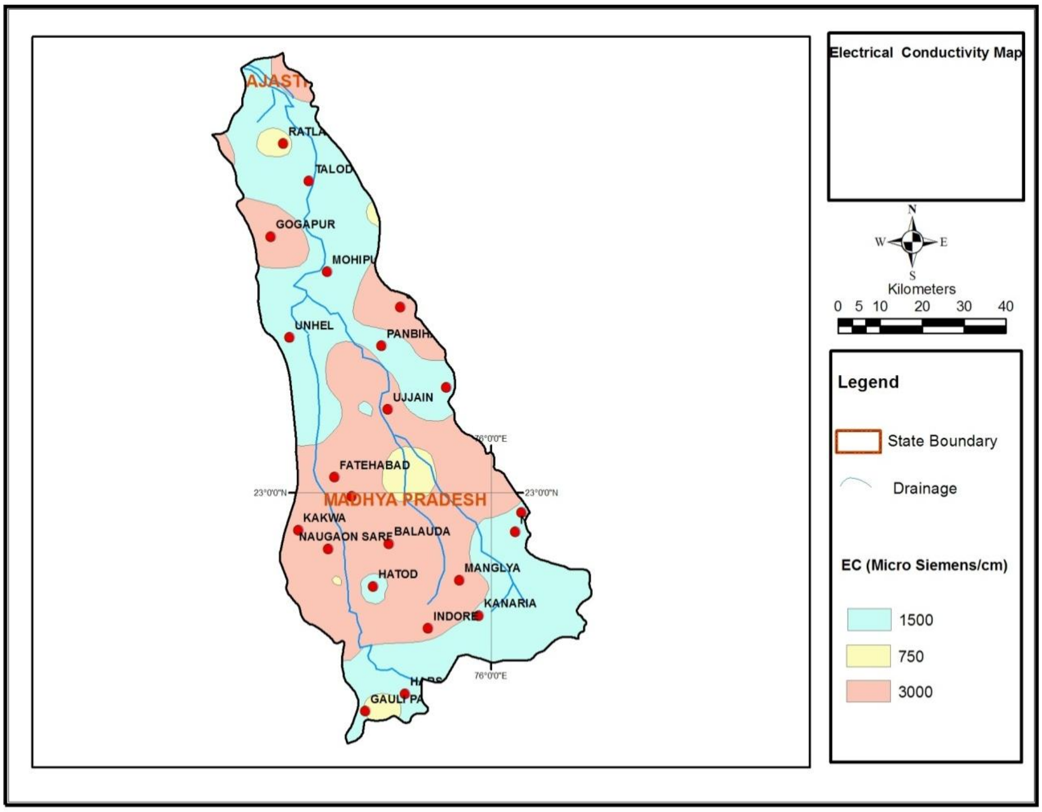
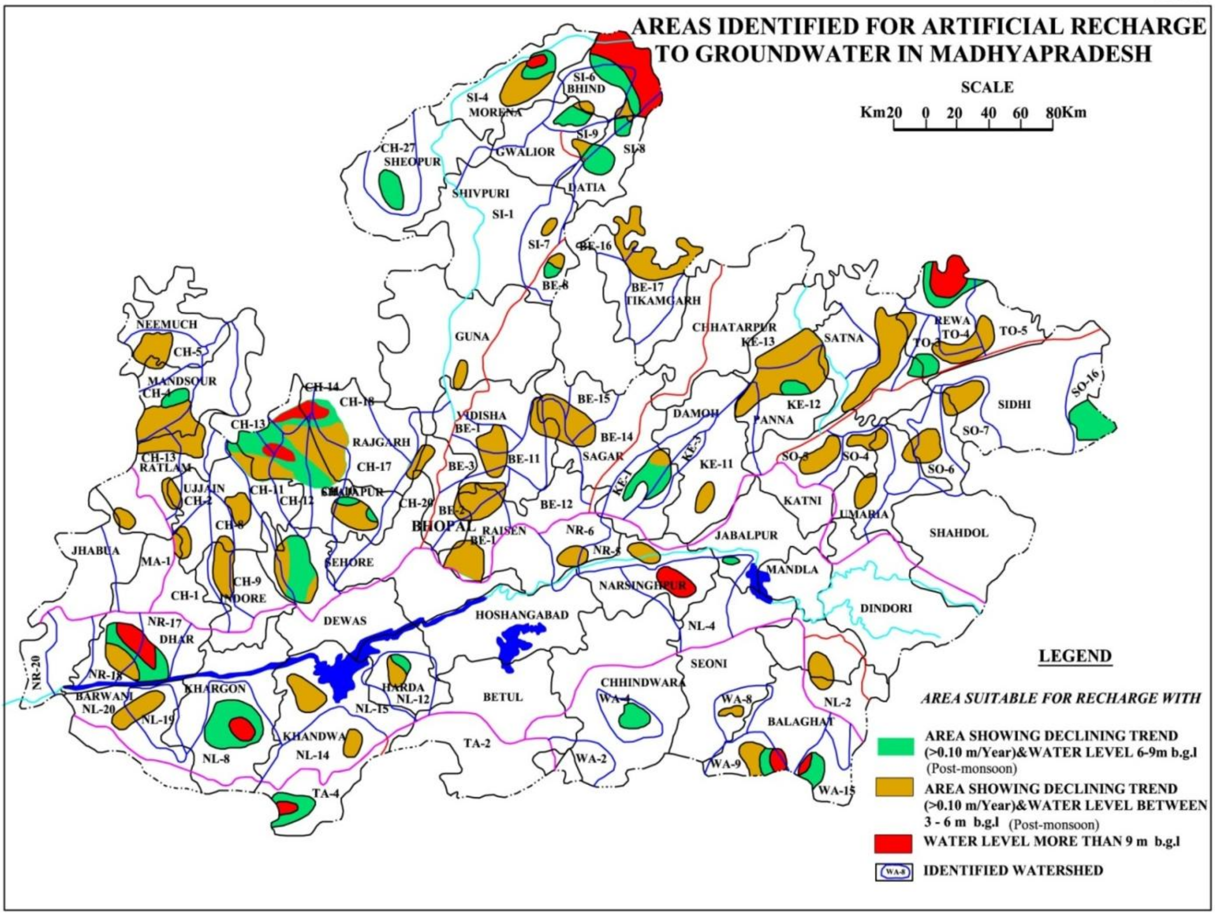


Figure 32: Areas Identified for Artificial Recharge in MP



III. IRRIGATION AND DRAINAGE

A. Introduction

36. The Chambal river originates from the of northern slopes of Vindhyan hills in Madhya Pradesh at an elevation of 840 Meter. The river flows in the northerly direction in the state of Madhya Pradesh for length of 345kms. It flows for a distance of 217km forming a border between Madhya Pradesh and Rajasthan and another 145 kms borders of Madhya Pradesh and Uttar Pradesh. After travelling a distance about 960kms and a fall of 730meters, it joins the river Yamuna in Uttar Pradesh draining an area about 143220 Km2. Chambal is rainfed river and passes through a flat terrain of Malwa plateau in Madhya Pradesh where some of the tributaries like Kshipra, Kali, Sindh, Parbati, Gambhir etc join the main river. The Malwa region in MP lies in the semi-arid zone has an elevation of about 500 m and is also known as Malwa Plateau and fully lies in the catchment (drainage) area of the Chambal river. The Kshipra River also known as Shipra rises in the Vindhya range and flows across the Malwa plateau to join the Chambal river. It is a sacred river to the Hindus and holy city of Ujjain is situated on its right Bank. Ujjain is venue of mammoth Kumbh Mela, held once in twelve year.

37. The catchment area of Kshipra sub-basin is 4750 Km^2 and is fed by two major tributaries namely Khan and Gambhir rivers which meet Kshipra at 70 and 120 Kms from origin of the river respectively. Climate of Kshipra basin is characterized by hot summer and well distributed rainfall during the south west monsoon season. About 91% of total annual rainfall takes place during monsoon (June to September). About 9% meager rainfall from October to first week of June is hardly sufficient to build up soil moisture for agricultural purposes and groundwater recharge.

38. As a rough estimate, the existing water bodies in the basin are having capacity of about 200 MCM, mostly in minor size irrigation dams namely Sahibkhedi, Dholawad, and Kazikhedi. Groundwater is the major sources of irrigation, drinking and industrial water in the basin. The groundwater occurs within the weathered and fractured zone of underlying multilayer hard compact basalts. Groundwater resources are quite variable in quantity and quality.

39. Kshipra river is reported to be perennial river up to 1980 but gradually the river has become dry during the non-monsoon season primarily due to over exploitation of groundwater. The river is not receiving sub-surface base flow. It is estimate that about 1.2 lack tubewells have been constructed during the last 25 years. Because of depletion of groundwater for irrigation purposes, the acute shortage of drinking has also been reported in many places. The drinking water requirement is met by transporting water. The cities of Indore and Dewas are dependent on river Narmada for their water supply, which is lifted and is reported to be very costly arrangement.

40. The farmers in the Kshipra sub-basin mostly harvest two crops. The main crops are: wheat, soybean, sugar cane, vegetable, gram, ground nuts and some other seasonal crops.

41. Considering that the average annual rainfall in the basin is 840mm and there is no possibility of major and medium irrigation projects in the basin, conservation of water, recharge of groundwater storage and efficient use of water appear to be the only solution to the existing water shortage in the basin.

B. Agriculture

42. Madhya Pradesh is the second largest state in the country in terms of area and seventh largest in terms of population; the state has 48 districts. The state is classified as a sub tropical region. Agriculture contributes 24% of the State GDP and employs 78% of the total workforce. The net sown area is 47.5% of the total geographic area (compared to the National average of 46%). The Gross cropped area is 18. 2million ha with a cropping intensity of 124. Small and marginal farmers account for 60% of land holdings and 22% of operated area. Irrigation covers 31% of the net sown area while the remaining 69% of the net sown area is rainfed. Madhya Pradesh with high geographical diversity, eleven agro-climatic zones and varied soil types is better placed for production of various horticultural crops. Horticulture crop covers 2.6% of the gross cropped area in the State. The area under Horticulture is 640,000 ha, with an annual production of 3.8 million tonnes.

43. Agricultural growth in the state during the Tenth plan (2002-2007) was 4% with a projected growth of 4.4% for the Eleventh plan against the India average of 4% and 4.4% for the Tenth and Eleventh plans. Despite the heavy outlay in agriculture, there remains nationally a declining GDP contribution from agriculture. The major constraints[5] include rapid urbanisation and land use for non agriculture,lack of assured and perenial irrigation, uncertain rainfall, lack of technologies to support higher productivities, lack of diversification in crops and poor supply of agricultural inputs,inadequate credit for small and marginal farmers and changes in climate.

44. Horticulture: The horticulture sector has contributed significantly to GDP in agriculture (28.5% from 8.5% area) is shown in Table 23.

Table 23: Area of Horticulture

	Type	**Area ('000 Ha)**	**Production (MillionTons)**
1	Fruits	63	1.2
2	Vegetables	246.2	2.2
3	Spices	309.8	0.3
4	Flowers	6.7	0.004
5	Medicinal Crops	15.6	Na
	Total	641.5	

45.

C. Surface Water Schemes

46. Some surface water schemes are in the planning and construction stage to augment the water resources. These are:

(i) Khan Reservoir Irrigation Project: On the river Khan irrigation to 18000 hectare land (cost estimate not firmed up as scheme at planning stage)
(ii) Chambal-Gambhir River Link Project: To augment drinking water storage on Gambher drinking water reservoir for Ujjain town water supply by diverting Chambal water to Gamber. (cost estimate not formed up as scheme at planning stage).
(iii) Irrigation Water Supply Project: For villages and Town of Dewas, Ujjain and Shajapur districts of Madhya Pradesh. The project is diversion of water from Narmada to 1500 villages and 27 town of Ujjain, Dewas and Shajapur districts at an pre-feasibility estimated cost of Rs, 2988 crores.
(iv) Construction of fourteen checkdams on the river Kshipra at at an estimated cost of Rs3.21 crores. These check dams are mostly about 2M high structures across the river to check the river flow in order to restore the perennial nature of the river Kshipra for aesthetic and religious purposes. This project is recently completed.
(v) Various watershed development programmes being executed by government departments with focus of water harvesting and soil conservation from the annual budgets of these departments.

47. Two important water management initiatives have become popular in the Kshipra sub-basin particularly in Dewas district.

(i) Spread of micro-irrigation schemes; and
(ii) Construction of farm (ponds/tanks) also called Balsam Talab.

48. During the field visits by the consultants to the farm lands with tanks, it is learnt that such measure are highly efficient in water conservation and groundwater recharge. Balram Tanks is a government subsidized scheme with 50% subsidy subject to maximum of Rs 50,000 is provided for all categories of farmers for construction of large tanks in the fields.

[5] Field study report on Impact Assessment of Micro Irrigation Schemes in Indore, Dr Venkataramanalah Indian Institute Management, Indore

49. Micro irrigation schemes have gained popularity in the Kshipra particularly in Dewas district. Many farmers have adopted micro irrigation because of increased crop productivity, saving in water and increased revenue. Crop production estimates were reported to be about 30% high where as water saving is reported to be 50%. Various soil moisture retentions techniques likes mulching the farmland with black plastic sheets were also seen to be popular in the basin.

D. Potable Water

50. Drinking groundwater problems are widely reported in the basin. Water shortage has been caused by large scale irrigation schemes, which have caused lowering of groundwater table in the basin as well as making the Kshipra river dry in the non-monsoon season. The annual requirement of domestic water is estimated to be about 200MCM.

51. It was found that drinking water problems are being tackled in some of the villages by adoption of local water conservation to support recharge to dug wells and small tubewells. With more than 800mm annual rainfall, the drinking water problem there are opportunities to support sustainable potable water at village level through conservation and storage of water with people’s participation.

52. The GOMP is presently formulating a major water supply project for supply drinking water to 1500 villages and 27 town in Ujjain, Dewas and Shajapur district from the Narmada river. This project when implemented is designed to solve drinking water problems of the Kshipra sub-basin. This very large project will require multiple pumping with pumping heads of around 800 metres at an estimated cost of Rs2988 crore.

53. **Indore Urban Water Supply**: Indore is the largest population centre, population growth over the last census decade shows growth of 40%. The city has a very high population density of 1028 persons per ha and severe problems of water and sanitation. Water supply is available for only 45 minutes on alternate days, covering 54% of the city population. Average water supply is 80 lpcd. 50% of water is unaccounted for (UFW) including 40% transmission and distribution losses. Only 55% population has access to sewerage network and 80% of sewers are underutilised for want of maintenance. Only 20% of roads have storm water drainage solid waste collection suffers from poor handling and management narrow road widths, high vehicular ownership, and a heterogeneous mix of transport modes resulting in traffic congestion problems and a high accident rate.

54. The city development plan for Indore is planning to provide 24/7 water supplies. The Indore Urban Water Supply is presently being upgraded through ADB support with an additional 360 MLD of new water supply with raw water intake completed. Testing and Commissioning in progress. The laying of water mains for 127Kms has been completed. This would add an indicative volume of 65 MCM per year to the Kshipra water balance (assuming 70% of capacity pumped and 70% non consumption).

E. Constraints Faced by Farmers in the Basin

(i) Because of the high cost of micro-irrigation scheme, poor farmers are finding it difficult to install the micro-irrigation schemes in spite of government subsidy.
(ii) Farm ponds have come up in Dewas district but have not been adopted in large scale in Indore and Ujjain districts because shortage of land and lack of awareness about its utility.
(iii) Higher transaction cost in proper packaging, and lack of logistics of farm produce marketing is the major worry for the farmers.
(iv) Inadequate weather forecasting system particularly seasonal forecasts and timely advisory information sharing is cause of concern among farmers.
(v) Crop risk management, like crop insurance and micro-credit flows have not become popular in the basin.

IV. WATER SECTOR COMMUNITIES AND STAKEHOLDERS

A. Introduction

55. Inclusive growth paradigm has made it almost mandatory to have stakeholders' participation in the design, implementation of public policy and decisions about the delivery of services (Martin, 2005) and also as peer monitoring group. Stakeholders are those who have an interest in a particular decision, either as individuals or representatives of a group. People who influence or can influence a decision as well as those affected by it can be considered as stakeholders. Community of stakeholders can become active with some specific goal. Without going into the definitional debate on 'community' across disciplines we can use it here to describe a group who shares identity on some specific respect and shares (any one or all) belief, resources, concerns, needs etc. The size of a community can vary.

56. A commonly shared vision by all stakeholders to have a successful intervention be it policy, technology or systemic. For the current assignment, specific goal around which we are trying to identify a community is "to examine intervention requirements, scope and strategies to improve the efficiency of water systems and how improved efficiency may be applied to climate change adaptation".

57. To identify water sector stakeholders from climate change point of view within the scope of this assignment we consider the community associated with the issue at hand. It covers part of the human society whose employment/livelihood/income/productivity stream will be directly impacted in future - become riskier/decline- with change in stock and/or flow of water. The stakeholders who are active with this goal are both national and state government across various departments, knowledge generators engaged in technological and social innovation, farmers, NGOs. In the context of this study stakeholders/community are broadly: water source owners, water flow service providers and water stock and flow users.

58. Water source ownership in the state is represented by multiple categories of stakeholders not fully coordinated and rules on human interventions on the natural water system if not governed by fully defined rules.

- Primary sources of water flow are natural[6] (rainfall) defining the overall constraint on primary water supply. In climate change context adaptation challenge is if the community has knowledge and preparedness to take actions now so that the individuals, households and community becomes resilient to uncertain water supply condition in future without affecting wellbeing (in micro sense we consider current and future income stream of farmers and in macro sense productivity in agriculture to make state domestic product resilient).

- Secondary sources are various institutional sources based on surface water flow: Interstate high level body (e.g ., Gandhisagar dam) in control of surface water flow with 10% share for MP, WRD department owned canal system, Agriculture department owned micro and medium irrigation systems and famers withdrawing water from open access ground water aquifers with variety of pumping technology and farm pond based water harvesting systems.

59. Stakeholder can be categorised into water providers and water users as shown in Figure 33.

[6] nature do not play an active role as stakeholder for our decision making purpose

Figure 33: Structure of Users and Providers

STAKEHOLDER	
WATER USERS	**WATER PROVIDER**
Water for final use: Household demand for drinking purpose **Water for intermediate use/input in production process:** Household demand for cooking, hygine and sanitation, bathing, gardening etc. Agricultural water demand for irrigation Industrial water demand for process	**Water suppliers/managers** **Formal:** Government managed water supply department for distribution of canal water for irrigation and drinking water Water users association **Informal**: Farmers with pump to lift ground water and sells at a cost either monetized (cash) or non monetized (in kind)

B. Stakeholder Perceptions to Surface Groundwater and Environment

60. In the Kshipra river sub-basin major water user is agriculture sector with changing and ever increasing demand. Residential sector as water user is important here with declining water table in and around urban areas of Indore and Ujjain. So, we have focused on farmers, rural households of various income strata (defined by landholding size) and water managers from irrigation, horticulture and public health and hygiene departments. Source of information is primary first hand data collected through rapid rural appraisal through face to face participatory focused group discussions and community consultations, household surveys and some secondary sources obtained from local scientists and government handouts. Goal is to identify key issues regarding surface water, groundwater, water related sectors and the environment to help in preparation of strategic framework planning. Also, to examine intervention requirements, scope, and strategies to improve the efficiency of water systems and study how climate change dimensions may effectively be incorporated in IWRM climate change adaptation roadmaps.

61. The specific goal of PRA and household survey has been to understand community perception at various levels and to get first hand :

- stakeholder assessment of current issues related to surface and ground water
- the problems and causes of issues
- perception of change in climate induced parameters and impact on water resource
- to test the response to potential initiatives to address water issues
- identify possible initiatives that could be further investigated

1. Adopted Methodology for the PRA

62. The PRA is designed to support the stakeholders through the process of analysis of the problems and help them identify appropriate response to the difficulties and opportunities. We have used preset questionnaire as checklist to get structured response. Qualitative response during focused group discussions has also been recorded, compiled, assessed and presented in the report. We have followed the conceptual framework of (livelihood, Institutions, Food security and Empowerment) LIFE approach[7] and Nine Square Mandal in preparation of questionnaire in cooperation with other team members involved in TA. In the sub basin three locations have been identified through prior visits, consultative processes with stakeholders. Locations selected are characterized by primarily diversity in conjunctive water use practices and related challenges. ADB-PRA team held stakeholder meetings[8] at the villages with stakeholders assembled in focused group discussion (FGD) in each of the three locations. However, primary data has been collected not only from FGD but also through household survey (39 households covered) and case analysis (three) – for

[7] Ghosh and Roy (2006)
[8] PRA meeting participant lists are given in annexure II

progressive farmers[9]. These three levels of interview methods have been followed to get community, household and individual perceptions.

2. Kshipra River Sub-basin

63. The primary criterion for selection of the field survey locations has been the diversity in conjunctive water use pattern and suggestion from state departments. Goal has been to understand if the stakeholders' challenges in diverse locations spread over the sub basin are diverse or not. Secondary criteria for survey location selection have been crop diversity, followed by ground and surface water quality and quantity. The site selections have been preceded by investigative field visit[10], consultation with all kinds of broad categories of stakeholders.

3. Community Perceptions

64. The stakeholders of various interest groups shared more or less a common vision on current water availability, access, distribution and quality in the region. Diverging views are reflected in quantification of the issues. This is presented below through ranges of values for various variables and parameters.

65. The perceptions to current issues relating to irrigation water access include:

- Multipurpose irrigation project with canal system from large village ponds (sasakiya talab) meet only very limited irrigation water demand with very limited command area. It is by gravity flow. As per rule there are water users association elected by command area residents. WRD department is in custody of these systems. Warabandi system was tried but failed. Surface water supply system leaves huge unmet demand in agriculture sector thereby shifting the demand pressure on unregulated ground water extraction at farmers' private initiative and cost. The traditional crop varieties : gram, cotton, paddy have now (more than a decade ago) been replaced by soyabean during rainy season followed by wheat in dry season where irrigation is available otherwise black gram, vegetables, horticulture. Major driver is level of certainty in current economic return (due to market support price for soyabeans, short crop duration, less water need, availability of processing units) from agricultural production to provide stable income flow to farmers.
- Surface water can meet only 0%-50% of irrigation demand in wheat cultivation.
- Farmers have high dependence (100-50%) on uncontrolled/open access ground water resources. During consultations it could be assessed that perception of common property/open access resource and knowledge on possible management practices either at theoretical level or from practical point of view is almost nil across all stakeholders. But open to new ideas when discussed. Ground water quality is hard.
- With introduction of tank at farm level in Dewas the conjunctive water use scenario changed. Lining of canal is costly almost four times than tank cost.
- Next generation is not all moving away from agriculture with increasing level of education and that itself is good for technology intensive horticulture practice scaling up, introduction of best practices, modernization etc. Labour is becoming scarce with competing demand in NREGA which is almost timed with harvesting season. Community feel activities can be timed differently to benefit both kinds of activities. Chart below show percentage of younger people interested to staying in agriculture across districts.
- In Chidawad Village 100% village households have agriculture as only primary occupation. 40% households have family members in Indian army. 90% have own land others work in others' lands as labour. Historically they used to grow Jowar and cotton when it was only one crop but now it is wheat, gram, groundnut. This has been made possible by water and electricity availability.
- In Khejuria-Rewari it is mostly inhabited by OBC community. It is 300-400 years old village. Migrants from Rajasthan got settled in the village. Migration was mainly due to drought. 250 households live of which 100% are agricultural farmers with 85% own land others work in other's land. Size varies between 100-150 bighas. 148 households are in BPL category.

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[9] Omprakash Patel: Chrawat Village, Yogendra Kausik –Ujjain, Rajendra Singh Solanki, village Barkheri-Ujjain.
[10] November 2010: Bhopal, Ujjain, Dewas, Indore

- In Naugaon 300 years old village two brothers from Marwar in Rajasthan started the village with Jowar and opium cultivation. Now it is soyabeans and cotton in last 30 years. 375 households are there. Bore hole based handpump (7-8) at 100-150 depth provide drinking water . 100 dugwells are seconday drinking water source. There are 75% households who can have one crop alone based on rainfall and 25% area can be under two crops. Dug well and electric motor based boreholes (25%) are water sources for agriculture. There has been no testing on quality. 144 BPL households . Four households have 100-250 bighas, 50 households with larger than 5 bighas and rest have 1-5 bighas. Water table is at 50ft but until January.
- In Indore there are 384 gram panchayats and 600 villages. 100% are agriculture dependent 5% have milk production for market as non farm income source. 70% have own land and 30% work in others' lands. Out of 7000 acres of cultivable land 41.82% is from ground water, 2% from canals and rest practice dry agriculture.
- Boreholes at 100-400 ft depth provide ground water source. There is over exploitation of ground water with increased agricultural activities and during dry season productivity is less by 30%.
- Farmers have very inequitable and high dependence (50-100%) on uncontrolled/open access ground water resources. Perception of common property/open access resource and knowledge on possible management practices either at theoretical level or practical point of view is almost nil across all stakeholders. But were receptive to new ideas when discussed. Ground water is depleting very fast. The area was known for high ground water level in the past historically but is drying up. Ground water exploitation is exclusively driven by unregulated private demand and affordability.
- Boring and recharge at various points in Kshipra river is happening. Nadi purnavaran project of state government has started with the aid of an NGO.
- Water quality is declining : Salinity and hardness is causing problem for agricultural productivity
- Tail enders do not get adequate water in gravity flow system due to declining water level in Government tanks. These tanks beds are allowed to be used for cultivation when there is low water level and understood to be very highly productive due to silt and organic matter etc. But there is discontent among community by caste for this privilege being given to lower caste. Government argument is that those whose lands were historically taken for tank are being allowed to use the tank bed for cultivation. The other complaining community has high demand for silt due to it's fertility and feel tank excavation can enhance gravity flow of canals.
- Current subsidy scheme on drip and sprinkler is seen as inefficient as these are targeted at BPL farmers who do not have other compatible infrastructure to take advantage of the scheme. There is a general feeling that it should have been for all and not BPL which could have scaled up the efforts faster.
- Most of the farmers have reported that they have not taken any loan from money lenders. The farmers who taken loan have used KCC facility.
- The Kharif crop is rain-fed. The rabi crop depends on irrigation. Two crops are grown in a year. About 25% of the agricultural area is single cropped for the lack of irrigation.
- Flood is not an issue in the region as the region is water scarce. Drought is major threat. Community want drought resistant shorter variety of soybeans, wheat.
- The households surveyed are of various landholding sizes. The small farmers have challenge in accessing ground water this share crop 50:50 with large farmers to get irrigation water lifted by pump at private cost.

4. Participatory Irrigation Management (PIM)

- Currently diverse irrigation water supply systems are run by diverse departments: agriculture department, horticulture department, WRD, watershed management programme, farmers' individual initiatives. There is need for integration of efforts, targets, information compilation and monitoring through coordinated community mobilization.
- High degree of farming community participation are characterise Kshipra basin. Pro-active farmers in Kshipra basin have been historically harvesting rainwater at the private farm level. There is strong community support to stop any run off from the basin to Narmada and hold the water where it drops.

- There is demand from farmers to de-silt the sasakiya Talabs (government owned public ponds that are very large in size with available infrastructure) that can enhance water retention capacity and meet irrigation water demand of the command area.
- Need for government regulation on ground water extraction was supported by all in PRA meetings. Household response for regulation and control vary district wise. While in Dewas 83% households feel there is need for regulation and control over ground water for long term sustainability responses are low in Ujjain and Indore (58% and 11% respectively). However, less support is found for electricity charges to control water withdrawal. The farmers are unhappy with current electricity charge collection system based on horse power of machines.

5. Response to Regulation and Control

66. The responses to various possible interventions on regulation and control are summarised in Table 24.

Table 24: Farmer Response to Possible Initiatives

	Strongly Agree			Strongly Disagree			Agree			Disagree			Mixed Feeling			No Opinion		
	D	I	U	D	I	U	D	I	U	D	I	U	D	I	U	D	I	U
For long term sustainability some type of regulations (control and restrictions) on groundwater is required	67	37	0	0	5	0	17	16	11	0	37	56	0	5	33	17	0	0
Government to introduce charges for power used for tubewell water to control use and reduce demand	0	11	0	8	0	0	8	5	0	25	63	89	33	11	0	25	0	11
Government to provide more subsidy for tank and micro irrigation	17	37	67	0	0	0	75	53	33	0	0	0	8	0	0	0	0	0
Government to take on greater control and regulation of groundwater use.	17	26	0	0	0	0	67	5	0	8	42	89	0	16	0	8	0	11
Greater Government controls to be introduced in tandem with programmes to support greater water use efficiencies and higher return cropping systems	58	53	22	0	0	0	33	5	67	0	21	0	8	5	11	0	0	0
Government to restrict the number of wells	8	11	0	0	0	0	42	5	0	33	58	##	17	16	0	0	11	0
Farmers and Community associations to take on greater control of surface and groundwater management	25	16	0	0	0	0	58	32	56	8	32	33	0	16	11	8	5	0
Community associations could take on responsibilities to control and mange groundwater abstractions	8	0	0	0	0	0	83	32	78	0	32	0	8	32	22	0	0	0
Government to change the price guarantees subsidies to promote non rice crops	50	32	##	0	0	0	33	11	0	8	21	0	0	16	0	0	0	0

Note D-Dewas, I-Indore and U-Ujjain

67. Farmers' strongly believe they can contribute towards ground water recharge through farm ponds. But there is no scientific monitoring of this. Over the years community has taken leadership to innovate farm ponds to get private access to secure water supply. This has now become a practice and been mainstreamed in policy action. There exist 70-80% government subsidy for balaram talab (farm ponds) which can be created in 10% of the farmer's own land. Madhyapradesh model of government support for scaling up community efforts is a good method to deliver adaptive action. Deamnd for more subsidy is observable from household responses (100% in Indore, 89% and 92% in Ujjain and Dewas). Jalabhishek, jal sangbad published regularly in Ujjain all are examples of is community participation in water management.

68. In promotion of drip and sprinkler irrigation in horticulture is also example of participatory management system. With government providing subsidy to the tune of 30-40% (higher for SC/ST categories) show cost sharing for promotion of water use efficiency.

69. While 100% of households in Dewas and Ujjain favour better surface water management as desirable strategy, in Indore it is for artificial ground water recharge and managing pollution in rivers are the most favoured strategies.

70. Both policy makers and farmers feel they need to work in tandem for providing water access security. But instead of government taking more control households prefer more community control. In Dewas 83-93% households feel community can better manage water systems, while in Ujjain the figure in favour of community participation 32-47% feel so and in Indore 56-78% think community can do a better job. However, all feel presence of government is necessary as a catalyst otherwise community on their own might not be able to take collective action. People are interested for role for the government for water management as this will help reduce social conflict. The household choice pattern for strategies to enhance water use efficiency across districts are shown in Figure 34, Figure 35 and Figure 36.

Figure 34: Possible Methods to Improve Water Efficiency (% households) Dewas

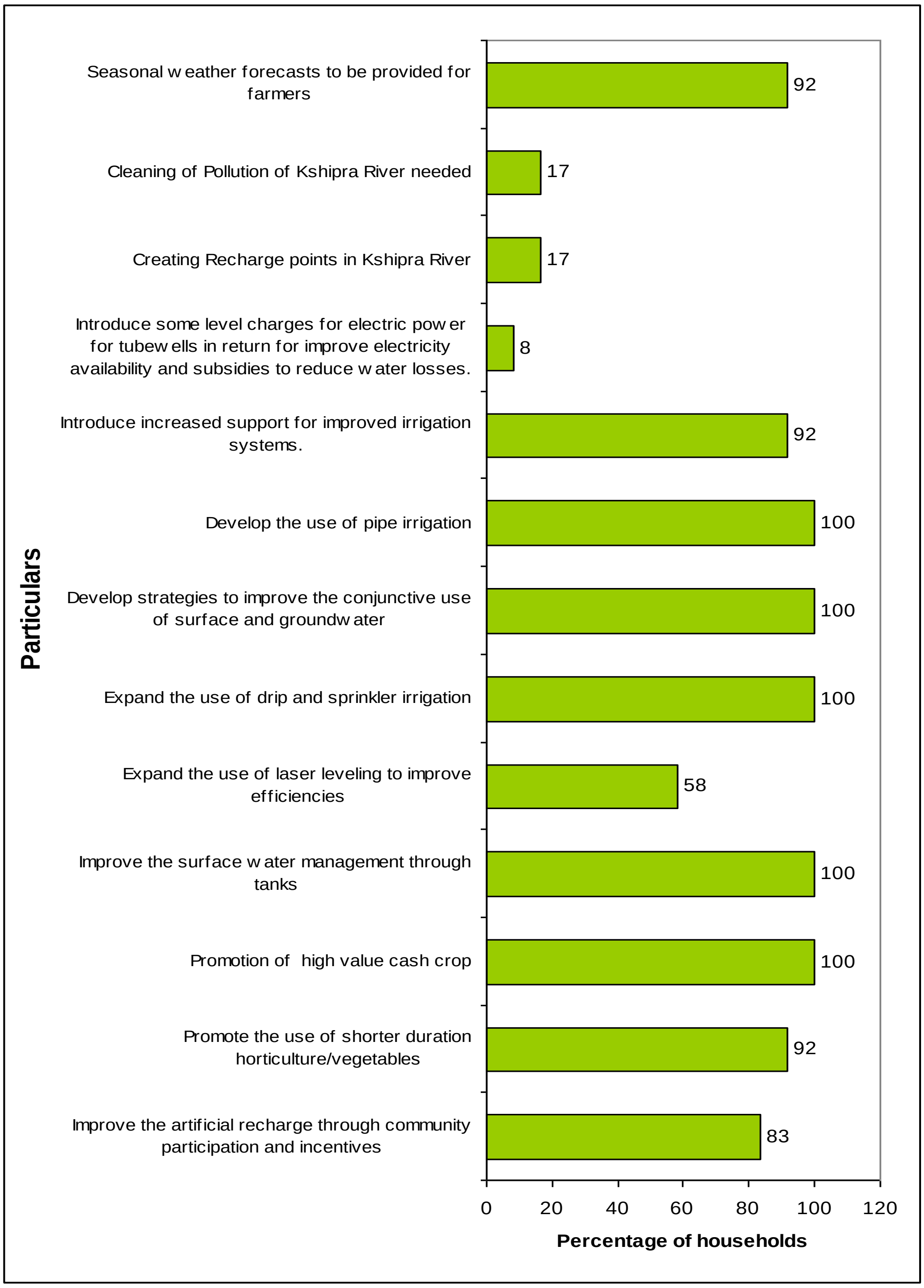

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Figure 35: Possible Methods to Improve Water Efficiency (% households) Indore

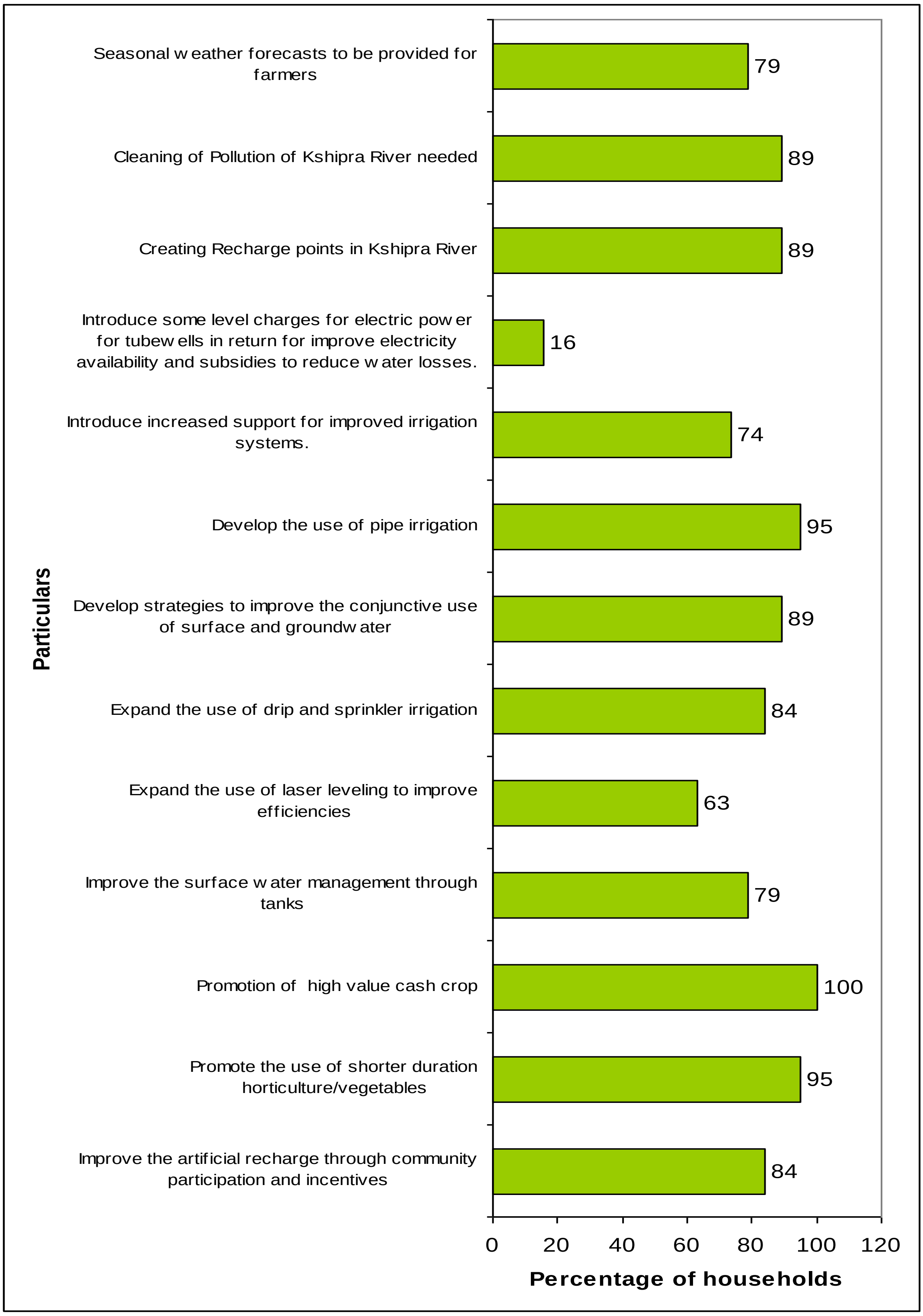
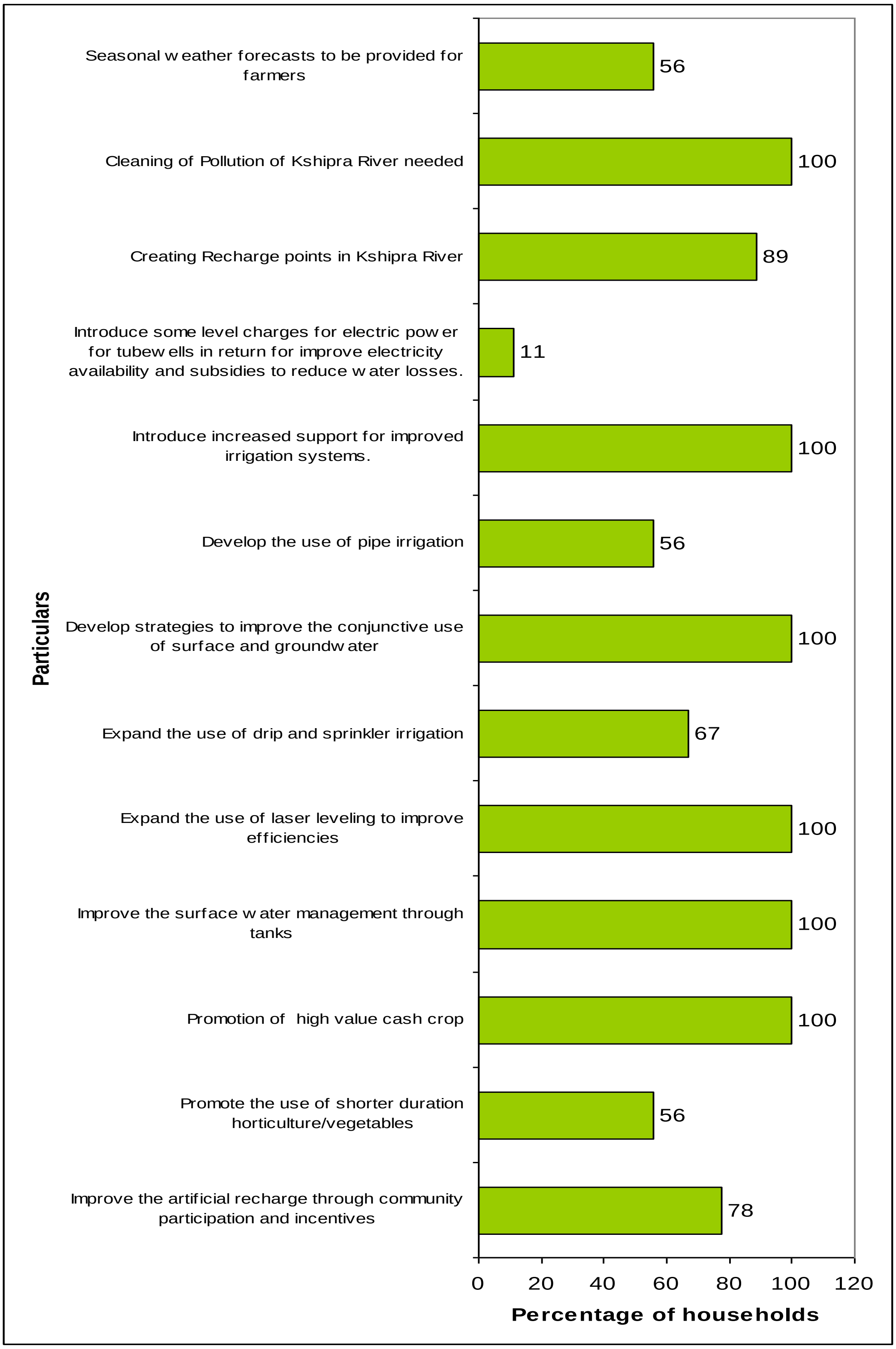


Figure 36: Possible Methods to Improve Efficiency (% households) Ujjain



6. Challenges in Drinking Water

71. Potable Use: The primary source of drinking water in all the three villages is bore well except for Dewas where piped water supply through public stand posts are primary sources. Drinking water availability is a major issue especially in Indore. A summary of the drinking water is shown in Table 25 to Table 28

Table 25: Primary drinking water in wet season (% of households from the sample)

Districts	Borehole Hand Pump	Borehole Electric Pump	Dug Well	Piped Supply-house connection	Piped Supply stand pipe
Indore	53	47	0	0	0
Ujjain	33	33	33	0	0
Dewas	17	8	8	25	42
Total	38	33	10	8	13

Table 26: Primary drinking water in dry seasons (% of households from the sample)

Districts	Borehole Hand Pump	Borehole Electric Pump	Dug Well	Piped Supply-house connection	Piped Supply stand pipe	Not Available
Indore	42	53	5	0	0	0
Ujjain	22	33	33	0	0	11
Dewas	75	0	0	0	8	17
Total	48	33	10	0	3	8

Table 27: Drinking Water Availability (% of Households from the sample)

Districts	Major issue	Some issue	Not an issue
Indore	53	0	47
Ujjain	22	22	56
Dewas	33	25	42
Total	40	13	48

Table 28: Drinking Water Quality (% of Households from the sample)

Districts	Major issue	Some issue	Not an issue
Indore	0	0	100
Ujjain	0	0	100
Dewas	0	0	100
Total	0	0	100

72. Ground water availability; even though ground water table is falling year after year, the groundwater is still used for irrigation. The government tube wells for drinking purposes are broadly at the same depth as the irrigation boreholes, as a result the drinking water well are very vulnerable Over the last 20 years, farmers have shifted from tanks/ dug well to bore well for their source of drinking water due to declining water table. Women and children now travel a long distance and spend time for fetching good quality drinking water. This is was observed to be very acute in Khajuria rewari village.

73. Ground water quality; was not seen as a major problem in all the districts surveyed. The waste water from the city of Indore released into the river Khan was seen as a problem. in one community. The polluted water enter into the village through canal, generating a foul smell. It also leached into the ground water. Villagers have reported that 10% of the bore holes are getting affected.

7. Challenges in the Agriculture Sector: crop choice and farming practice

- Farmers mainly grow Soya in the Kharif season and wheat in the Rabi season. Soya cultivation has significantly changed farming practices, To ensure good drainage field bund types and contouring has changed. Land preparation is now designed to drain quickly excess water out of the fields during rain. this has increased runoff and downstream silt deposition and reduced infiltration.

- Horticulture is labour intensive so which is a major limitational factor for horticulture expansion.
- Policy innovation and technological innovation along with training for farmers has had major impacts on the agricultural system in Madhya Pradesh. The opportunity niches have significantly scaled up over time, and good benefits have been achieved in the short term. More recently the rising scarcity in availability of agricultural labour has affected the production models. Food security has dominated the goal from public policy perspective while profitability and higher income has been the driving motivate of the farmers.
- The support price for soya has provided a major incentive towards income security and led into the major expansion in the area grown under soya.
- Organic farming practice is increasing slowly in Dewas. Farming household however do not feel there is enough scope for changing cropping pattern given their soya-wheat–vegetable cycles. Continuing research by BISA on wheat and maize, of JAICA on soybean to get short duration variety are seen as positive steps by farmers. There is a need for research/information on applicability of drip irrigation for soybean. Cotton cultivation has been identified as a potential interest by the communities.
- Ujjain and Indore felt that with changing temperature mulching is becomeing a necessity to keep soil moisture content stable.
- Only 11-42% of households think there is some possibility as they grow very little paddy anyway (0-32%). There can be substitution of wheat by zero tillage oil seed (kusum)/pisiculture etc. But shift to horticulture with irrigation infrastructure subsidy is preferred by larger number (22-53%). While farming households (83%) in Dewas think future sustainability of water supply strategy is important it is somewhat different in Indore (42%) and Ujjain (0%). But they express funding need for strategic actions towards water quality management, management of nallas, series of dams creation etc. , desiltation.
- Experts feel monocropping pattern with soyabean crop disease risk is increasing and there is need for crop diversification. Soil is becoming zinc deficient.

8. Future issues : Perception about Climate Change

74. Future issues have been very interestingly identified by the stakeholders based on their perception of changing climatic parameters and rising demand; there is less divergence among stakeholders in this regard. The objective was to ascertain the past ten year's perception of climate. Given the presence of stakeholders of varied age group historical past this is reflected in recall based statements.

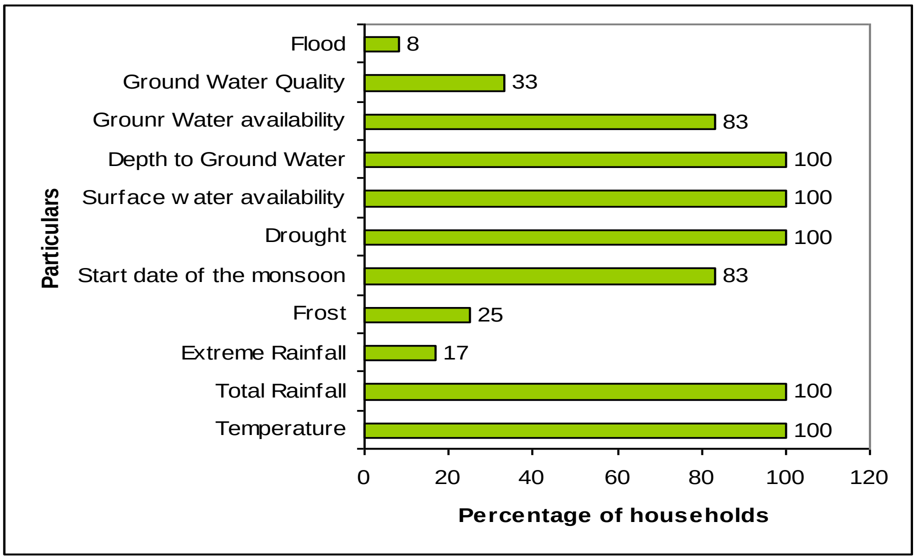
75. Perceived change in temperature and consequent rainfall is supported by all interviewed across all cross sections during PRA or household survey. While farmers in Ujjain and Dewas are more (100%) concerned about the declining surface water availability in Indore similar (100%) concern is for declining ground water table. Increased urbanization and competing demand for water is suggested as one source of concern by the community. While 100% of households in Dewas and Ujjain favour better surface water management as desirable strategy, in Indore it is for artificial ground water recharge and managing pollution in rivers are the most favoured strategies. Villagers have very strong opinion about deforestation that is causing changes in local level rainfall patterns, as described below and in Figure 37

- Changing climate is affecting high value cash crop as well: gram, potato, chilli, fruits papaya, vegetables. Untimely harvest time rain is damaging crops more than 40%.
- Household responses on perceived changes in the last 10 years on following parameters are shown in charts below.
- Most of the households are unanimous about rising temperature, declining surface water availability and ground water.

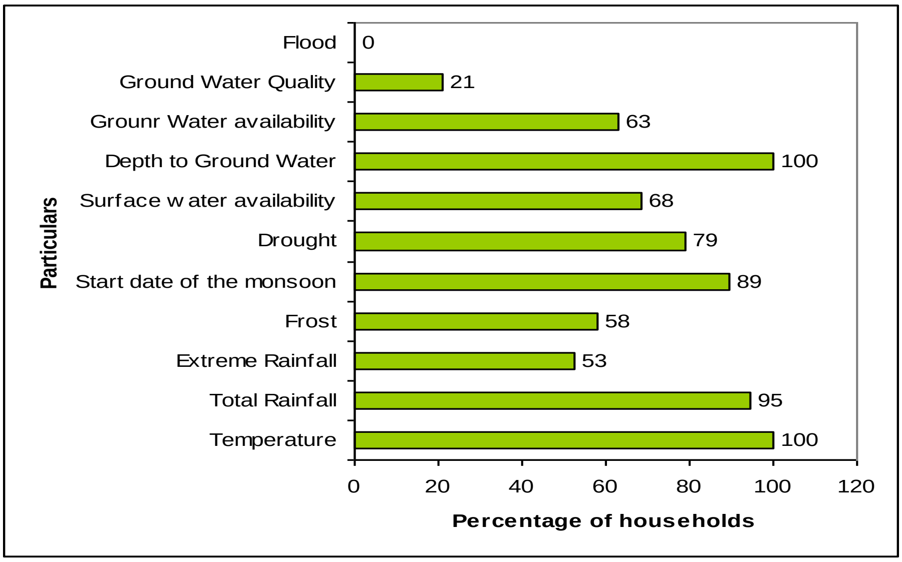
:

Figure 37: Climate Changes as Observer in the Last 10 years

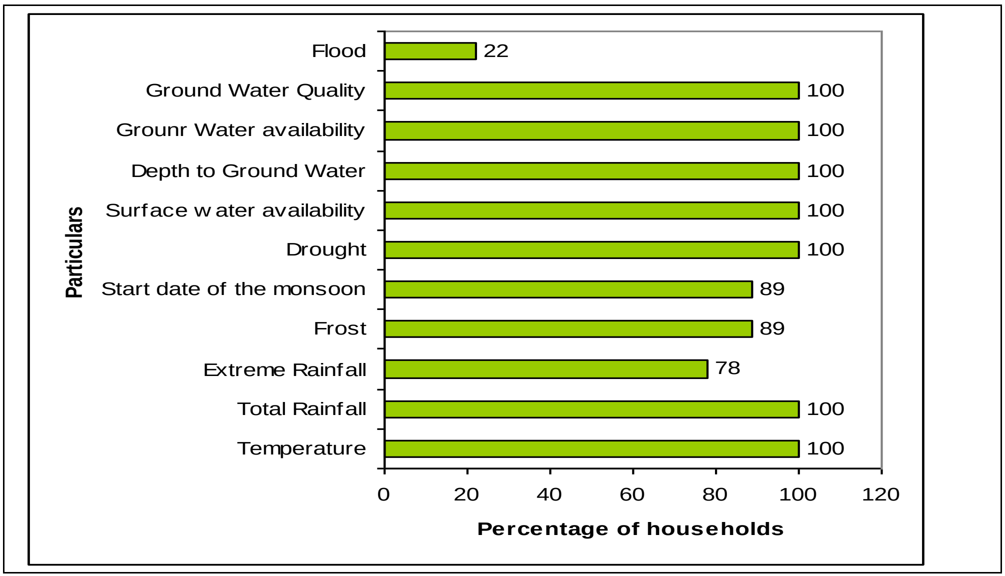
Dewas



Indore



Ujjain



9. Water Management Issues

76. Water Management issues and possible solutions received a very high support from all stakeholders as described below..

77. While check dam in Dewas were identified by most households as an issue ; in Indore and Ujjain electric supply was identified as the major issue. In Dewas second the second key issues on the list was lowering of ground water table and concern for future sustainability appears as majority issue in both Ujjain and Indore. The need for check dams was identified as second important priority. Poor maintenance of tanks is identified as next major issue if judged by household response. The responses are summarised in Figure 38.

10. Possible Mechanisms to Enhance Resilience and Reduce Vulnerability

78. Household were asked what do they consider to be the most important from list of actions. Responses favoured market support price as the highest priority, followed by ground water recharge and water access security, followed by crop insurance, revival of old tanks and reservoirs, least importance has been attached to subsidy . The household responses are described below and shown in Figure 38: Water Management Issues

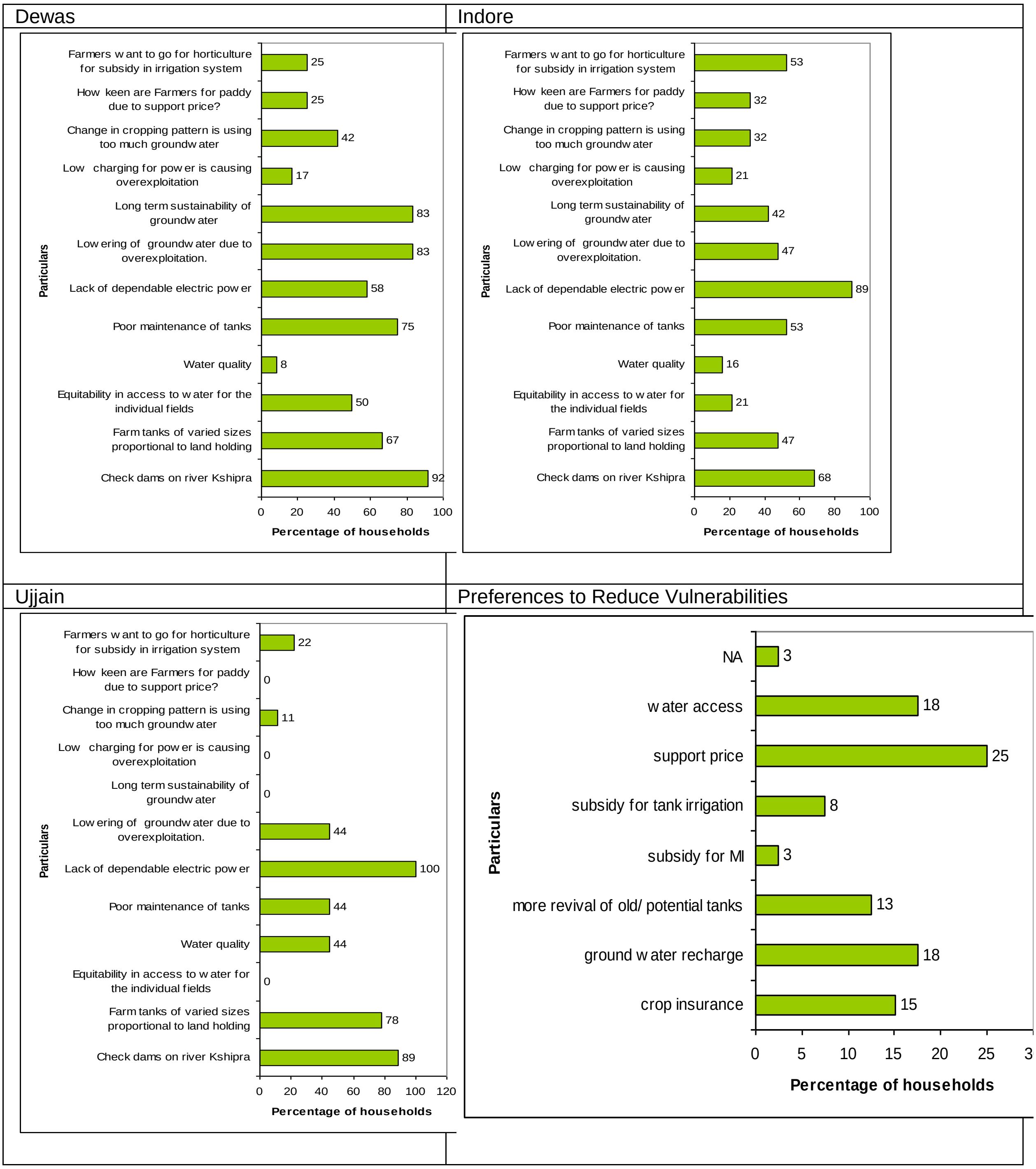
- In Madhya Pradesh the need was seen to create adaptive capacity for water resource management and to reduce future vulnerabilities. The need is also for institutional reorganization was considered important, the need to get the forest department as an active partner was seen important; which is not the case now.

- Villagers during PRA expressed that best way to deliver adaptive action to reduce vulnerability to climate change risks might be by rejuvenation through desiltation of all kinds of traditional water storage facilities within the villages: farm ponds, government ponds (shasakiya Talab), wells (kuaon), drainage channels (nallas), Kshipra river perennial flow revival, cleaning of pollution of tributaries like khan, artificial recharge of ground water through abandoned tubewells. This however they feel needs technical knowledge and equipments. Community involvement through sharing of silt, putting in labour/equipments to supplement government effort is offered by all the farmers interviewed. Local NGO s are working as a bridge to community and government for the Kshipra punarbharikarn (rejuvenation) programme.

- Securing water and sanitation systems to climate change risks are priority areas for the state.

- River linking discussion may be revived and explored more. Some people have argued that Kshipra should be linked with Narmada and Khan rivers.

Figure 38: Water Management Issues



11. Recommendations for Community Capacity Building and Training Needs

79. A summary of responses include;

- Training of farmers by farmer master trainers can enhance community cooperation and scaling up of best practices.
- Youths with better education and exposure, veteran farmers with leadership quality can be further trained to act as master trainers.
- Training for drip irrigation technique be made widespread.

- Training for non farm income generation capacity. Farmers feel their eco-service generation through ponds and cascade of those can become a point of attraction. They need more training for making use of idle months which is sometimes as high as four months.

80. Based on assessment of community response it is clear that a strategic plan aimed at providing micro level livelihood/income and macro level productivity security/risk minimization through a portfolio of measures is required.. No single action can ensure adequate adaptive capacity. Simultaneous implementation of portfolio of actions might bring in desired radical change. The portfolio of actions can range over a number of interventions, including;

- Water security at farm level
- Community empowerment through knowledge dissemination
- Provision of desiltation mechanism and funding.
- Afforestation programmes.
- Crop diversification from soya to move away with adverse impacts of monocropping practice. Marketing facility, storage facility and market support price for crops other than soya and wheat, promotion of horticulture practice, oil seed like kusum.
- Alternative irrigation techniques: drip , piped, mulching
- Ground water recharge
- Water quality management
- Water course lining vs. farm ponds need further assessment
- Managed conjunctive water use
- Water use monitoring by ground water permit system /bore hole restrictions/ground water use regulation/reliable electric supply/rationalization of surface water supply/payment for eco service
- Improved Weather forecast
- Enhancement of non farm income sources such as milk or pisiculture
- Farmers training regarding the optimum use of water for improving overall water situation

12. Road Map for Community Actions

81. The implementation of strategic plan need an Integrated approach, including:

- How information systems on water use and supply can be developed. Such a system can bring the roles of the stakeholders together observationally. Current level of information is scattered across different departments and does not lead to integrated approach in strategic action plan on a cross cutting issue like water.
- How informal ground water market can be transformed into formal participatory water management system needs to be explored further through research and subsequent consultation with the stakeholders.
- What combination of actions in strategic risk minimizing policy portfolio be included for various districts need to be checked through simple cost benefit analysis and further stakeholder consultation.
- Subsidy versus PES (payment for environmental services) as strategic policy instrument needs further community consultation.
- How IWRM institution can work towards formalizing informal ground market needs further check.
- What can be the contribution of changes in technology, policy and behavior of farmers needs an assessment.

V. INSTITUTIONS

A. Summary of Policy Acts and Institutions

82. State Water Policy of MP is in accordance with the guidelines and general directions in the National Water Policy. The State water policy makes specific reference among others to: (i) Information system development as principal necessity in the planning of water resources; (ii) Water resource planning to be multipurpose and accord priority for drinking water and development of hydroelectricity; (iii) development and conjunctive use of surface and groundwater; (iv) The quality of the surface water and groundwater shall be tested on regular basis by concerned departments; (v) water rates should be such which conveys the beneficiary the scares value of water; (v) The water resources planning structure to be correlated with demand base of water distribution and necessary institutional reforms are taken; (vi) establishment of Water Zones and Water Shed Management; (vii safety of water conservation structures, Research on river formation works and construction material and (viiii) water distribution system and Remote sensing techniques.

Acts: Good water governance includes regulatory measures. Regulations are necessary to maximize the economic and social benefits, resulting from water use in an equitable manner. Good water resource regulation requires an enabling environment, which ensures the rights and assets of all stakeholders and protects public assets such as intrinsic environmental values. Madhya Pradesh Irrigation Act, 1931 is progressive in terms of asserting direct state control over water. Further, the Regulation of Waters Act, 1949 of MP reasserted that ‘all rights in the water of any natural source of supply shall vest in the Government.

83. With regard to surface water, existing rules still derive from the early common rule of riparian rights. Thus, the basic rule was that riparian owners had a right to use the water of a stream flowing past their land equally with other riparian owners to have the water come to them undiminished in flow, quantity or quality. In recent times, the riparian right theory has increasingly been rejected as the appropriate basis for adjudicating water claims. In respect of groundwater, the basic principle governing the groundwater use is that access to and use of groundwater is a right of the landowner, in other words, it is one of the rights that landowners enjoy over their possessions. The state WRD prepared the *Madhya Pradesh Boojal Vidheyak 1999* (draft) in line with the Model bill circulated by the Ministry of Water Resources (MOWR) Government of India (GOI) and the draft bill got approved by the department of law in 1999. However, model bill 2005 received from MOWR, GOI prompted the state to revise their earlier bill of 1999 and the new Madhya Pradesh (Regulation and control of Development and Management) Act 2007 has been prepared and awaiting approval by the government of MP. The key features of groundwater bill are: (i) notification of areas, (ii) grant of permit to extract and use groundwater in the notified area; (iii) registration of existing users in the notified area; (iv) registration of users of new wells in non-notified areas; (v) registration of drilling agencies; (vi) rain water harvesting for groundwater recharge in over exploited areas (vii) protection of public drinking water sources and (viii) two tier of authority i.e. State level Groundwater Authority and District level groundwater authority as an implementation mechanism.

84. **PIM Act[11]:** The basic idea behind Farmers’ Managed Irrigation Systems (FAMIS) was to improve the overall efficiency of irrigation system, generate sense of ownership among farmers and to improve the irrigation revenue recovery rate. This laid the seeds for Participatory Irrigation Management (PIM) in India. The first Farmers’ Management of Irrigation System Act was enacted by Andhra Pradesh in 1997. Subsequently many other states i.e. Chattishgarh, Gujarat, Madhya Pradesh, Maharashtra, Orissa, and Tamil Nadu came up with act or legislation governing farmers’ involvement in irrigation management. Before formulation of PIM act, GOMP took several other initiatives to have farmers’ involvement in irrigation management. They established the Irrigation *Panchayats* (IPs) in early 1984-85 under MP Irrigation Act, 1931. The functions of these IPs, their rights and duties were not clearly defined under the then existing MP Irrigation Rules, 1974. Consequently these IPs became defunct. In 1994-95, Farmers Management Committees (FMCs) were formed on pilot basis. Their design principles were very much similar to the farmers’ cooperatives in the state of Gujarat and Maharashtra. These FMCs were registered under the

[11] Source: Irrigation Management Transfer In India: The Processes and Constraints by Nitin Bassi, Research Consultant, Institute for Resource Analysis and Policy (IRAP)

Cooperative Society Act of the State, but these FMCs were not able to deliver goods as desired of them and did little to involve farmers in irrigation management. in 1999 MP PIM act called as “Madhya Pradesh *Sinchai Prabandhan Mein Krishkonka Bhagidhari Adhiniyam* 1999” was brought into force for the entire state. The rules for act implementation were passed in the same year (Madhya Pradesh Farmers Organization Rules, 1999) by the state government. The Act provides for a three-tier farmer’s organizations (FOs) for irrigation management. The lowest tier in the institutional hierarchy is Water Users’ Association (WUA) at minor canal level of the irrigation system, secondary unit is Distributory Committee (DC) at distributory canal of the irrigation system and tertiary unit is Project Committee (PC) at the whole irrigation project level.

85. The apex institution in Madhya Pradesh for development and management of water resources is the Water Resources Department (WRD). The department has extensive expertise in design, construction, operation & maintenance of water resources projects and has offices in all parts of the state. Other water sector line agencies include the Public health engineering Department, Panchayat and Rural Development Department, Agricultural Department, Energy Department, Tourism department, Forest Department, Fisheries department, Urban Development Department, Industries Department, etc., which have vital stakes in the management of water resources. However, various institutions are operating within the state having functions related to water sector. Specific functions of WRD in the state of MP could be broadly classified as: (i) planning and development functions to cover preliminary and detailed project planning and project preparation including Investigation and project design; (ii) field Functions relating to operations, maintenance and construction. The operational functions include: (i) operating the irrigation systems, including dams, canals, distributaries, minors, outlets; (iii) scheduling water distribution along with WUAs and the instructions of the water (c) determining water services provided and computing cost of water delivery (iv) interfacing with WUA, NGO/CBO, and private parties to manage and maintain distribution system at designated levels, and in the case of WUAs to assist in providing engineering support in activities like land levelling, alignment of watercourses, construction of small structures, use of simple water measuring devices, and drainage channels etc. (v) of new technologies like underground water distribution system, sprinkler irrigation, drip (vi) irrigation etc. for effective utilization and conservation of water and (vii) public grievance handling while maintenance functions cover: and (viii) drawing up planned preventive maintenance schedules and scheduling requirements including repairs and maintenance and estimating funds for maintenance.

86. IWRM principles and practices necessitate the need for role transformation within the existing departments. It is clear from an institutional mapping exercise in the three states is the sectoral approach to water resource development has little or no emphasis on integrated approach to water management. The functions carried out by various departments do not necessarily indicate institutional readiness to plan and manage the adaptation response to climate change impacts requiring strong and well coordinated planning and management.

87. An overview of the main institutional mechanism for state-level planning and management of water resources indicates that: there is a lack of conjunctive planning and regulation of surface and groundwater, poor understanding of the conjunctive water balance systems. Water quality data is monitored but not linked planning and management and artificial recharge is important but not incorporated into the overall water resource planning. Further, all the agencies see their responsibility as developing water resources for the public good.

88. In conclusion, one could say that any sound policy, acts and mandates of water centric institutions aiming at water resource development and management should recognize in its totality: (i) *Information Systems and Resource Planning* to provide much needed information about groundwater availability, quality and withdrawal, etc., for use by planners and for the purposes of monitoring and further research; (ii) *Demand-Side Management* for regulating groundwater withdrawals at sustainable levels and such mechanisms to include, for example, licences, laws, pricing systems, use of complementary water sources and water-saving crop-production technologies (In conformity with IWRM principles) (iii) Supply-Side Management to augment Groundwater recharge by means of mass rainwater harvesting and recharge activities and to maximize surface water use for recharge and the introduction of incentives for water conservation and artificial recharge and (iv) Groundwater Management in a River Basin Context to maximize efficiency and the focus of interventions could be expanded (from a very ‘local’ level to the level of entire river basins).

Appendix 3B Kshipra Sub Basin,Madhya Pradesh

Strategic Framework Plan

APPENDIX 3B STRATEGIC FRAMEWORK PLAN

VI. INTRODUCTION

A. Approach

89. The issues of water resources in Kshipra sub-basin are complex; with very limited surface water there is a very high reliance on groundwater and with evidence that current use of groundwater is unsustainable. There are reports that climate change effects are already occurring and projections of the likely climate changes are presented.

90. The approach taken for this study is to: (i) assess and prepare a strategic framework to meet current issues; (ii) review and assess these proposals against projected climate change impacts and (iii) revise and adjust the strategic framework to incorporate the projected changes into a climate resilient adaptation framework plan

B. Summary of Key Issues

91. Water is an very major issue in the Kshipra sub-basin, with very limited surface water, groundwater is a critical resource and groundwater overexploitation in some parts presents a key challenge.

92. Water supplies and sanitation are major issues especially during the dry season when many wells run dry and water has to be brought in by tanker; gradually declining groundwater is increasing the problem. Data on rural water supplies show that only about 45%-50% of rural households are fully covered with access to safe water[12.] Rural sanitation is poor with 91% of rural households do not have access to any form of toilets. Among those who had toilets, 43% had pit latrines and only 29% had water closet latrines[13]. The urban centres also suffer similar problems; in Indore, water from the town supply is severely rationed.

93. The major expansion of groundwater irrigation has provided significant benefit to the communities and there is now a large dependency on groundwater to meet household income requirements. Groundwater depths now require the use of submersible pumps and increased pumping depth. Groundwater resources are depleting, the depletion is not uniform; with eight of sixteen blocks as critical (>90% stage of groundwater GW) and the rest probably in a semi critical/marginal category. The stage of development is shown in Table 29.

Table 29: Number of Blocks and Stage of GW Development

District	Nr of Blocks	Stage of GW Development (%)			
		>100%	90-100%	70-90%	<70%
Dewas	6	0	2	0	4
Indore	4	2	1	1	0
Ujjain	6	3	0	3	0

94. **Surface water** contributes to about 5% of the irrigated area, largely as supplementary water during the kharif season; a number of surface schemes are under consideration. Development of surface water schemes is complicated by the interstate agreements. The potential areas are quite limited due to the limited runoff. The Narmada river offers some access to perennial water, however, the very high pumping head precludes this option for irrigation and remains an option albeit at very high cost for potable and industrial use. Indore and Dewas and are presently supplied water from the Narmada river.

95. **Water Quality**:The tributary streams of Kshipra are heavily polluted with untreated urban and industrial wastewaters. Nitrate and fluoride was elevated in some groundwater areas. The Kshipra River has become ephemeral (running dry) for periods of the year. This paucity of water limits other beneficial uses including dilution of wastewater discharges, environmental flows and surface water abstractions. The decline of river base flows is attributable to lowering of the groundwater levels.

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[12] BHEP Bhopal 2005
[13] 2001 census

VII. STRATEGIES TO ADDRESS CURRENT ISSUES

A. Strategy for Adaptation Planning

96. The application of climate projections into the development of adaptation planning requires to be cautious and pragmatic. Framework planning for the sub-basins has been based on three stages as described below;

Stage 1: Adaptation Strategies for Current Issues: The Kshipra sub-basin has very significant levels of issues that are already affecting long term sustainablity. The approach will be to develop an initial adaptation plan for current issues based on present climate variabilities. Current issues include meeting the development needs of increasing population and intensifying agricultural production systems.

Stage 2: Viabilities of Adaptation Strategies Against Climate Change Impacts: The resilience of the 'Adaptation Plans for Current Issues' will be tested against projected climate change impacts. The incorporation of the projected climate changes into the planning will depend on:

(i) **The level of confidence** of the projections; some projections are more robust than others; for example projections for temperature are more robust than rainfall patterns.

(ii) **The type and estimated design life of any investment:** Major investments/programmes with long design life require to incorporate climate projections beyond 30 years whereas shorter simpler initiatives can be designed to meet present climate variations. Major long term investments based on low levels of projection confidence would be avoided.

(iii) **Scope for flexibility of the adaptation design:** Incorporating facilities wherever possible to upgrade adaptation design step-by-step to meet progressive climate changes.

(iv) **An assessment of the incremental costs**: To meet the projected impacts will be made; where incremental costs are low then it these might be factored into the adaptation design whereas major cost implication maybe left out in the interim. The aspects of safety and implications of delayed action would be assessed.

Stage 3: Preparation of a Climate Change Adaptation Framework: Adjustments will be made the present issues planning based on the outputs of the testing under stage 2.

97. This section describes the various possible strategies to address current issues

B. Farmers' Perceptions

98. To understand the issues of the communities a Participatory Rural Appraisal was carried out as described in the sub-basin profile. The farmers in the Kshipra have shown that in general they are well aware of climate change; key points include:

(i) **Temperature**: farmers observed there is significant change in the temperature in the last 10 years. The summer temperature has risen significantly and the winter temperature has fallen significantly in all the districts.
(ii) **Total Rainfall**: there is variation in the change in the total rainfall pattern in the last 10 years across the regions. Respondents from Indore told that rainfall has not changed significantly in the last few years, though people in the other districts said that there is significantly less rainfall.
(iii) **Frost:** in Indore, frost has caused huge damage on agricultural production in all the districts, though the damage is seen to be less in Indore.
(iv) **Start day of the Monsoon**: farmers assess that on average starting day of the monsoon has been delayed by 10-15 days.
(v) **Water Table**: farmers report that the average water table has gone down from an average level of 200-250 ft to 400 ft in Dewas.

99. It is felt that high temperature and erratic rainfalls are causing part of the problem; the water table is declining in all the districts surveyed. Farmers are of the view that this was due to the

increased temperature causing more evaporation. It is reported that there is less rainfall in the recent years except for some villages in Indore. Stakeholders mostly believe that climate change will have perceptible impact on their livelihood through its effect on agricultural production, human health and livestock population. The main areas of vulnerability of climate change is seen to be the agricultural sector and drinking water.

1. Perceived Water Management Issues and Possible Solutions

100. Communities identified a wide number of possible mechanisms to enhance future resilience and reduce future vulnerabilities, these include:

- Enhanced access to drinking and irrigation water was considered of the highest priority; drinking water access was first priority by women groups.
- Tank irrigation was seen to be very important. There is widespread support for the enhancement of the depth of the irrigation tanks (talav) and construction of new tanks. Poor maintenance of tanks is an issue, tanks are supposed to be taken care of by the government. There is no water users' association (WUA) for the tank command area in surveyed villages. Subsidies for micro tank irrigation are already exist. Desilting of rivers and tanks is considered important; silt material can be used for road construction.
- The river linking process may be explored more. Some people have argued that Kshipra should be linked with Narmada and Khan rivers.
- Drip irrigation should be supported by creating more awareness amongst cultivators; the subsidy for micro irrigation is important; the present subsidy mechanisms limit this to some farmers only. The level of awareness of the farmers is very low about the new technologies, and the slow take up is reported to be due to the lack of awareness. In Dewas, some farmers have expressed doubt about the use of sprinkler for agriculture. In general most of the farmers have supported the use of new technologies. Some big farmers have adopted sprinkler irrigation in their own initiative, but the technology needs to be improved for greater use in the agricultural fields. There is a need for improved training and subsidy on sprinkler an drip irrigation. Farmers showed some support for pipe irrigation for surface water, two problems are: (i) the cost of irrigation pipe is very high and (ii) the river dries up in the rabi season.
- It was considered that recharging of groundwater for each farmer should be made compulsory for the farmers, roof top rain water harvesting should be made compulsory. Farmers are very supportive of artificial recharge, if the subsidy is provided,
- More plantation of trees which will not only improve the soil conservation, but also increase recharge potential. There is huge scope of improving water position through National Rural Employment Guarantee Act (NREGA). It is not working at all in the village because of some lapses in the policy. There is much delay in the payment. The NREGA policy of not using of machineery is causing strain to the labourers for digging because of the hard rock of the region. In Dewas, villagers have supported check dams on river Kshipra and Tillar.
- Water quality; water should be treated properly before it is being released into the river.
- Lack of dependable electric power is seen as a major issue in all the districts. People get generally get 5-6 hours of intermittent electricity in a day. Farmers are of the view that charges for electricity are already very high. Subsidy on electricity is not an issue rather farmers are interested in subsidy on other inputs which is leading to cost escalation and interested in direct subsidy coming to farmers.
- Support Price: there is a confusion among farmers that there is no support price for soyabean, which is the major Kharif crop in all the districts. Even though there is support price for wheat, farmers are compelled to sell it to the private traders in the market because of the delayed payments from Government. The farmers want support price for vegetables.
- Regulations on groundwater: there is still no regulation for groundwater use. Farmers have a mixed feeling in this issue. Some farmers feel that even without regulation they will use that much of water, which is needed. Others feel that regulation is needed to restrict overexploitation.
- Agriculture: Farmers are supportive of short duration crops if the yield is some, not all farmers are using short duration crops because of the non accessibility. Farmers have a mixed feeling of these short duration and high yield crops because high value cash crops with requirement of more water, which is not feasible in the region. Farmers, in fact have abandoned the sugarcane cultivation and cotton cultivation for this reason. Because of the topography of the regions, farmers argue that there is no necessity of laser levelling.

- Artificial recharge points in river: The farmers nearer the river are very supportive of this. Any enhancement of water efficiency will be taken back by activity rise. If more water becomes available 25% of the non cultivable months will become come under cultivation. Government regulation on bore holes number/water withdrawal pattern.
- Equitability in access to water; equitability in the distribution of water is not regarded as a major issue.
- Water associations are almost non existent.
- Rapid land use change is changing the groundwater hydrology.
- Conjunctive management of surface and groundwater is seen as important.
- It was considered that there is no single solution but portfolio of solutions needed; conjunctive use with more groundwater recharge farm ponds, re-excavation of govt ponds to enhance water flow, dams on nallas are all seen as important.
- More technical assessment needed to understand feasibility of various options including the use of tanks for irrigation and groundwater recharge. Feasibility study for recharge technique scientific means should be used to better understand the groundwater potential is considered important.
- Enhance non farm income sources was seen as an important need.

C. Surface Water Resources

101. In the Kshipra sub-basin main source of irrigation and drinking water in through groundwater resources; surface water from canals and tanks is less than 3% with the exception of Indore as indicate in Table 30[14] below:

Table 30: Net Area Irrigated from Different Sources (ha)

District Name	Canals	Tank	Tube wells + other wells	Other sources	Total
Area (ha)					
Dewas	2,360	944	123,955	11,044	138,303
Indore	12,591	528	71,492	9,111	93,722
Ujjain	716	3,229	123,241	16,711	143,897
Total	15,667	4,701	318,688	36,866	375,922
Percent of Total					
Dewas	2	1	90	8	100
Indore	13	1	76	10	100
Ujjain	0	2	86	12	100
Total	4	1	85	10	100

102. Farmers are growing two crops. The main crops are wheat, soybean, sugar cane, vegetables, gram and groundnuts, mostly irrigating from tube wells and other wells..

103. There is no major surface water resources project in the Kshipra basin. The river Kshipra flows in the monsoon season only, with no post monsoon flow in the river. Madhya Pradesh has constructed some check dam in Chambal river for water conservation but the same is objected by Government of Rajasthan as the inflow into Gandhi-Sager dam are likely to reduce due to upstream utilization through check dams.

1. Proposed Surface Water Schemes

104. A number of surface water schemes are presently under consideration and are relevant to the current study. Surface water development must be referred to the interstate board. The inter-state Board-"Chambal Board is functioning for inter-state co-operation for Chambal water between Rajasthan and Madhya Pradesh. There is also a Chambal agreement between the two states for sharing of Chambal waters. Three dams and a barrage have been constructed on the main Chambal River downstream of the confluence of Kshipra with Chambal. The agreement provides for equal

[14] Ministry of Agriculture GOI

division of irrigation and power benefits. Due to downstream water utilization any water resources project in the tributaries in Malwa region needs agreement between the two states through the Chambal Board

105. **Kalisindh Chambal Link Project;** this project is a river interlinking project namely- 'Kalisindh Chambal link project' is under study by NWDA (The National Water Development Agency) for which a feasibility report was also prepared in 1991 by NWDA. The project envisages diversion of 820MCM of water from Kalisindh to river Chambal at Rana Pratap Sager dam or at Gandhi Sager dam. The water was proposed to be utilized at Kota Barrage and water of Chambal thus saved was proposed to be utilized for the irrigation in the Malwa region in Chambal in Ujjain district in Kshipra basin. However, this project is not in progress due to failure to reach any agreement between Rajasthan and Madhya Pradesh on sharing of water and other issues. Location of seven dams identified by NWDA in the Kshipra and adjoining basin are shown in Table 31.

Table 31: Proposed Dams in Kshipra

Name Of Project	District	Tehsil
Sonechiri	Ujjain	Khachrod
Ramwasa	Ujjain	Ujjaina
Bachora	Indore	Depalpur
Padunia	Dhar	Badnawar
Sewarbheri	Ujjain	Ujjain
Sebri Sultanpura	Ujjain	Barnaga
Chitabal	Ujjain	Mahidpur

106. **Narmada Irrigation Transfer Project**: There is also a proposed transfer of Narmada water to Kshipra basin through river linking project, but no proposal for the same has formally been developed. With about 300metre of lift head it is not generally considered a viable option.

107. **Narmada Water Supply Transfer Project**: There is also another project under survey and investigation for transfer of Narmada water for drinking water supply to Indore, Ujjain, and Dewas to Malwa plateau namely *'Integrated Water Supply Project for Villages and Towns of Dewas, Ujjain and Shajapur District of Madhya Pradesh'* at an estimated cost of Rs.2988 crore ($664 million). The project report is likely to be completed in about one year's time. This project would be complementary to the completed water supply systems[15] supplying Indore and Dewas, which are presently sourcing and lifting Narmada water.

108. **Sewarkhedi Project**: Located on the Kshipra 22km south of Ujjain this project involves construction of a 2000m wide 17 high storage dam with estimated live storage of 157 MCM. The dam would provide supplementary water to Ujjain as well as irrigation of about 25000ha. Only very preliminary studies completed by the Ujjain water resources division.

109. **Khan Reservoir Project**: Located on the river Khan with estimated live storage of 85 MCM would provide water for irrigation, industrial and support flushing flow of pollutants in the heavily polluted and non perennial river Khan. The identified irrigation area is 18000ha, the command area is largely the same as the Sewarkhedi project.

110. **Chambal-Gambhir Link**: A link canal from the Chambal river to be provided by a new diversion barrage on the Chambil at Kapileshwa that would provide supplementary water for water supplies at Ujjain. The diversion would support the filling of the existing Gambhir Dam, which is yielding insufficient runoff as well as some loss of yield due to the upstream Yashwant Sagar Dam in Indore district.

111. The gestation time of surface water projects tends to be long. It is considered important to directly address the issues of groundwater especially in the immediate term. The average annual

[15] The second stage supply for Indore being funded through ADB is presently being commissioned.

rainfall is 939mm in Indore, 1083mm in Dewas and 916mm in Ujjain (CGWB 2009), 91% of this rainfall occurs during the four monsoon month from June to September only. The water requirement for most of the Rabi and Kharif crops in the region is 300mm to 500mm. From this, it would appear that conjunctive use of rainfall and recharge to groundwater would be able to sustain two crops from the average annual rainfall. Average water requirement for the major crop grown in Chambal basin is shown in Table 32.

Table 32: Crop Water Needs

Crop	Crop Water Requirement (mm)	Watering regime
Kharif		
Ground nut	400 to 450	(Paleo watering required)
Urd, Moong, Arher	300	(One or Two watering)
Mustard	400 to 450	
Oil seeds	150 to 200	
Rabi		
Wheat	380 to 400	(3 irrigation watering)
Gram	300	(One or Two watering)
Potato	500 to 600	(frequent watering)

D. Agriculture Options to Reduce Water Demand

112. Major constrains for agriculture activities include: hot summer months, low humidity, high evapotranspiration and meagre rainfall during winters and summer months. Irrigation watering is provided mostly through tubewells. Stage of groundwater development is 104% in Indore, 64% in Dewas and 109% in Ujjain. Decline of groundwater table is becoming a problem in the area. Shortage of drinking water is reported in many areas in the basin. The key requirements for water management in the sub- basin to meet these needs includes: (i) conservation of water; (ii) recharge of groundwater and (iii) efficient use of irrigation water. Discussion with farmers[16] revealed that they are partially aware of water conservation techniques and the linkages sustainability but less aware of the details and the opportunities of new ideas.

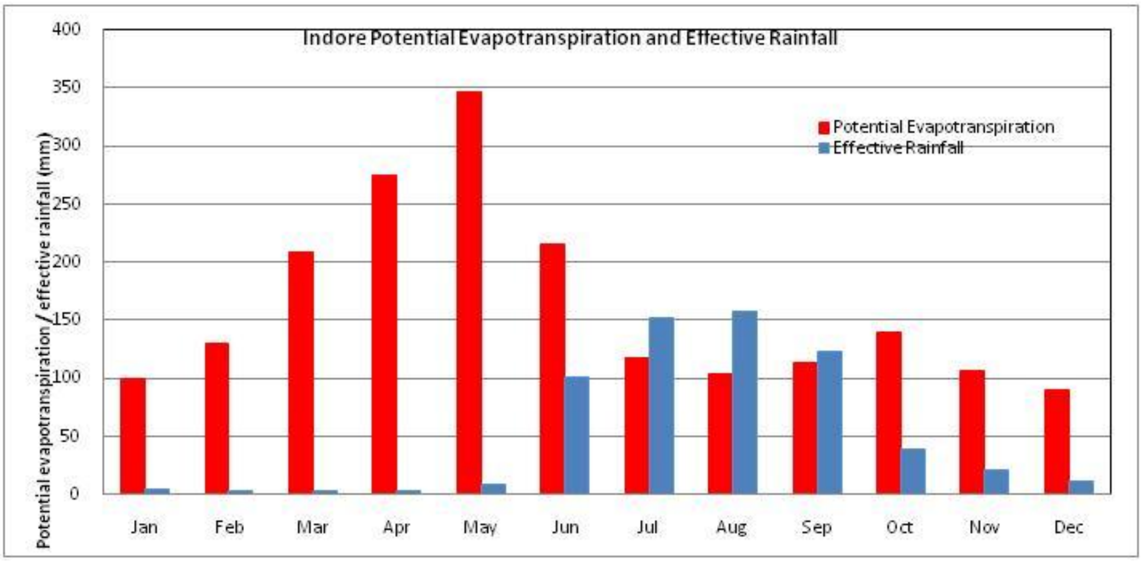
1. Crops

113. There are various cropping options to reduce water demand; these include a move to high yield shorter duration crops as well adjustments to the planting calendar to optimise the use of the rainfall. With the present fixed electricity rates for pumping, there is no real incentive to economise on pump use. The PRA conducted for the study identified some reluctance to change to short term high yield crops due to uncertainties in the irrigation supplies-for the groundwater erratic power was quoted as an issue.

114. Delayed monsoon planting offers opportunities to better use the effective rainfall and consumptive use. From an analysis of the effective rainfall and potential evapotranspiration shown in the sub-basin profile shows the very large additional water consumption if farmers plant before June as shown in Figure 39. The net of saving in demand between planting in June as opposed to May would be about 200mm.

[16] NAPPC S-NWM Participatory Rural Appraisal 2011

Figure 39: Indore Potential Evapotranspiration and Effective Rainfall



2. Water Conservation Tank Programmes

115. There are several schemes under which subsidy are provided by the government to the farmers for construction of ponds in their fields' like *Khet Talab Yojna*, construction of small tank under Micro-Minor irrigation, *Balram Talab Yojna*. The water conserved in the ponds provides irrigation to the farm lands and effective groundwater recharge has also been observed. The objective of this scheme is to conserve rainwater in the field for irrigation. For digging ponds under Balram Tal Yojana, every beneficiary is given 25% subsidy, the upper limit of which is Rs 50,000. The benefit of the scheme is given to the applicants registered after May 25, 2007. The tanks are becoming more popular. There is, however, some reservation from smaller farmers who have to allocate scare land for the tanks. The tanks are most effective on the areas of black cotton soils.

116. Balram Talabs are larger water tanks, which can irrigate up to 50 hectare area, the uptake has been good with a reported 7500 tanks constructed to date. Mulching of crop fields is also becoming popular, which helps in soil moisture conservation and high reduction of water demand by the crops.

3. Micro Irrigation

117. Micro- irrigation schemes are also becoming popular in the basin. A field study by India Institute of Management (IIM), Indore on 'Impact Assessment of Micro Irrigation schemes in Madhya Pradesh' reveals that financial benefits of micro irrigation scheme to the farmers outweigh the cost involved in addition to big water savings. The programme started in 2008 with a 40% subsidy from central government and initially progress was slow. The state has added a 30% subsidy for general farmers and 40% subsidy for small farmers and since then the uptake has increased. The promotion of the drip is being supported by the private sector suppliers; farmers are allowed to select from a list of fifty five suppliers. A precision farming development centre has recently been established in Bhopal. The farmers are using the drip to grow a wide range of crops including crops not normally considered so suitable with drip. It is reported that there is no real evidence that farmers are switching their cropping. The growth of sprinkler has exceeded drip but this is thought to be the cheaper cost of sprinkler over drip; however, from studies the productivity of the drip is higher than the sprinkler.

118. The major benefits include:

- Water usage improved by more than 2.5 times. Water saving of about 50% observed in many cases.
- Increase in the revenue from agriculture, about 20% reduction in labour cost.
- 30% to 50% reduction in fertilizer and pesticide usages.
- About 20% saving in power bills.
- 2-3 times increases in crop yield for many crops.

- Drastic reduction in weed problems.
- Significant improvement in quality of produce.

However, IIM Indore study also reveals that spread of micro irrigation in the Ujjain, Dewas and Indore district (Kshipra sub-basin) is quite low as compared to the adjoining districts in the state. Growth of micro irrigation is limited because of several constrains including:

- Although Government support in around 70% and farmers share about 30% general farmers and 40% small farmers but the farmers are spending more. Poor farmers are not able to adopt the scheme due to higher investment and risk involved. Limited credit support from banks and high interest rate of private loans and lack of insurance support.
- Uncertainty of power supply.
- Lack of awareness among all categories of farmers on crops selection and benefits of MIS.
- Lack of assured market for produce and no MSP for crops appropriate for MIS.
- Long processing time and delays in approval for MIS grants.

4. Water Saving Benefits of Micro Irrigation.

119. Both drip and sprinkler demonstrate water savings over flood irrigation. Indicative savings put drip as the most efficient and sprinkler slightly lower. The main loss in sprinkler is evaporation loss; when considering conjunctive efficiency of surface and groundwater evaporation is effectively a total loss; infiltration losses on the other support groundwater recharge.

120. Furrow irrigation using gated pipe is slightly less efficient than both sprinkler and drip but is significantly cheaper (about 50% of sprinkler and 20% of drip capital costs) and works at low pumping heads. Gated pipe and furrow is a potential system probably appropriate for Madhya Pradesh but not currently considered; it is less sophisticated than drip.

Figure 40 : Gated Pipe and Furrow Irrigation

The losses from furrow irrigation using gated pipe are largely infiltration losses which in terms of conjunctive efficiency of the surface and groundwater are not effectively lost to the overall system. Gated pipe and furrow irrigation are suitable for surface and groundwater; efficiencies can be improved by incorporating surge irrigation[17], the use of gated pipe to grow cotton is shown in Figure 40. The use of furrows has lower evaporative losses than basin irrigation. It is recommended that economic studies are carried out to assess the relative merits of different irrigation systems. An advantage of the gated pipe and furrow irrigation is that it could be used both for tubewells, farm ponds and canals which would not be possible for drip or sprinkler systems due to suspended solids.

121. In groundwater or combined surface and groundwater systems, it is very important to incorporate the 'conjunctive surface and groundwater' efficiency into the assessment.

[17] Surge is achieved by fully opening the small sliding gate to initially fill the furrow , the gate is partially closed when the initial furrow filling is completed. Surging can also be achieved by surge valves.

E. Groundwater

1. Issues and Assessment of Sustainability Present and Future

122. The major issue in the basin is diminishing surface and groundwater resources. The net annual groundwater draft for drinking and irrigated agriculture exceeds the annual recharging availability. The tributary streams of Kshipra are variously polluted with untreated urban and industrial wastewaters. Nitrate and fluoride was elevated in some groundwater areas. The Kshipra river has become ephemeral and runs dry for periods of the year. This paucity of water limits other beneficial uses including dilution of wastewater discharges, environmental flows and surface water abstractions.

123. The basin districts of Dewas, Indore and Ujjain are under significant stress due to expanding groundwater extractions and strong dependence on stakeholders on use of groundwater resources. In Dewas district, Dewas block, which is located in the headwaters of the Kshipra river, is reported as having a Groundwater Development Stage (GDS) of 96% (CGWB-NR, 2007)[18]. In Indore District, Indore block, Sanwer block and Depalpur, which all cover part of the Kshipra sub-basin are reported as having a GDS of 137%, 133% and 94% respectively (CGWB-NR 2009)[19]. Ujjain district has an overall GDS of 109%, with Ujjain block, through which the Kshipra river flows, having a GDS of 144% (CGWB-NR, 2008)[20]. Nitrate was reported at elevated levels (>45mg/l) in all three districts and for Dewas district, fluoride was reported at elevated levels (>1.5mg/l) in Dewas, Sonkatch and Tonk Khurd blocks.

124. Groundwater in the Kshipra basin is derived from weathered Deccan Trap basalts and while its characteristics are variable typically they have relatively low storage, which has impacts for sustainable groundwater management and artificial recharge opportunities. Figure 41 below provides cross-sections of groundwater occurrence in the Deccan trap basalt terrain indicating varying resource potential and management implications (World Bank, 2010)[21].

2. Framework Strategy for IWRM at Basin Level

125. Groundwater is a key element for the integrated water resources management (IWRM) in Madhya Pradesh and the Kshipra sub-basin. The aquifers of the Kshipra sub-basin are however in a highly stressed condition. For the continued and sustainable use of this precious resource a combination of supply and demand measures will be required within an overall context of better conjunctive use of surface and groundwater.

126. IWRM is an approach that promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. This includes more coordinated development and management of: land and water; surface water and groundwater; the river basin and its adjacent coastal and marine environment; upstream and downstream interests as well as managing physical resources. IWRM is also about reforming human systems to enable people, both men and women to benefit from those resources.

3. The Enabling Environment

127. Efforts have been made by GoMP to effect change on the demand and supply side concerning groundwater. For example, on the demand side efforts have been made to promote Micro Irrigation Systems (MIS), with associated water savings of over 50% per unit area; a recent study indicated that the districts of Dewas, Indore and Ujjain had 172, 1904 and 462 hectares respectively under MIS by 2009-10. Similarly on the supply side the districts of Dewas and Indore have completed a number of projects on artificial recharge and rain water harvesting.

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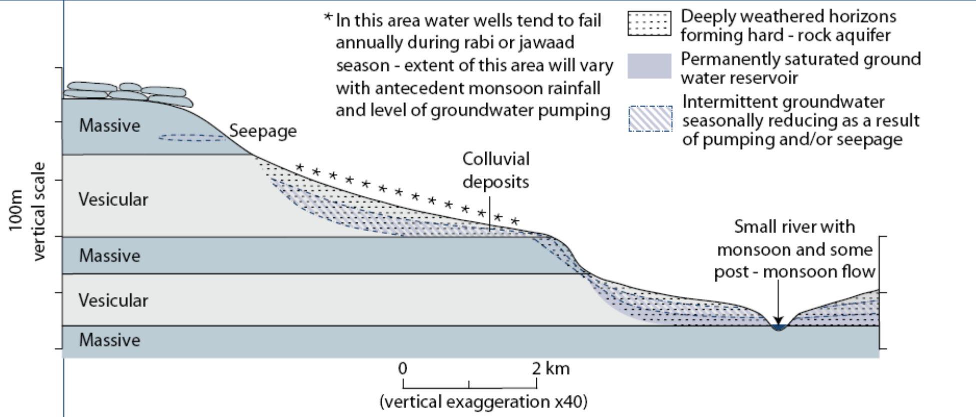
[18] CGWB Northern Central Region (2007) Dewas District groundwater information booklet, Bhopal.
[19] CGWB Northern Central Region (2009) Indore District groundwater information booklet, Bhopal.
[20] CGWB Northern Central Region (2008) Ujjain District groundwater information booklet, Bhopal.
[21] World Bank (2010) Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India. World Bank, Washington.

Figure 41: Cross Section of the Aquifer



Groundwater body	Runoff zone	Seasonal (recharge zone)	Perennial (storge zone)
Groundwater resource potential	Extremely limited – associated with localized weathered pockets and occasional thin flows of more fractured or porous basalt.	Patchy limited storage and yield, draining repidly after monsoon recharge–used for village water supply and sometimes for rabi irrigation but suffers severe yield reductions during Feb-May.	"Groundwater body" of limited extension and modest storage but capable of useful well yields for both kharif and rabi irrigation (or perennial crop production) on significant land area.
Village water supply improvement options	Scope for augmenting existing water wells should be evaluated and groundwater pockets associated with structural features may be worth pursuing - but may be insufficient and need supplementing periodically by tanker.	Establish performance of existing water wells and potential for recharge enhancement. Village-level water committee must protect improved sources from irrigation well construction.	Groundwater available but good sources required for larger villages– sometimes necessary for village-level water committee to requisition irrigation wells for village supply or to reduce interference on village wells.
Approach to groundwater resource management	Not needed but village-level water committee involvement for improved sanitary and pollution protection of any existing water wells and small springs.	No systematic approach necessary or feasible but village-level water committee could participate in aquifer-level organization because of recharge significance of zone.	Form aquifer-level organization for "groundwater body" by village–level water committee and other stakeholders to regulate dry season irrigation use, facilitate water savings and resolve conflicts.
Socioeconomic development level	Only very small villages that have difficulty in finding sufficient water for domestic needs and livestock watering, and struggle for subsistence given only dryland farming (insufficient water availability for irrigation).	Occasional larger village–kharif irrgation but little rabi cropping, thus population has to migrate seasonally to work in irrigated agriculture or urban industrial areas.	More densely populated–irrigation of rabi and/or perennial crops practiced on significant proportion of land area (15-25%) but competition for available storage can lead to conflicts between irrigators and drinking water supply.

128. In Indore District, the CGWA has notified Sanwer block and Indore Municipal Corporation due to overexploitation of groundwater. In Ujjain district the CGWA has notified Ujjain, Ghatia and Badnagar blocks due to over-exploitation of groundwater. A lot more is however, needed to arrest the over-exploitation of groundwater and to facilitate a move away from groundwater mining to a more sustainable use of this resource within a wider integrated water resources management approach. Areas that need further policy approaches include:

(i) Establishment of a clear logical framework for the management of water resources, such as catchments and aquifers. Whilst the current practice of using administrative units (e.g. districts and blocks) is practical, it ignores flows between these units either through natural topographic gradients in the case of surface water or regional aquifer flows in the case of groundwater.

(ii) The subsidized nature of electricity provision to farmers, thereby facilitating lifting groundwater at ever increasing depths. This is a sensitive topic, however until the true cost of groundwater abstraction (energy costs, equipment and externalities such as impacts on downstream users) is factored into an overall resource management equation this element of supply will continue in an uncontrolled manner. Farmers report problems of erratic power which causes difficulties in irrigation at the correct times to meet crop needs. Farmers tend to irrigate when power is available rather than according to proper scheduling. There would appear to be scope to link improved power supplies with some measures to conserve water.

(iii) Strategies need to be developed to determine effective water allocation mechanisms including decision support systems to prioritize water needs. Water allocation approaches will need to adopt the principle of conjunctive use of surface water and groundwater at its core so that all water is managed as one resource. Conjunctive use, if implemented judiciously can help maximize the available renewable resource through the storage of excess water in aquifers during times of surplus and the use of this stored water to augment surface water flows for irrigation, environmental flows and other beneficial uses during times of water deficit.

4. Institutional roles

129. The institutional framework includes government institutions, local authorities, private sector, civil society organizations, farmers' organizations and other community-based organizations. Capacity building will be needed at each of these levels either through the development of existing water management arrangements or by forming new ones. Some particular issues requiring capacity building within this institutional framework include the following:

(i) As identified above there is a need to link the current approach to groundwater resource assessment with more hydrogeologically sound approaches. A way forward could be to maintain the current practice of collecting water resources data at the smallest administrative units (e.g. block) but when aggregating these data use hydrological based divides (topographic divides and hydrogeologically connected aquifers units). A precursor to this approach would be an improved understanding of the hydrogeological system particularly concerning regional aquifer flows for shallow and deep aquifers and on the nature of groundwater-surface water interactions. This approach would also require relevant staff at district level to work together to develop these aggregated datasets supported by a wider state body or in the case of interstate water resources a central government agency.

(ii) Different methodologies for quantifying groundwater recharge should be trialed in pilot areas to confirm and improve the current methodology for groundwater resource assessment (Water Level Fluctuation method). These improved methodologies could subsequently be applied to the new hydrogeologically sound areas of assessment discussed in the previous bullet. This catchment based assessment would help overcome the issue of unknown specific yield in the WLF method. Marechal et al. (2006)[22] provide such an approach for a fractured hard-rock aquifer in Andra Pradesh. Rangarajan and Athavale (2000)[23] estimate a mean annual natural recharge of 71mm for a Deccan Traps aquifer in Shahdol district in Madhya Pradesh using the injected tritium method.

(iii) There is a need to separate water resources management functions (overall management of water resources as a whole) from service delivery functions (irrigation, hydropower, water supply and sewerage) to avoid conflicts of interest and encourage commercial autonomy. Capacity building will be needed to support effective water resources planning of surface water and groundwater. Such an arrangement is being proposed for Maharashtra[24] State, which is dominated by Deccan Trap aquifers.

(iv) Effective and early public participation approaches will be required particularly with farmers' organizations to ensure that they are involved in the planning and decision-making processes. Capacity building of WUAs and Panchayats will be particularly important to ensure take-up of new approaches to groundwater use and aquifer management.

5. Management Instruments

130. The major issue in the basin is diminishing surface and groundwater resources. The net annual groundwater draft for drinking and irrigated agriculture exceeds the annual recharging availability. Nitrate and fluoride was elevated in some groundwater areas. There are a number of remedial measures that are required to arrest the key issues of: (i) current over-exploitation of groundwater reserves in the Kshipra sub-basin; (ii) options for artificial recharge and increasing base flows in the Kshipra rivers and (iii) the issue of some naturally occurring hazards and other contaminants in localized areas. The management instruments needed to address these issues is outlined below.

131. To address the over-exploitation of groundwater reserves both the supply and demand approaches need to be addressed. In supply terms this includes developing ways to enhance recharge to aquifers so that depleted aquifer storage can be replenished (through artificial recharge), or on the demand side through irrigation methods that result in groundwater resource savings or changes in cropping patterns, which are discussed below.

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[22] Marechal, J.C. et al. (2006) Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture. Journal of Hydrology, 329, 281-293.

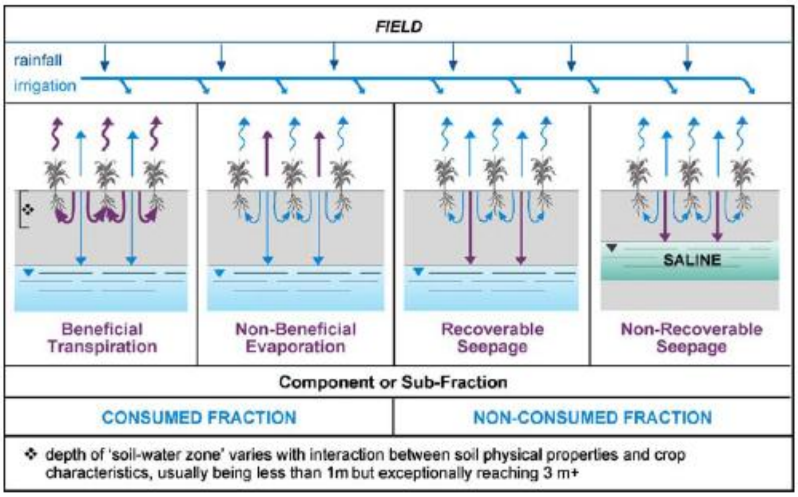
[23] Rangarajan, R. and Athavale, R.N. (2000) Annual replenishable groundwater potential of India—an estimate based on injected tritium studies. Journal of Hydrology, 234:38–53.

[24] Foster, S. et al. (2007) Confronting the Groundwater Management Challenge in the Deccan Traps Country of Maharashtra - India . GW-MATE Case Profile Collection Number 18. World Bank.

6. Options for Irrigation

132. Concerning irrigation and groundwater resources[25] it is necessary to identify the main fractions of water when it reaches a permeable soil. One of the potential consequences of improved irrigation water-use efficiency is further deterioration of groundwater resources due to shifting to spray irrigation from flood irrigation resulting in loss of return flows to aquifers. The water and energy saved is often used to extend the irrigation command area resulting in further loss of return flow to groundwater. A schematic of the utilisation and fate of water applied to permeable soil and their relationships with groundwater resources and irrigation management is shown in Figure 42.

Figure 42: Linkage of Surface and Groundwater Resources



133. In irrigated systems, the only real savings to groundwater can be achieved where modifications to irrigations and cropping-practices reduce the 'non-beneficial evapotranspiration'. If more water savings are needed, than consideration should be given to explore options for switching to cultivation of less water-consuming crops or crop-strains (with shorter growing season, or suited to cooler periods when potential evaporation and transpiration are lower). In some areas, it may be appropriate to restrict cultivation of certain types of irrigated crops in the critical groundwater areas. Dewandel et al. (2010)[26] modelled the impact on changes in cropping patterns (switch from rice to vegetables) in a hard rock aquifer system in a watershed in Andhra Pradesh and reported significant recoveries of water tables.

7. Options for Artificial Recharge to Groundwater

134. **Artificial recharge (AR)** systems are engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources. AR requires permeable surface soils to infiltrate to the aquifers. Where this is not available trenches or shafts in the unsaturated zone can be used. To design a system for artificial recharge of groundwater, infiltration rates of the soil must be determined and the unsaturated zone between land surface and the aquifer must be checked for adequate permeability and absence of polluted areas. The aquifer should be sufficiently transmissive to avoid excessive build up of groundwater mounds. Knowledge of these conditions requires field investigations and, if no fatal flaws are detected, test basins to predict system performance (Bouwer, 2002)[27].

135. Some water conservation and artificial recharge projects have been undertaken in the broader Chambal basin in Dewas and Indore districts (CGWB North Central Region, 2007 and 2009). In

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[25] Foster, S. and Perry, C. (2010) Improving groundwater resource accounting in irrigated areas: a prerequisite for promoting sustainable use. Hydrogeological Journal, 18:291-294.

[26] Dewandel et al. (2010) Development of a tool for managing groundwater resources in semi-arid hard rock regions: application to a rural watershed in South India. Hydrol. Processes, 24, 2784–2797.

[27] Bouwer, H. (2002) Artificial recharge of groundwater: hydrogeology and engineering. Hydrogeology Journal, 10:121-142.

Indore, a roof top rain water harvesting project was completed in Phed colony in Musakhedi involving a total roof area of 2710sq metre through which water was channelled to troughs into collection chambers with filters before being recharged. After this project a rise in water level of 4-5m was recorded in a monitoring well after the monsoon.

136. In Dewas district, five water conservation and artificial recharge projects have been completed. In Londri river (bordering Kshipra basin watershed boundary to the south), a series of control structures (gabion, boulder check dam, stop dam and sub-surface dyke) across the river, resulting in water level rises of 0.3 to 2m. It is reported that dug wells that were drying up in January now hold water until April. Such an approach may be possible in the headwaters of Kshipra river, but investigations would be needed to evaluate the degree of hydraulic connectivity between groundwater and the river system. In Dewas city, some 1000 houses with existing boreholes were retro fitted for roof top harvesting. In 2001 it was estimated that this resulted in recharge of 50,000 cubic metres in an area of 1km^2. In Tonk Khurd and Dewas blocks a series of recharge shafts were dug in existing tanks to break through an impermeable layer to ensure hydraulic connectivity with groundwater table. Two further recharge projects were carried out in district hospital Dewas city and Dewas Bank Note Press.

137. The Central Groundwater Board (CGWB) Groundwater Recharge Master Plan follows two criteria for identifying recharge: availability of surplus water and availability of storage space in aquifers. The investments in the program would therefore be driven by the potential available for groundwater recharge, and not by the need for recharge. Therefore there are some concerns nationally about whether the implementation of this plan will benefit the most water stressed areas. Indications are also that AR may not be suited to all hydrogeologically situations and may prove quite costly. Therefore, AR will be part of the overall solution in certain circumstances but should not be seen as the panacea for over-exploitation or a justification for not tackling the demand related issues.

138. It is estimated that an area of 448,760 km^2 — about 14% of total land area of India — is suitable for managed aquifer recharge and that a volume of the order of 36,400 MCM is available for recharge annually. This is equivalent to an average of 80 mm over the entire area and the volume equates to about 18% of the 200,000 MCM of groundwater that is currently utilised annually for irrigation. However, the estimates of recharge sites in a DFID/BGS study (2006)[28] (that are not limited by storage in the aquifer), were found to be about one order of magnitude lower (4 mm to 10 mm) than the CGWB estimates and to represent only about 1% of rainfall.

139. The CGWB Master Plan for groundwater recharge has estimated that 14MCM and 32 MCM could be recharged in the Kshipra and Ghambhir basins (4751km^2 based on Kshipra Area Water Partnership, 2002[29]) respectively through a variety gully plugs, gabion structures, contour bunds in the upper reaches of the watersheds, percolation tanks, nala bunds in the runoff zones and recharge shafts, gravity head wells in downstream areas. This equates to a depth of recharge of approximately 10mm across the 4751km^2 ([0.04628 cubic kilometers/4751km^2]*1,000,000 = 10mm). This annual artificial recharge must be put against water table fall rates of upto 0-2 metres per decade (1997-2008) for Dewas and Ujjain and 2-4 metres per decade (1997-2008) for Indore (CGWB North Central Region, 2009[30]). The cost and benefits accrued through this artificial recharge approach will need to be weighed against groundwater resource savings that could be achieved through other means such as demand related savings .

8. Options for Geochemical Hazards

140. Groundwater quality issues in the Kshipra basin include nitrates (>45mg/l) from suspected agricultural sources for Dewas, Indore and Ujjain districts and fluoride (>1.5mg/l) in Dewas for blocks Dewas, Sonkatch and Tonk Khurd. Table: 33 provides an overall strategy in short and long term horizons to tackle the issue of naturally occurring trace elements in the groundwater. Anthropogenic

[28] Calow, R C , Neumann , I, Moench, M, Kulkarni , H, Mudrakartha, S and Palanis ami , K. (2006) Managed Aquifer Recharge: an assessment of its role and effectiveness in watershed management. British Geological Survey Commissioned Report, CR/06/107N. 80pp.

[29] Kshipra Area Water Partnership (2002) Water for the 21st Century, Vision for Action, Kshipra River Basin Global Water Partnership.

[30] CGWB North Central Region (2009) Groundwater year book (2008-2009) Madhya Pradesh, Bhopal.

derived contaminants such as nitrate should be targeted to reduce or eliminate their production at source. Key issues in the definition of an integrated strategy for mitigation of a naturally-occurring trace element problem in groundwater[31] is shown in Table: 33 below:

Table: 33 Key Issues

ACTION	ISSUES TO BE RESOLVED
SHORT TERM	
Evaluation of Problem	• appropriate scale (local/provincial/national) for groundwater quality survey • selection of appropriate analytical technique(s) (field kit/lab method) • government initiative versus private responsibility • availability of specialist advice for hydrogeochemical interpretation • assessment of other potential groundwater quality problems
Water Supply Management	• advice on well use (community information/well closure or labelling) • practical and social considerations on well switching • prioritization of field analytical screening (to confirm safe wells) • appropriate screening policy (universal or selective/temporal frequency)
Public Health Programme	• patient identification (active program or via medical consultation) • establishing relationship between health problem and water source(s) • diagnosing incipient symptoms • immediate patient treatment (organization of bottled water provision)
LONG TERM	
Water Treatment Option	•cost at scale of application (town/village/household) and effectiveness/ sustainability at scale of operation.
Alternative Groundwater Supply	• usually involving (a) water wells with modified (often deeper) intakes or (b) reticulation from local high-yielding, acceptable quality sources, both of which must be based upon systematic hydrogeological investigation and implemented with appropriate well construction standards
Alternative Surface	• sustainability in terms of drought reliability and quality variability
Water Supply	• evaluation of risks associated with treatment plant failure

F. Government Institutions

141. The current functions of the various water sector departments in their present form do not provide adequate operational basis[32] for implementing IWRM. Effective institutions are characterized by stability and non fragmentation and non-overlapping of responsibilities, clearly defined but separated roles and is supported by strong and comprehensive, but flexible legislation, regulations, decrees, etc. and is lead by an “apex” body with clearly defined regulatory functions. The functions and tasks performed by the existing institutions do not lend support for integrating climate risk management in development as adaptive development. Therefore, transformation in roles/rules and relationship among the institutions is essential which could facilitate: (i) holistic water planning; (ii) review of financial instruments like targeted subsidies to support adaptation; (iii) participation of stakeholders in planning and management; (iv) strategizing environmental management and control measures ; (v) facilitate inter basin planning and management. (vi) separation of roles like service provider-managers and regulators; (vii) conjunctive planning and regulation of surface and groundwater (viii) monitoring of quality of water (ix) effective planning for disaster (flood) management

[31] Foster et al. (2006b) Natural Groundwater Quality Hazards avoiding problems and formulating mitigation strategies. GW-MATE Briefing Note Series Note 14, World Bank.

[32] Source: (ADB TA NO. 7418-IND): Integrated Water Resource Management and Sustainable Water Service delivery in Karnataka- COMPONENT 1 report on Institutional Analysis and Proposed Reforms for IWRM-2010

(x) revenue recovery mechanism to be effective (xi) post project performance evaluation (outcome & impact) is not being carried out flow and discharge measuring installations.

142. A nodal agency for ensuring coordinated and integrated planning and management approach by various water centric institutions is needed. Improved integration of planning between the departments of groundwater, surface water, agriculture and water supplies all of which are responsible or affected by the surface and groundwater management principles.

1. Public/private/community roles and initiatives

143. With the change in context, it has become necessary to explore the potentials and risks associated with the state, private and community sector roles in water management and water service provision. The appropriateness of different public/private/community roles and responsibilities in different contexts needs to be addressed. Agenda of assistance/support needs to engage with these roles and responsibilities to plan appropriate mixes of market-based, institutional and participatory approaches in management and service provision. An appropriate mix and linkage between roles, and the social acceptability of this mix and linkage, have to be identified for each specific case.

144. **Community-based management** raises questions of capacity, financial management and participation. Long term sustainability and better demand-driven services and infrastructure have been the major objective of involving communities in the management of the resources. As support for community systems have moved from household wells to larger-scale and more complex community piped systems, so the challenges have grown. Operations and maintenance and financial sustainability have been the biggest challenges with community managed systems, followed closely by institutional and cultural challenges. Furthermore, recent experience suggests that as rural incomes increase, communities are demanding both higher levels of service and management arrangements that release them from day-to-day decision-making. Nevertheless, community involvement in water resource management remains a significant governance prerogative. Community consultations have indicated a willingness to participate in planning and policies for sustainability.

145. **Key issues:** Governance reform to meet the needs the Kshipra requires integrating the largely uncontrolled groundwater abstractions into a more coordinated and directed strategy with Government and Communities working together to develop mechanisms for sustainability, combined with maximum productivity from agriculture as well as high levels of service delivery of potable water. Power is also a factor and strategies for supplying power have also to be incorporated into the planning. The state departments irrigation, potable water, agriculture, groundwater and power have to work together to coordinate their activities to develop holistic planning and strategies. It is important that planning of the rural and urban sectors is better integrated.

2. Catchment Management and Artificial Recharge

146. **I**ntegration is a key governance process to address fragmentation in managing water in its catchment context. IWRM has become the standard for good in this context. But one needs to identify the operational elements of IWRM for it to become an effective instrument for bringing water governance as there are number of perceived tensions, in catchment management through IWRM, between: (i) top-down and bottom-up approaches, (ii) the holistic philosophy that lies behind integrated river basin management and the participatory ideal of decentred decision making; (iii) the science-based approach that takes advantage of complex ecological knowledge, hydrological and water allocation models, and tools such as GIS, on the one hand, and community-based initiatives oriented to local knowledge on the other; (iv) catchment management institutions' role to allocate an increasingly scarce and finite resource (water) versus a catchment management institutional role to mobilise developmental resources and funds for new infrastructure to take yet more water off the river and (v) prescriptive approaches to river basin management and institutional design and negotiated approaches, outcomes and institutional arrangements. There is a need for convergence of the catchment management departments to better coordinate the various catchment programmes towards supporting effective groundwater recharge these would include the departments of rural development (NREGA), groundwater, forestry and panchayats.

3. Equity Implications of Market and Property Rights

147. It is important to understand/analyze different equity implications of market-based approaches to water. Gender, poverty and indigenous dimensions of water regulation needs to be addressed with specific reference to the enhanced roles of markets and changing property regimes. Development outputs/outcome of the National Action Plan for Climate Change (NAPCC) need to achieve a balance between efficiency, social equity and sustainability. Equity is a key concern for water related development assistance. Though many water resource development interventions have been premised on increasing the supply of water to people and for food, there are raising disparities in water access between the rich and poor within and between the states.

148. Human intervention, whether through technology or governance, alters the allocation of water. There is no 'natural' distributive justice in water availability due to the significant variations between seasons, upland and lowland areas, and regions. Yet human regulation re-distributes water according to the economic and social objectives of those who control structures at a given scale. Negotiation over water distribution and equity between various actors, whether they be neighbours sharing a well or states sharing a large river, are shaped by underlying issues of power, culture and values. Negotiation and equitable outcomes thus vary greatly according to societal context. Water quality wherever and whenever available, is an issue. The dimensions of water quality is characterized by: (i) ways in which water property rights are defined and associated rules for water allocation; (ii) tensions between equity and efficiency and between equity and sustainability; (iii) provision of 'safety nets' for the poor to ensure basic water entitlements; (iv) the extent to which water governance engages with gender inequalities; (v) the extent to which water governance addresses the interests and concerns of minority groups; (vi) sectoral water equity and competition between agricultural, industrial and urban water uses; and (vii) the degree to which management of conflict addresses underlying inequalities and injustices rather than dealing only with superficial symptoms when confrontations occur.

149. The way in which **water rights** are articulated through a country's governance structures (whether through law or custom) has significant implications for equity. There is always tension (sometimes creative) between the considerations of water as an economic good and the view of water as first and foremost a human right. Prioritizing water as an economic good often involves the privatisation of water rights. When water is seen as a basic human right (and it is recognized as such in international law), it is more likely to remain in public ownership. Property rights paradigms often reflect the dominance of one of these positions without appropriately defining a balance between the two.

150. **Water equity** can also be considered with reference to competition between sectors. Agriculture remains the largest water user in the basin. Yet water supply for agriculture is coming under increasing competition from other water uses, such as industry and urban water supply, as societies and economies change. Those engaged in agriculture, and other natural resource based livelihoods may be vulnerable to re-allocations of water to other sectors, or changes in the timing or quality of water availability. Whilst agriculture may not be the most economically profitable use of water, however, the provision of adequate supplies of water for agriculture is critical to food security next only to drinking water.

151. The nature of water is such that it can be easily captured and diverted, and as such water can be tapped, stolen and systems of regulation subverted. Whether at a community or national scale, for equity to be maintained in a system it requires a high degree of social acceptance in order to minimize the cost of regulation and enforcement. In the same way, reform to any system of water governance also requires a high degree of social acceptance to ensure conflict is avoided. To have some sort of reallocation of water, for example towards a more equitable, efficient or sustainable arrangement, requires negotiation, compensation, and a transition process that is both iterative and socially acceptable.

4. Effective Information Systems for Good Water Governance

152. In the present institutions, participation in decision making is a means to an end, and the goal of informed decision-making requires good & reliable quality information on a range of issues, spatial, technical, social, economic, legal and institutional. This necessitates: (i) establishment of an integrated data and information unit & also basin level knowledge centres; (ii) capitalization of knowledge

emerging form various initiatives like Hydrology project supported by the World Bank, land use information developed under different schemes; (iii) developing climate related information archives to promote climate literacy among the various stakeholders in general and village panchayat leaders in particular; (iv) development of decision support systems for effective water management (v) establishment of updated design parameters to the impact of extreme events due to climate change and (vi) development of data base related to water and climate for carrying out climate research

5. Knowledge and Human capacity

153. Knowledge and human capacity[33] are critical to implementing successful water resource development and management initiatives within the framework of IWRM. New skills and capacities within water management institutions are critically important—at a time when various forces are supposedly weakening governments' capacities to attract and hold people with this expertise. While capacity development focuses on actors (individuals and institutions) but includes their environments (systems) that affect their capacity; Capacity development should not be conceived as necessarily involving formal projects or activities with specific capacity development objectives. Capacity development also takes place through learning by doing, participation, observation, comparison of experiences, and a host of other informal activities. The potential area of work in capacity development extends across a range from individual, through organizations to systems. Within each grouping separation can be made into capacity development in areas of self, social (interactions between individuals) and methodological. However, the underlying assumption is that the capacity building initiative shall help towards new and stronger institutional capacity for management, service delivery, resource generation and management.

6. Strengthening of Ground and Surface Water Institutions

154. The institutional framework includes government institutions, local authorities, private sector, civil society organizations, farmers' organizations and other community-based organizations. Capacity building will be needed at each of these levels either through the development of existing water management arrangements or by forming new ones. Some particular issues requiring capacity building within the institutional framework for groundwater include the following:

(i) There is a need to link the current approach to groundwater resource assessment with more hydrogeologically sound approaches. A way forward could be to maintain the current practice of collecting water resources data at the smallest administrative units (e.g. block) but when aggregating these data use hydrological based divides (topographic divides and hydrogeologically connected aquifers units). A precursor to this approach would be an improved understanding of the hydrogeological system particularly concerning regional aquifer flows for shallow and deep aquifers and on the nature of groundwater-surface water interactions. This approach would also require relevant staff at district level to work together to develop these aggregated datasets supported by a wider state body or in the case of interstate water resources a central government agency.
(ii) Different methodologies for quantifying groundwater recharge should be trialed in pilot areas to confirm the viabilities and improve the current methodology for groundwater resource assessment (Water Level Fluctuation method). These improved methodologies could subsequently be applied to the new hydrogeologically sound areas of assessment discussed in the previous bullet.
(iii) There is a need to separate water resources management functions (overall management of water resources as a whole) from service delivery functions (irrigation, water supply and sewerage) to avoid conflicts of interest and encourage commercial autonomy. Capacity building will be needed to support effective water resources planning of surface water and groundwater.
(iv) Effective and early public participation approaches will be required particularly with farmers' organizations to ensure that they are involved in the planning and decision-making processes.

[33] Capacity is the ability of actors (individuals, institutions, and societies) to perform functions effectively, efficiently and sustainably. Capacity is the power of something (person, institution, system) to perform or produce.

Capacity building of WUAs and Panchayats will be particularly important to ensure take-up of new approaches to groundwater use.

7. Capacity Building and Development

155. Based on state consultations, a summary of the key capacity building areas towards institutional strengthening[34], water resource and user institutions development are presented in Table 34 below:

Table 34: Key Areas for Capacity Building

○ Water Management practices for sustainable agriculture ○ Volumetric supply of water and installation of measuring devises ○ Basics of Farmers Managed Irrigation Acts and formation of WUA ○ GIS and Autocad applications ○ On New Institutional arrangements and the roles to be played by WRD ○ Community involvement in managing irrigation infrastructure ○ Preparation of thematic maps for the selected basins ○ Knowledge on and Utilization of modern equipments for Topographical and cadastral survey ○ Modern design on irrigation structure and coastal structure ○ Budgeting. accounting and financial management including fund-flow arrangements ○ Environmental assessment and redressal systems in the social & environmental assessment framework ○ Maintaining MIS ○ O & M of the irrigation assets and allocation of adequate funds ○ Project Planning, Monitoring and Evaluation ○ GIS Applications in Irrigation ○ Modern Survey Techniques (Total Station and LADAR- Laser Detection and Ranging ○ Environmental Impact Assessment & Management (EIA/EMP of irrigation projects) ○ Project Economics ○ Procurement & Contract Management (including procurement procedure) ○ Procurement/ Tendering ○ Planning of Irrigation Projects ○ Modern Irrigation Techniques like Sprinkler/Drip Irrigation ○ Benchmarking of Irrigation Projects ○ Water Use Efficiency/Water Auditing of ○ Irrigation Projects ○ Productivity Enhancement in Command Area ○ Design of Dams ○ Land Acquisition and Encroachment Issues ○ Modern Construction Technology and Techniques ○ Quality Control of Construction ○ Revenue Recovery and Related Issues ○ Canal and Drainage Hydraulics ○ Mirco-distribution Network, Plan & Design ○ Preparation of Operational Plan for Irrigation Projects ○ SCADA - Canal Automation ○ Design & Operation of Canal Flow, Flow Measurement and Control Structures ○ Dam Safety Aspects
OTHER DEPARTMENTS
○ Integrated Farming ○ Adoption of Micro irrigation technology ○ Promotion of Hybrid vegetable and Horticultural crops ○ Promoting fodder cultivation ○ Seed production and seed certification ○ Agro-climatic zones and agronomy ○ Pest Management
COMMON TO ALL DEPARTMENTS
○ Concept, principles and practices of IWRM ○ Basin approach in Planning and Implementation

[34] Main goals of institution strengthening is the strengthening of management and therefore capacity building areas must cover management issues.

- National and State Acts & Rules
- Formation and functioning of RBO s
- Legal Issues and Related Software
- Legal Issues and Use of LIS (Legal Information System)
- Human Resource Management/Strategic Human Resource Management
- Right to Information ACT
- Leadership, Motivation and Team Building
- Developing Communication Skills
- Time, Stress and Conflict Management
- Participatory Irrigation Management
- Gender Issues and their Integration
- Management of Organizational Change
- Building Organizational Culture for Performance
- Competency Mapping and Management
- Public Private Partnership

VIII. CLIMATE CHANGE SCENARIOS

A. Introduction

156. The Kshipra river rises in the Vindhya Range north of Dhar, from a hill called Kokri Tekdi (situated at a distance of 11km from Ujjain). The Kshipra river is 195km long. Its main tributaries are the Khan and Gambhir rivers. The Kshipra flows south across the Malwa Plateau to join the Chambal river.

157. The Chambal river is a tributary of the Yamuna river in central India, and forms part of the greater Gangetic drainage system. The river flows north-northeast through Madhya Pradesh, passing through Rajasthan, then forming the boundary between Rajasthan and Madhya Pradesh before turning southeast to join the Yamuna in Uttar Pradesh state. The Chambal river is 960km long and its drainage basin covers an area of 143,219 km^2.

158. The summer months (April–June) are harsh with temperatures reaching up to 45°C. In addition, hot winds (called lou) may blow in the afternoons, worsening the heat and increasing evapotranspiration. The winter months (November–February) are pleasant and cool with daytime temperatures typically 20°C, though they may drop below zero at night. The monsoon typically arrives in late June and the months of June through September receive moderate to heavy rainfall. There are periods of rainfall followed by long periods of bright sunshine and high humidity. The month of October generally is very warm and with high humidity.

159. The Kshipra sub-basin is relatively small and hence the regional climate model has only a small number of grid points over the area. Gridded data for precipitation and temperature exist for the region, at resolutions down to 25km. In this study, the India Meteorological Department (IMD) dataset has been utilised for observed precipitation.

B. Summary of Observed Changes to the Present Time

1. Community Perceptions

160. The communities have observed significant change in the temperature in the last 10 years. The summer temperature has risen significantly and the winter temperature has fallen significantly in all the districts. The reports of rainfall change are mixed; respondents from Indore have told that rainfall has not changed significantly in the last few years, though people in the other districts are of the view that there is significantly less rainfall. During 2010 frost caused huge damage on agricultural production in all the districts, though the damage is seen to be less in Indore.

161. The average response from the communities has been that some delays in the starting day of the monsoon has been observed, with delays reported of around 10-15 days. Stakeholders mostly believe that climate change will have perceptible impact on their livelihood through its effect on agricultural production, human health and livestock population.

C. Relevant Climate Change Studies and Findings

162. Researches into the wider Ganges basin are very numerous, but there are only a few key research outputs for Kshipra. Saini, of Geological Survey of India, published in 2008 on “Climate Change and its Future Impact on the Indo-Gangetic Plain (IGP)”, which mentions some of the issues investigated in this project, namely groundwater depletion.

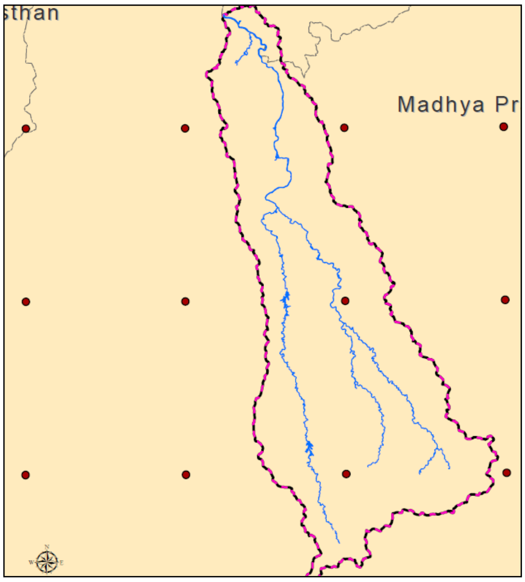
163. Dasgupta et al performed a review in 2010 “Indian Agricultural Scenario and Food Security Concerns in the Context of Climate Change: a Review”, concluding that the food insecurity situation was “moderate”. They also note “*The available studies on supply and demand for foodgrain and other food products do not account for the impact of climate change on the production and consumption of food.*” .

164. The scoping study for Madhya Pradesh State Climate Change Action Plan has been produced in 2010[35]. The study assesses both climate change mitigation/energy as well as adaptation. The main issues relating to water include: (i) water is identified as being under serious threat both in terms of quantity and quality; (ii) surface run-off during heavy rainfall of sewage, and fertilisers causes pollution; (iii) post-monsoon flow in most rivers is used for irrigation which further reduces flows-rivers get converted into a series of small ponds; (iv) water use efficiency in irrigation is generally very low and there are major concerns regarding resource depletion; (v) there should be a reduced dependence on irrigation and enhance agriculture productivity through improved technologies; (vi) in many districts, groundwater is being drawndown at an alarming rate encouraged by highly subsidised or free electricity; (vii) continuous efforts are made to reduce the gap between potential and actual irrigation; (viii) the total storage of rainfall through major and minor irrigation dams is quite small and the tradition of building small check dams and storage ponds in low lying land has declined in the past 50 years; (ix) while the Government of Madhya Pradesh (GoMP) has done a good job of initiating water harvesting and water shed development, investments are required to treat land and a much larger level of investments will be needed to ensure that a significantly higher proportion of rainwater is captured and used; and (x) whilst overall fertiliser consumption is low it is heavily applied in some areas and high concentrations have been found in all groundwater..

D. Scenarios for Change

165. For climate change projections in the Kshipra sub-basin, output from a member of the UK Hadley Centre HADCM3 global climate model (GCM) QUMP ensemble (Quantifying Uncertainty in Model Predictions) has been downscaled using the Hadley Centre PRECIS (Providing Regional Climates for Impact Studies) regional climate model (RCM). Apart from the baseline (1961-1990) which represents the present, the following two time slices for the future have been investigated: mid-century (2021-2050) and end-century (2071–2100); all three time slices use the IPCC SRES (special report on emissions scenarios) A1B scenario. The PRECIS data grids are shown in Figure 43. The SRES A2 and B2 scenarios are also available for the end of century.

Figure 43: The PRECIS Data Grids



1. Temperature

166. HADCM3 simulations downscaled with PRECIS indicate an all-round warming over the Indian subcontinent associated with increasing greenhouse gas concentrations. Seasonal mean daily maximum and mean daily minimum temperatures from the PRECIS simulation of the A1B scenario are given in Table 35 below. Figure 35 presents a comparison of projected changes in temperatures for the basin with the A1B, A2 and B2 scenarios for the end of the century.

[35] Scoping Study for Madhya Pradesh State Climate Change Action Plan MERYLYN HEDGER and VAIDEESWARAN S IDS and CCDC March 2010

Table 35: PRECIS Simulated seasonal temperatures, A1B scenario

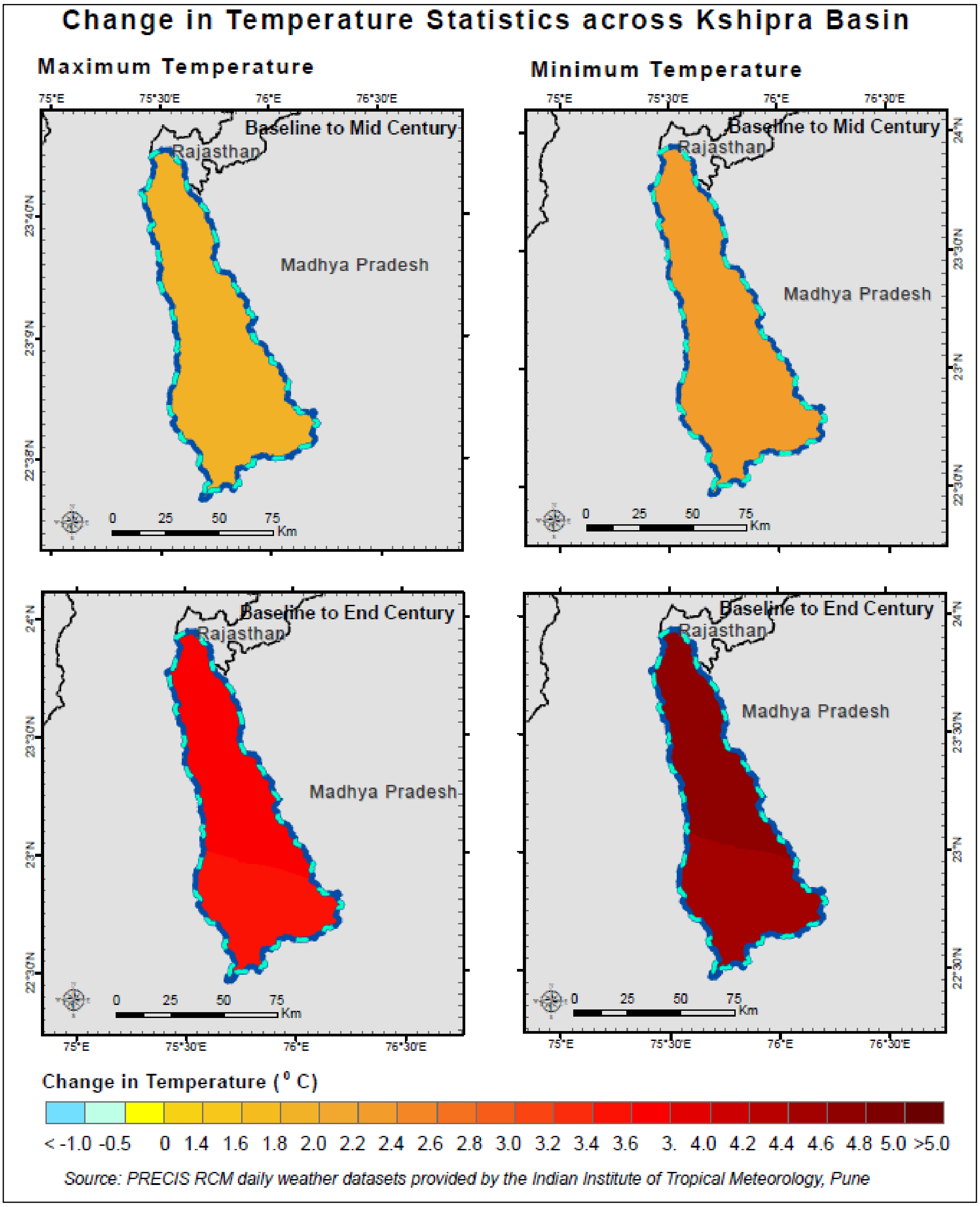
Time Horizon	**Mean daily maximum temperatures (°C)**				
	JF	**MAM**	**JJAS**	**OND**	**Annual**
Baseline (1970s)	27.0	39.3	30.2	28.9	31.4
mid-century	29.3	41.4	31.7	30.8	33.3
end-century	30.9	43.3	33.6	32.7	35.1
	Mean daily minimum temperatures (°C)				
Baseline (1970s)	10.3	22.5	22.0	12.4	16.8
mid-century	17.3	28.2	23.7	15.2	21.1
end-century	20.1	30.4	26.0	19.1	23.9

Table 36 Comparison of projected changes in temperatures, A1B, A2 and B2 scenarios, 2080s

Mean daily maximum temperatures					
Scenario	JF	MAM	JJAS	OND	Annual
A1B	3.9	4.0	3.4	3.8	3.7
A2	4.4	3.8	3.4	5.4	4.2
B2	2.7	2.3	2.7	4.6	3.0
Mean daily minimum temperatures					
A1B	9.8	7.9	4	6.7	7.1
A2	5.8	4.9	3.2	5.3	4.8
B2	4.1	3.4	2.5	5.8	3.9

167. Both maximum and minimum temperatures are projected to rise significantly under the PRECIS A1B scenario. Mean daily maximums are project to increase by about 2°C by the 2050s and by almost 4°C by the 2080s. Increases in the monsoon season are lower than in the dry seasons. The A2 scenario produces similar changes in Mean daily maximum temperatures as the A1B scenario, but the increases under the B2 scenario are much lower. Mean daily minimum temperatures are projected to increase by as much as 10°C in the dry season by the 2080s, and by a more modest 4°C in the monsoon season under the A1B scenario. The A1B scenario produces much larger increases in mean daily minimum temperatures than either the A2 or B2 scenarios, particularly in the dry season months. Temperature changes are shown in Figure 44 for the A1B scenario. The pattern of projected changes in similar under the A2 and B2 scenarios.

Figure 44: Change in Average Daily Temperatures



2. Rainfall

168. The Kshipra river basin receives most of its rain during the monsoon season, which starts in late June. The mean seasonal precipitation amounts simulated by PRECIS are as shown in Table 37 below. Data are presented for four seasonal periods: JF - January, February; MAM - March, April, May; JJAS - June, July, August, September; OND - October, November, December. Table 38 presents a comparison of changes to end-century under the A1B, A2 and B2 scenarios. Figure 45 and Figure 46 show the pattern of changes in annual and seasonal rainfall under the A1B scenario. The pattern of change is very similar under the A2 and B2 scenarios.

169. Under the A1B scenario, rainfall is projected to increase. Mean annual rainfall increases by about 140mm by mid-century, and by about 180mm by end-century under the A1B scenario. The A2 scenario produces a similar change in precipitation to the A1B scenario, but with the B2 scenario, the

change in precipitation is less than half of that under A2. Most of the increases occur in the monsoon period. There is a slight decline in OND and JF rainfall to mid-century under the A1B scenario. Mean monsoon rainfall increases by 160 mm by end-century under the A1B scenario.

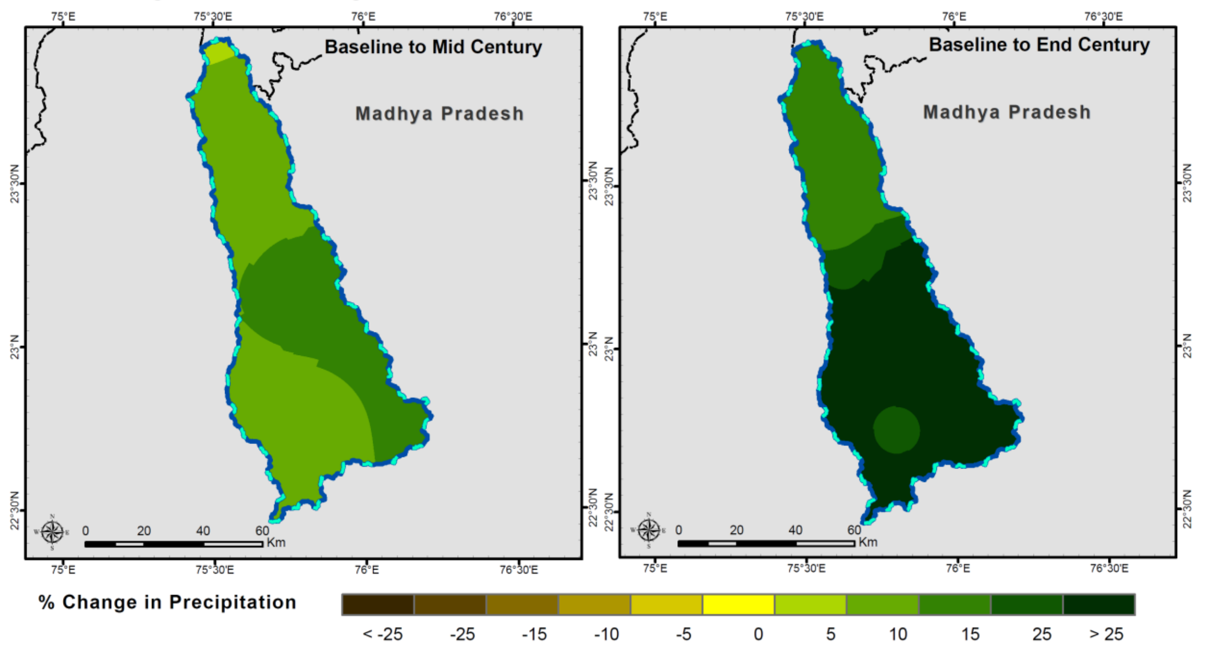
Table 37 PRECIS Simulated seasonal precipitation in the Kshipra sub-basin, A1B scenario (mm)

	JF	MAM	JJAS	OND	Annual
1970s baseline	31	39	745	68	883
mid-century	10	40	918	55	1023
end-century	19	43	905	97	1065

Table 38 Projected changes in seasonal precipitation under the A1B, A2 and B2 scenarios, to 2080s

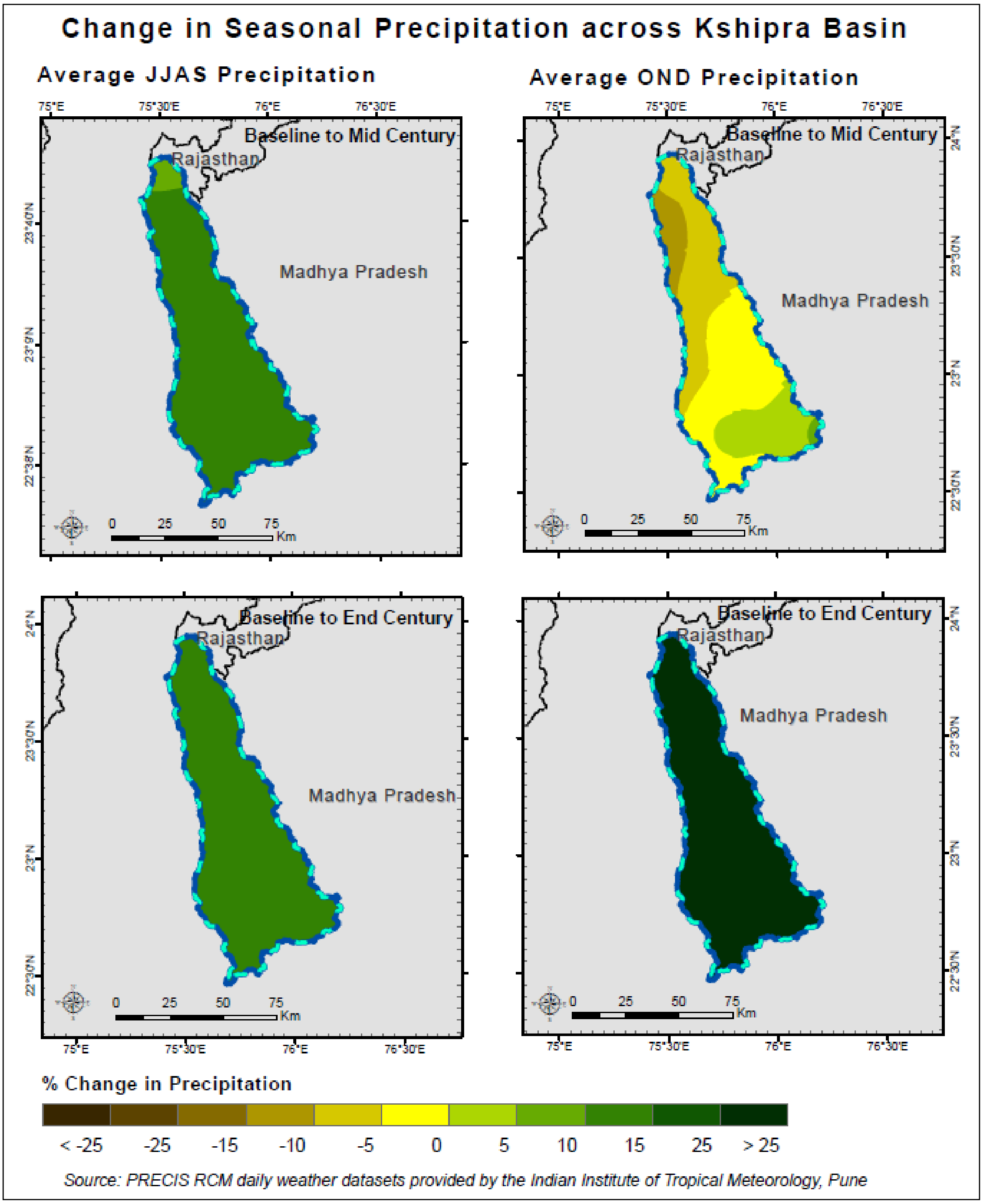
Scenario	JF	MAM	JJAS	OND	Annual
A1B	-12	4	160	29	182
A2	6	10	132	1	150
B2	2	9	79	-19	71

Figure 45: Change in Average Precipitation



Source: PRECIS RCM daily weather datasets provided by the Indian Institute of Tropical Meteorology, Pune

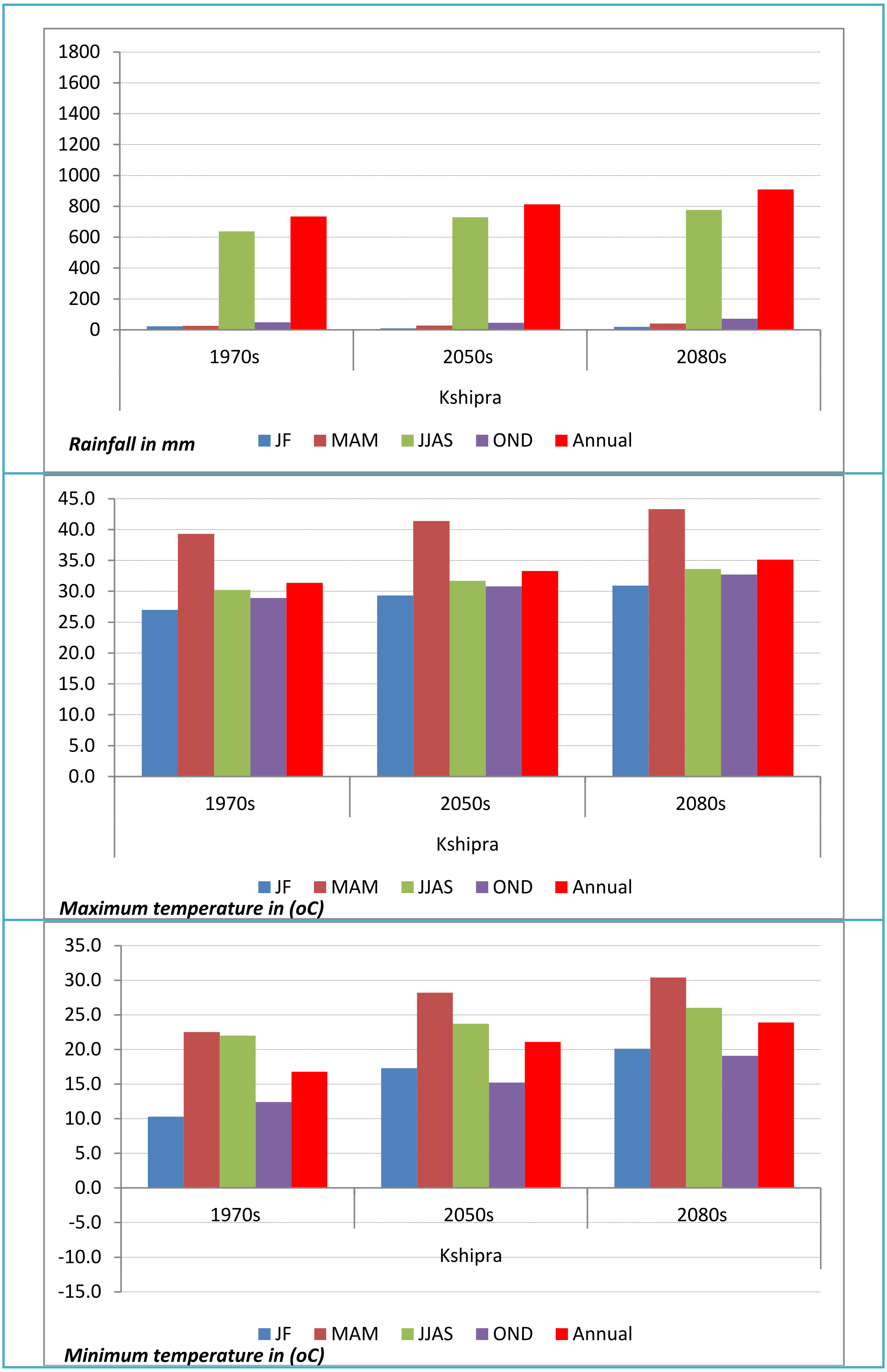
Figure 46 : Change in Average Seasonal Precipitation



3. Combined Rainfall and Temperature

170. Figure 47 given below indicates the absolute changes in seasonal and annual rainfall and temperature for the A1B scenario.

Figure 47: Simulated Seasonal and Annual Rainfall, A1B scenario



E. Analysis of the Climate Change Data

171. The PRECIS data on precipitation, maximum and minimum temperature have been analysed for the Kshipra basin.The forecast changes in precipitation under the PRECIS A1B and A2 scenarios are significant, being 15%-20%. The change is less significant with the B2 scenario. These changes could improve the water resources situation, depending upon the intensity and inter-annual variability with which the rainfall falls. The extent to which increased temperatures and potential evapotranspiration offset the increase in precipitation has been investigated using the SWAT (Soil Water Assesssment Tool) rainfall-runoff model. Increasing rainfall intensity, has implications for drainage design, and catchment management including water harvesting and soil erosion. At present regional climate models do not represent rainfall well, and only subjective assessments may be possible.

F. Water Resources

1. Hydrological Simulation Studies

172. Evaluating the potential impacts of climate change on water resources requires the application of hydrological simulation modelling techniques, driven by scenarios of changes in precipitation and potential evapotranspiration derived from global and regional climate modelling studies. As indicated above, precipitation is one of the least well represented processes in climate models at present, and the uncertainty in projections of climate change impacts on water resources is therefore high. Current practice is to try and use a range of different climate models to create an ensemble of possible futures through which an appreciation of uncertainty can be gained, and the robustness of adaptation responses evaluated. The near future (2030s) is the main focus for planning, and for this the model projections are largely independent of the emission scenarios, as the changes are mainly due to historical emissions and the slow response of the Earth's climate system. However, inter-model uncertainty should be considered

173. The SWAT model has been used with climate simulations from the A1B emissions scenarios from the PRECIS RCM with HADCM3 boundary conditions. The model was calibrated using data from the IMD 0.5^o precipitation and temperature data, and observed flow data from the Central Water Commission (CWC) and state gauging stations.

174. The Indian Institute for Tropical Meteorology (IITM) have run the PRECIS model on the A1B emissions scenario with three perturbed model parameter sets that provide for some level of inter-model variability. The full integrations for these PRECIS runs were requested, but only one was available, and only for the baseline , 2021-2050 and 2071-2098. The PRECIS model has also been run with the A2 and B2 scenarios, but only for the time slice 2071-2100. The SWAT model was run only with the A1B scenario.

2. Background to the SWAT Model

175. The Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998[36], Neitsch et al., 2002[37]) is a distributed parameter and continuous time simulation model. The SWAT model has been developed to predict the hydrological response of un-gauged catchments to natural inputs as well as the manmade interventions. Water and sediment yields can be assessed as well as water quality. The model (a) is physically based; (b) uses readily available inputs; (c) is computationally efficient to operate and (d) is continuous time and capable of simulating long periods for computing the effects of management changes. The major advantage of the SWAT model is that unlike the other conventional conceptual simulation models it does not require much calibration and therefore can be used on un-gauged watersheds (in fact the usual situation).

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[36] Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. 1998. Large-area hydrologic modeling and assessment: Part I. Model development. J. American Water Res. Assoc. 34(1): 73-89

[37] Neitsch, S. L., J. G. Arnold, J. R. Kiniry, J. R. Williams, and K. W. King. 2002a. Soil and Water Assessment Tool - Theoretical Documentation (version 2000). Temple, Texas: Grassland, Soil and Water Research Laboratory, Agricultural Research Service, Blackland Research Center, Texas Agricultural Experiment Station.

176. The SWAT model is a long-term, continuous model for watershed simulation. It operates on a daily time step and is designed to predict the impact of land management practices on water, sediment, and agricultural chemical yields. The model is physically based, computationally efficient, and capable of simulating a high level of spatial details by allowing the watershed to be divided into a large number of sub-watersheds. Major model components include weather, hydrology, soil temperature, plant growth, nutrients, pesticides, and land management. The model has been validated for several watersheds.

177. In SWAT, a watershed is divided into multiple sub-watersheds, which are then further subdivided into unique soil/land-use characteristics called hydrologic response units (HRUs). The water balance of each HRU in SWAT is represented by four storage volumes: snow, soil profile (0-2m), shallow aquifer (typically 2-20m), and deep aquifer (>20m). Flow generation, sediment yield, and non-point-source loadings from each HRU in a sub-watershed are summed, and the resulting loads are routed through channels, ponds, and/or reservoirs to the watershed outlet. Hydrologic processes are based on the following water balance equation:

$$SW_t = SW + \sum_{i=1}^{t} (R_{it} - Q_i - ET_i - P_i - QR_i)$$

178. where SW is the soil water content minus the wilting-point water content, and R, Q, ET, P, and QR are the daily amounts (in mm) of precipitation, runoff, evapotranspiration, percolation, and groundwater flow, respectively.

179. The soil profile is subdivided into multiple layers that support soil water processes, including infiltration, evaporation, plant uptake, lateral flow, and percolation to lower layers. The soil percolation component of SWAT uses a storage routing technique to predict flow through each soil layer in the root zone. Downward flow occurs when field capacity of a soil layer is exceeded and the layer below is not saturated. Percolation from the bottom of the soil profile recharges the shallow aquifer. If the temperature in a particular layer is 0ºC or below, no percolation is allowed from that layer. Lateral subsurface flow in the soil profile is calculated simultaneously with percolation. The contribution of groundwater flow to the total stream flow is simulated by routing a shallow aquifer storage component to the stream (Arnold, Allen, and Bernhardt 1993[38]).

180. SWAT also simulates the nutrient dynamics. Sediment yield is calculated based on the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975[39]). The movement of nutrients, i.e. nitrogen and phosphorus is based on built in equations for their transformation from one form to the other. The total amounts of nitrates in runoff and subsurface flow is calculated from the volume of water in each pathway with the average concentration. Phosphorus however is assumed to be a relatively less mobile nutrient, with only the top 10 mm of soil considered in estimating the amount of soluble P removed in runoff. A loading function is used to estimate the phosphorus load bound to sediments (McElroy et al, 1976[40]). SWAT calculates the amount of algae, dissolved oxygen and carbonaceous biological oxygen demand (CBOD - the amount of oxygen required to decompose the organic matter transported in surface runoff) entering the main channel with surface runoff. CBOD loading function is based on a relationship given by Thomann and Mueller (1987)[41].

181. The SWAT model possesses most of the attributes which are identified to be the desirable attributes that a hydrological model should possess. The SWAT model is a spatially distributed physically based model. It requires site specific information about weather, soil properties, topography, vegetation, and the land management practices being followed in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc.

[38] Arnold, J.G., Allen, P.M, and Bernhardt, G.T. 1993. A comprehensive surface groundwater flow model. Journal of Hydrology, 142: 47-69

[39] Williams, J.R. 1975. Sediment routing for agricultural watersheds. Water Resources Bulletin, 11 (5): 965-974.

[40] McElroy, A.D., Chiu, S.Y. and Nebgen, J.W. 1976. Loading functions for assessment of water pollution from nonpoint sources. EPA document 600/2-76-151, USEPA, Athens, GA

[41] Thomann, R.V. and J.A. Mueller. 1987. Principles of surface water quality modelling and control. Harper & Row Publishers, New York

are directly modelled by SWAT using these input data. This approach results in major advantages, such as:

- Un-gauged watersheds with no monitoring data (e.g. stream gauge data) can be successfully modelled.
- The relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, etc.) on water quantity, quality or other variables of interest can be quantified.
- The model uses readily available inputs. The minimum data required to make a SWAT run are the commonly available data from local government agencies.
- The model is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money.
- The model enables users to study impacts on account of human interventions which makes it very suitable for scenario generation.
- The model is also capable of incorporating the climate change conditions to quantify the impacts of change.
- The model has gained a wide global acceptability. Currently 720 peer reviewed papers have been published based on the SWAT model (http://swatmodel.tamu.edu). The current rate of publication is about 120 peer reviewed papers per year. There are more than 90 countries using the model for practical applications and at the least, more than 200 graduate students all over the world are using it as part of their M.S. or Ph.D. research program. In the U.S alone, more than 25 universities have adopted the model in graduate level teaching classes.

182. SWAT is a public domain model actively supported by the Grassland, Soil and Water Research Laboratory (Temple, TX, USA) of the USDA Agricultural Research Service.

3. SWAT Model Setup

183. **Spatial data** used in setting up the SWAT model included:

- Digital Elevation Model: SRTM, of 90 m resolution[42]
- Drainage Network – Hydroshed[43]
- Soil maps and associated soil characteristics (source: FAO Global soil)[44]
- Land use: Global Map of Land Use/Land Cover Areas (GMLULCA), IWMI's Global Map of Irrigated Areas (GMIA) (source: IWMI) [45]

184. **Hydro-meteorological** data pertaining to the river basin required for modelling include daily rainfall, maximum and minimum temperature, solar radiation, relative humidity and wind speed. These weather data were available as per following details:

- IMD gridded weather data (1971–2004) – 5 years of weather data was used as warmup/setup period for the Kshipra basin model thus outputs were available from 1976 to 2004
- Climate Change: PRECIS Regional Climate Model outputs for Baseline (1961–1990, BL) , near term (2021-2050, MC) and long term or end-century (2071-2098, EC) for A1B IPCC SRES scenario[46] (Q14 QUMP ensemble)

185. Mapping the Kshipra Basin: The ArcSWAT (Winchell et al., 2007[47]) interface was used to pre-process the spatial data for the Kshipra river system. Figure 48 shows the DEM derived from the

[42] http://srtm.csi.cgiar.org
[43] http://hydrosheds.cr.usgs.gov/
[44] http://www.lib.berkeley.edu/EART/fao.html
[45] http://www.iwmigiam.org/info/main/index.asp
[46] http://www.tropmet.res.in/static_page.php?page_id=51
[47] Winchell, M., Srinivasan, R., Di Luzio, M., Arnold, J., 2007. ArcSWAT interface for SWAT2005. User's Guide. BRC, TAES, USDA-ARS, Temple, TX

SRTM 90 data. The DEM is used in basin and sub-basin delineation. A summary of the elevation statistics is given in Table 39.

Table 39 Elevation Summary – Kshipra Basin

Parameter	Elevation (masl)
Minimum Elevation	388
Maximum Elevation	831
Mean Elevation	510

186. **Sub-basin delineation**: ArcSWAT performs automatic delineation of watersheds using the DEM with a target outflow point selected interactively. The Kshipra river basin was delineated using 5,000 ha as minimum stream threshold. This resulted in 41 sub-basins. These sub-basins are shown in Figure 49. The basin area of the Kshipra up to the basin outflow point is 562,110 ha. Care was also taken to incorporate the locations of stream gauge measurement locations while undertaking the delineation process.

187. Land use/land cover is an important element of data that is required for pre-processing. The merged landuse and irrigation source map from IWMI, as shown in Figure 50, was used for the present study. IWMI derived the Ganges River Basin Irrigated Area product using MODIS 500-m and AVHRR 10-km satellite sensor data merged with IWMI's Global Map of Land Use/Land Cover Areas, to derive a new landuse map with agriculture landuse as well as sources of irrigation. The Kshipra basin is part of the Ganga basin. Land use categories and the area covered under each is summarised in

188. Table 40. The major part of the basin is under agriculture land use, and soyabean is the predominant crop.

Figure 48: Digital Elevation Model of Kshipra Basin

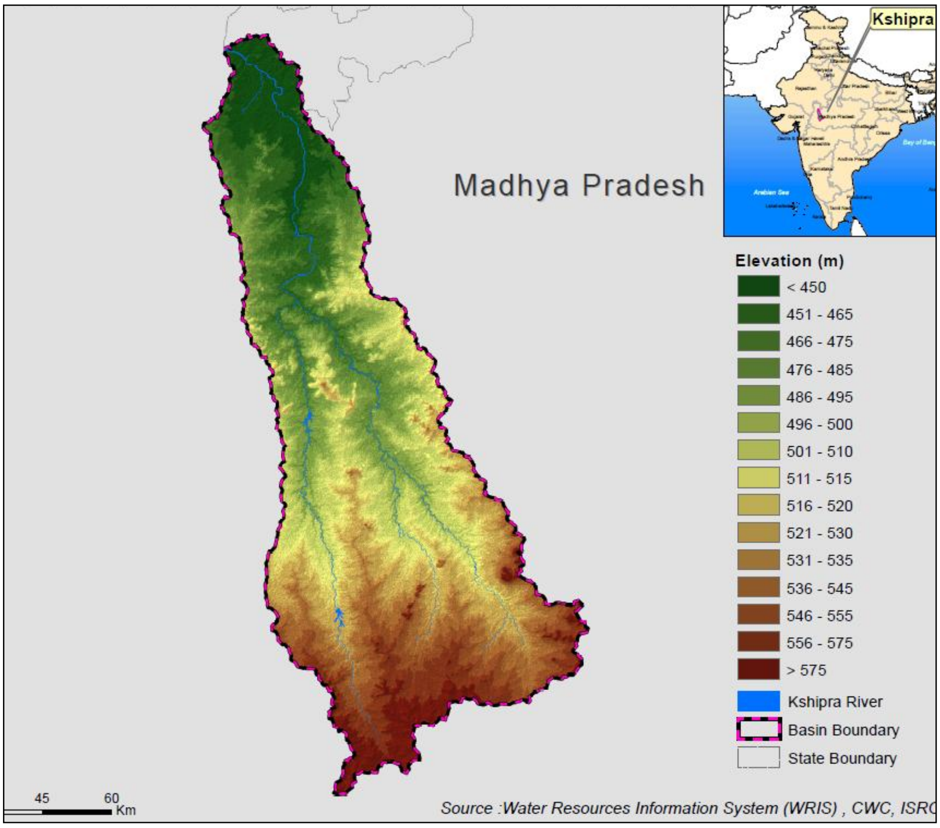


Figure 49: Sub-basin delineation

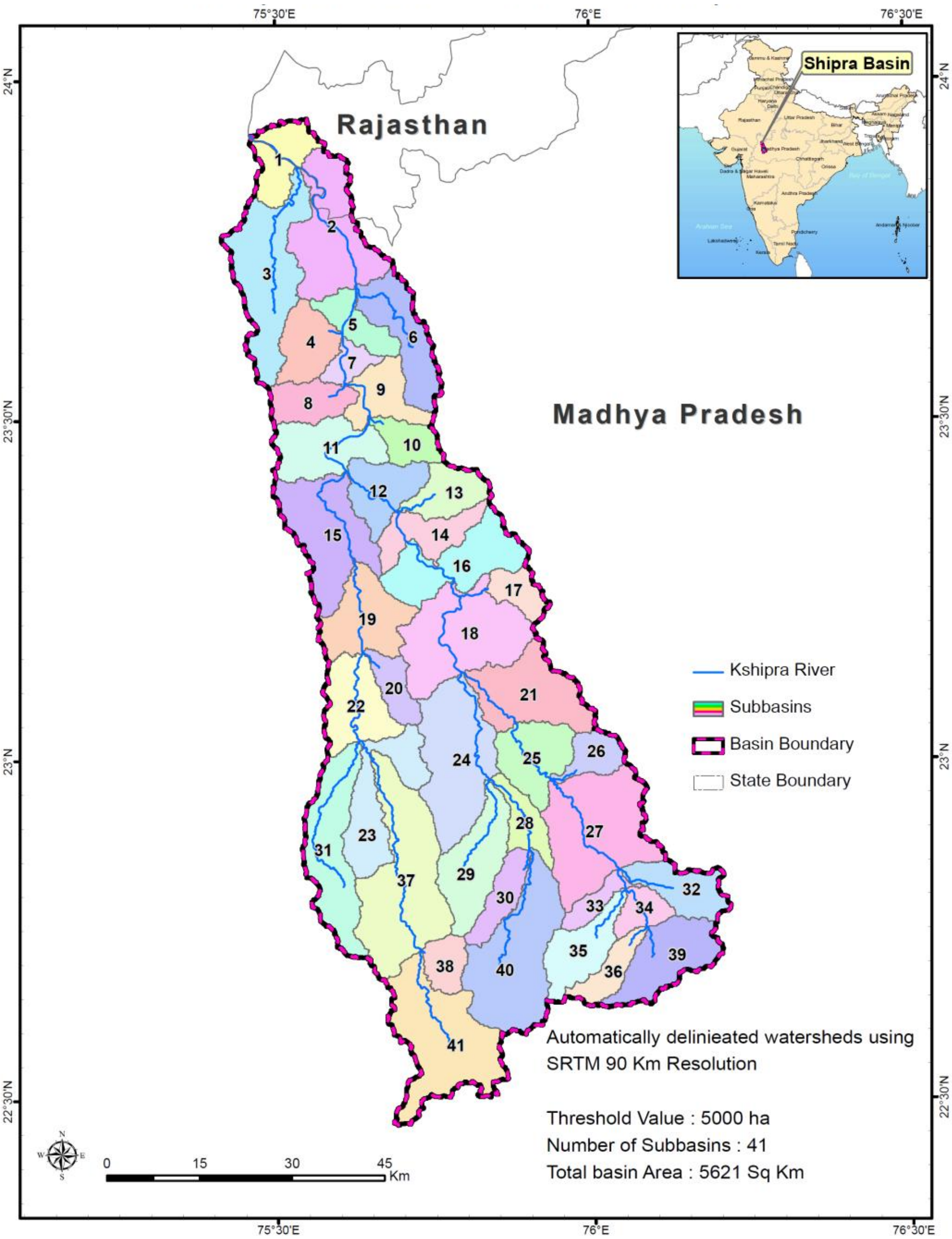


Figure 50: Kshipra Basin land use

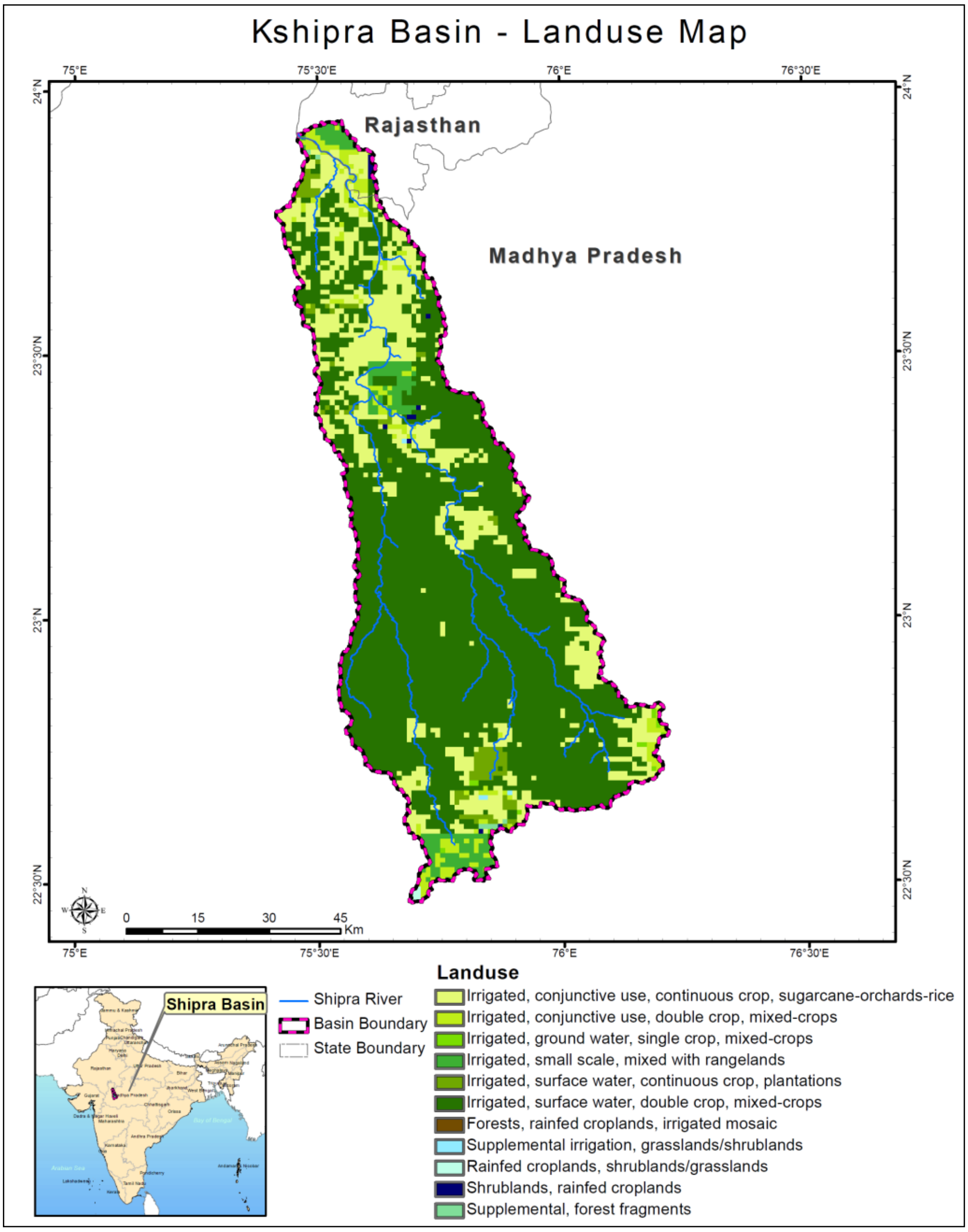
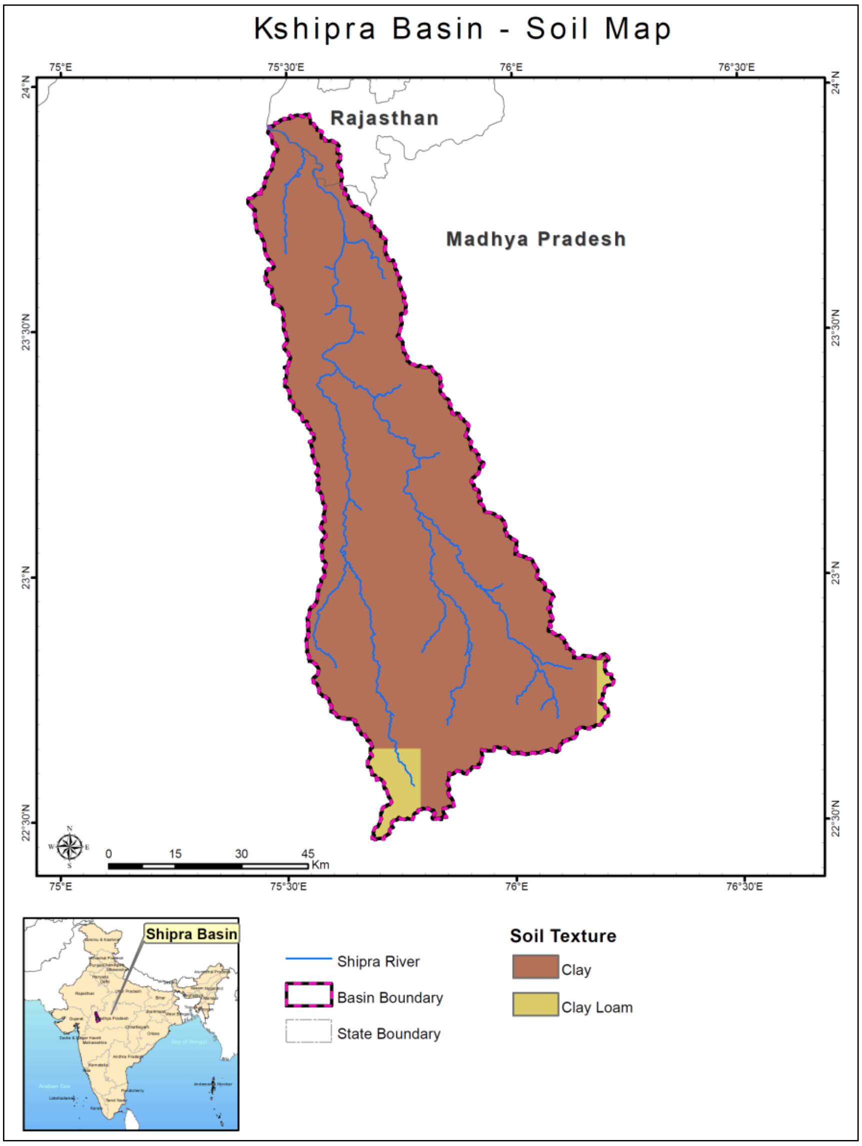


Table 40: Land use Categories – Kshipra Basin

Land Use	Area (ha)	% of Watershed Area
Wheat	126723	23
Rice	18372	3
Sugarcane	9149	2
Tomato	19495	3
Soyabean	388371	69

189. **Soils**: Information on the soil profile is required for simulating the hydrological character of the basin. In the absence of high resolution soil data, the FAO global soil map was used for the modelling of the Kshipra basin. The soil is predominantly clay. However, clay loam is also present in the south. The soils map is shown in Figure 51.

Figure 51: Kshipra Basin soils



4. SWAT Model Calibration and Performance

190. **Model Evaluation Statistics (Dimensionless):** Statistical parameters, namely regression coefficients (R^2) and Nash Sutcliffe efficiency coefficient (NSE) were used to assess the model efficiency on monthly SWAT hydrologic streamflow predictions. The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information") (Nash and Sutcliffe, 1970[48]). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. NSE is computed as:

$$NSE = \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2} \right]$$

where Y_i^{obs} is the i^{th} observation for the constituent being evaluated, Y_i^{sim} is the i^{th} simulated value for the constituent being evaluated, Y^{mean} is the mean of observed data for the constituent being evaluated, and n is the total number of observations. NSE ranges between −∞ and 1.0 (1 inclusive), with NSE = 1 being the optimal value. Values between 0.0 and 1.0 are generally viewed as acceptable

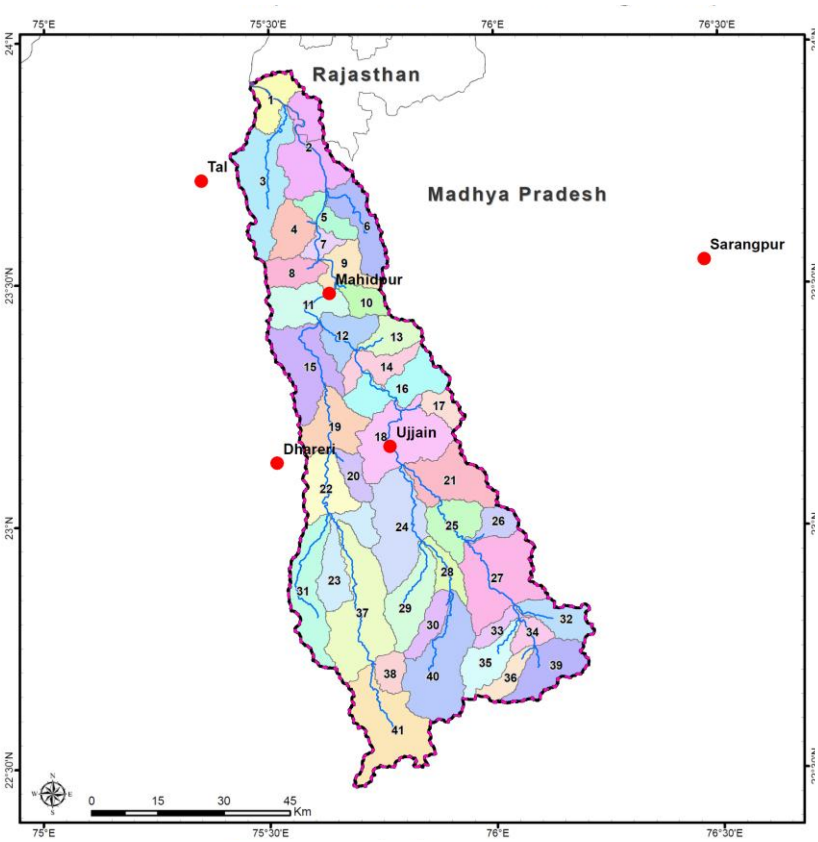
48 Nash, J. E., and J. V. Sutcliffe. 1970. River flow forecasting through conceptual models: Part 1. A discussion of principles. J. Hydrology 10(3): 282-290

levels of performance, whereas values <0.0 indicates that the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance[49].

191. **Coefficient of determination (R^2)**: Coefficient of determination (R^2) describes the degree of co-linearity between simulated and measured data. R^2 describes the proportion of the variance in measured data explained by the model. R^2 ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Santhi et al., 2001[50], Van Liew et al., 2003[51]). R^2 is oversensitive to high extreme values (outliers) and insensitive to additive and proportional differences between model predictions and measured data (Legates and McCabe, 1999[52]).

192. Model validation has been made using the observed data for the period 1976-2004 at monthly scale. For this purpose data from 2 stream flow monitoring stations (Figure 52) were available. Before performing statistical comparison of streamflows, the reasonableness of the model for general evapotranspiration, runoff, base flow/return flow, and crop yields against district averages were analyzed and found satisfactory. The SWAT model results and time series plots are presented in Table 41 and Figure 53 and Figure 54 for each observation stream flow station. The long-term simulation monthly mean at all drainage area levels are on par with observed means, the R^2 and Coefficient of efficiency are above literature acceptable ranges from 0.79 to 0.82 and 0.45 to 0.82 respectively.

Figure 52 Kshipra Basin – Observed Stream gauge locations



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[49] Moriasi, D. N., J. G. Arnold, M. W. Van Liew, R. L. Bingner, R. D. Harmel, and T. L. Veith, 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations, Transactions of the ASABE, Vol. 50(3): 885−900 2007

[50] Santhi, C, J. G. Arnold, J. R. Williams, W. A. Dugas, R. Srinivasan, and L. M. Hauck. 2001. Validation of the SWAT model on a large river basin with point and nonpoint sources. J. American Water Resources Assoc. 37(5): 1169-1188

[51] Van Liew, M. W., J. G. Arnold, and J. D. Garbrecht. 2003. Hydrologic simulation on agricultural watersheds: Choosing between two models. Trans. ASAE 46(6): 1539-1551

[52] Legates, D. R., and G. J. McCabe. 1999. Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation. Water Resources Res. 35(1): 233-241

Table 41: SWAT model efficiency parameters for the Kshipra Basin

Gauge Site	Catchment Area*(km^2)	Mean Flow*(m^3/s)	Start Year	End Year	COE**	Correlation coefficient
Ujjain	2070 (2288)	12.9 (15.8)	1976	2009	0.45	0.79
Mahidpur	4430 (4467)	29.8 (30.6)	1976	2009	0.66	0.82

Note: * Model parameter is shown in bracket, ** Nash-Sutcliffe coefficient

Figure 53: Kshipra Basin – Calibration at Ujjain

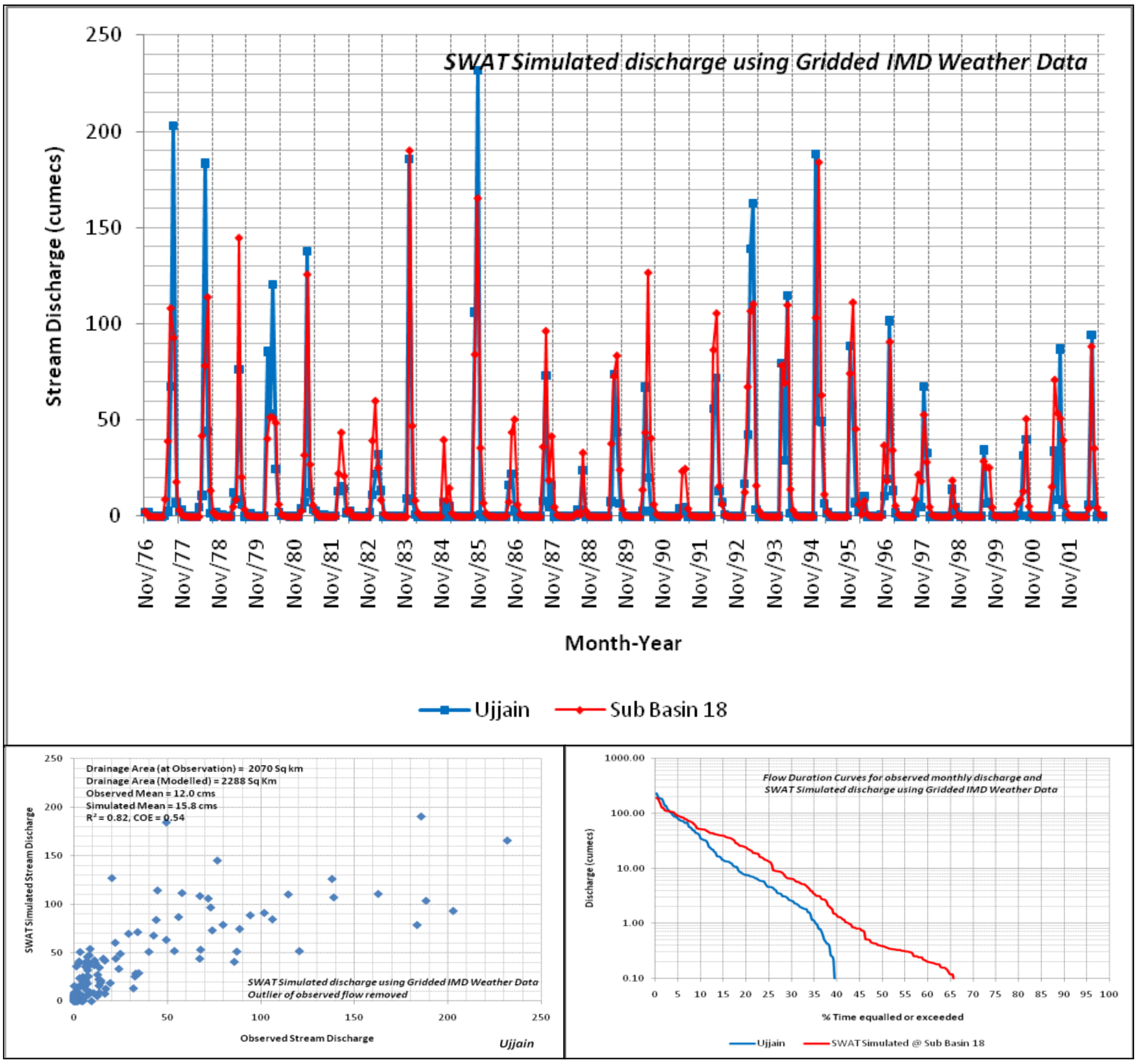
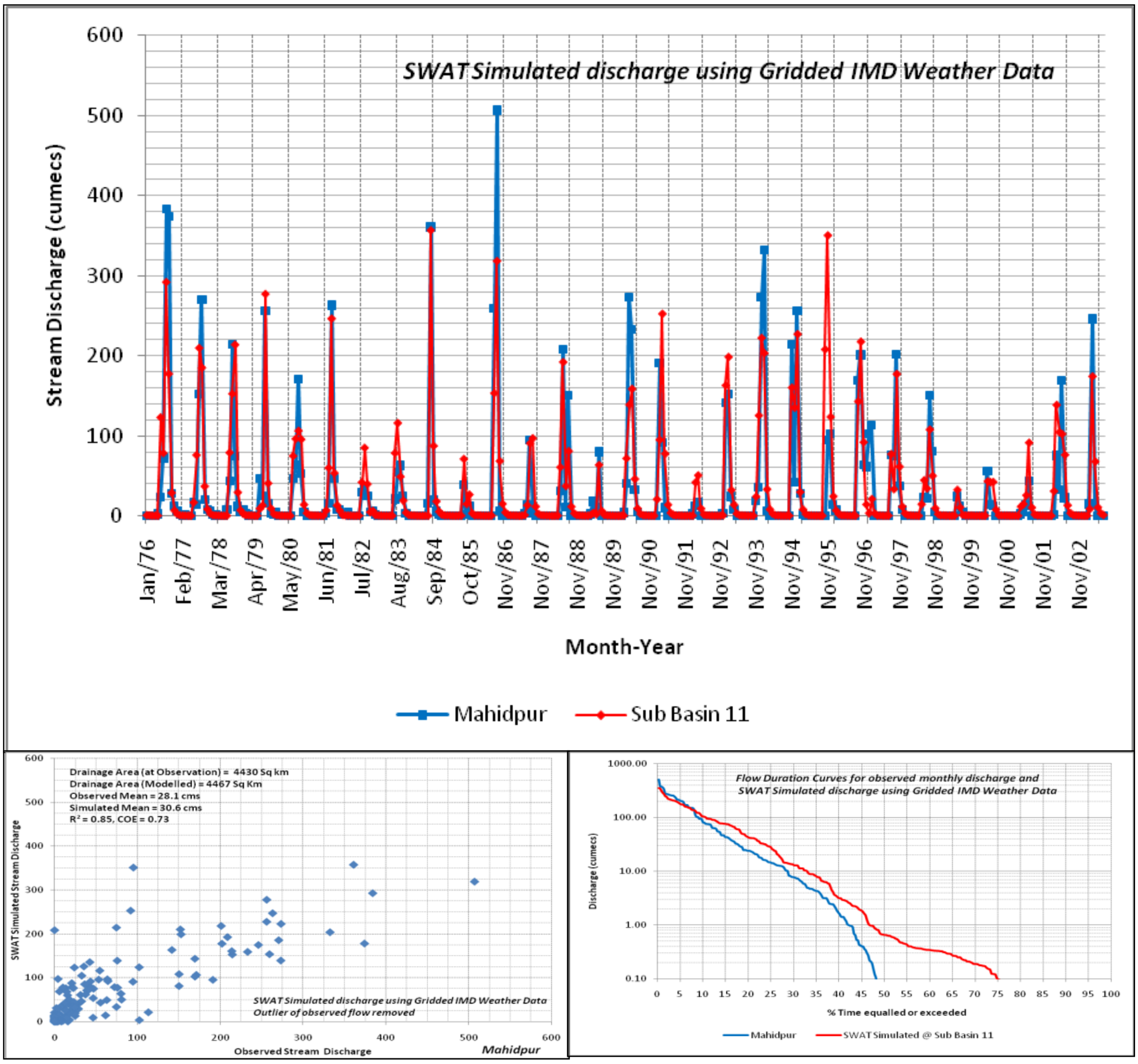


Figure 54: Kshipra Basin – Calibration at Mahidpur



5. Modelling Climate Change Impacts on Hydrological Response

193. **Model Outputs**: The outputs provided by the model are very extensive, covering all the components of water balance spatially and temporally. The sub components of the water balance that are most significant and used for analyses, include:

- Precipitation
- Total flow (Water yield) consisting of surface runoff, lateral and base flow
- Actual evapotranspiration (Actual ET)

194. Mean annual and seasonal precipitation is shown in Figure 55, and the coefficients of variation in Figure 56. Most precipitation occurs during the southwest monsoon and coefficients of variation during this period are significantly lower than during the northeast monsoon.

Figure 55 Kshipra Basin – Annual, JJAS and OND precipitation

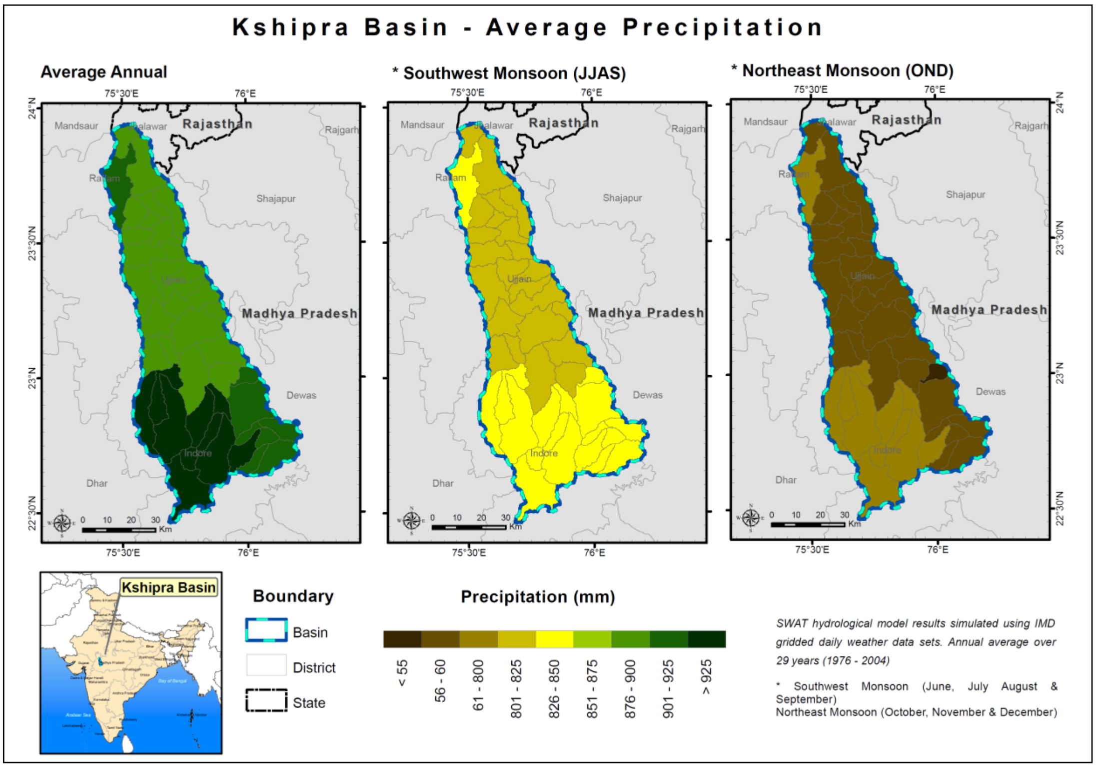
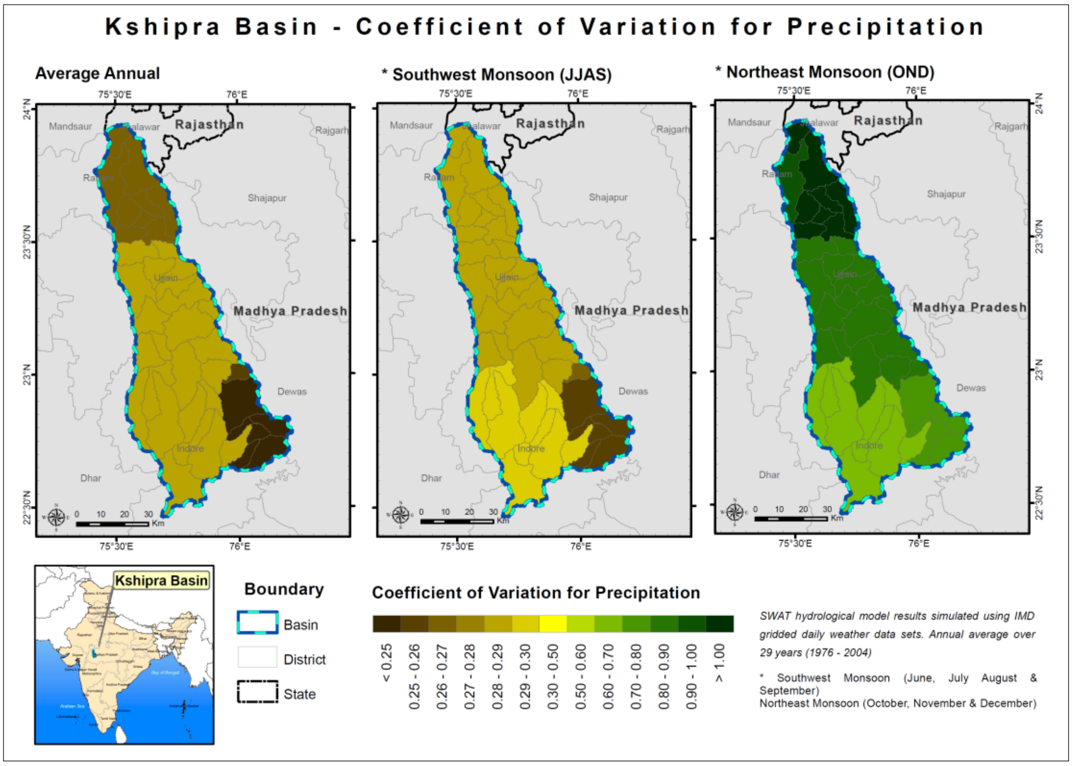


Figure 56 Kshipra Basin – Coefficient of Variation in Annual, JJAS and OND precipitation



195. **Simulation with A1B baseline**: Prior to analysis of climate change scenarios, and assessment was made how well the characteristics of SWAT streamflows simulated from the PRECIS A1B baseline weather, matched with those simulated from observed weather. Figure 57 presents a comparison of mean monthly discharges at Ujjain and Mahidpur simulated from observed weather and

from the PRECIS A1B baseline weather. The indication is that the PRECIS simulation of baseline weather is quite satisfactory. Comparison of mean monthly flows is given in Table 42

Figure 57: Mean Monthly Discharges Simulated from Observed and PRECIS A1B Baseline

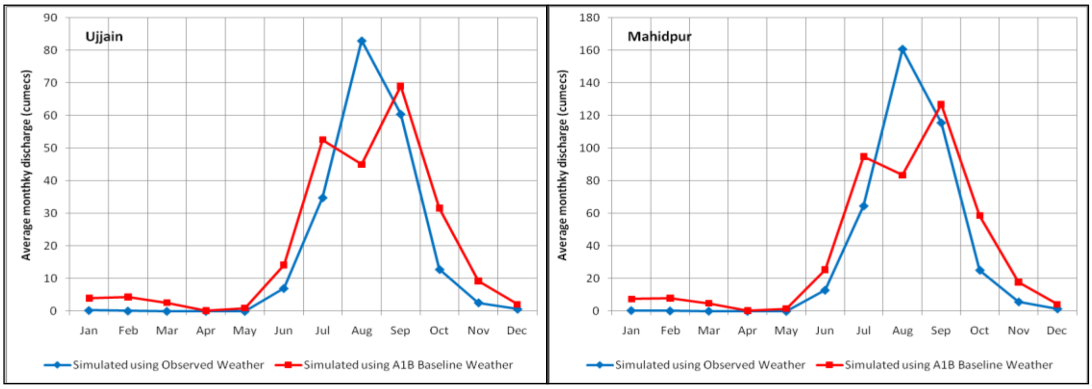


Table 42: Mean Monthly Flows simulated from Observed and PRECIS A1B Baseline Weather

Date	Mahidpur flows (m^3/s)		Ujjain flows (m^3/s)	
	Simulated using Observed Weather	**Simulated using A1B Baseline Weather**	**Simulated using Observed Weather**	**Simulated using A1B Baseline Weather**
Jan	0.50	7.47	0.27	3.98
Feb	0.27	7.93	0.10	4.35
Mar	0.12	4.84	0.01	2.59
Apr	0.01	0.31	0.00	0.15
May	0.00	1.61	0.00	0.97
Jun	12.93	25.38	7.02	14.16
Jul	64.55	94.82	34.85	52.60
Aug	160.63	83.54	83.01	45.02
Sep	115.53	126.89	60.49	69.06
Oct	25.18	58.67	12.83	31.60
Nov	5.80	17.85	2.62	9.26
Dec	1.50	4.24	0.65	2.09
Mean	32.25	36.13	16.82	19.65
CV	0.67	0.63	0.65	0.62

196. **Potential climate change impacts:** climate change and climate variability will affect irrigated agriculture, installed power capacity, drought frequency and duration, flood frequency, water supply, and urban drainage.

197. **Approach and methodology**: the calibrated SWAT model was used to run the climate change scenarios. For the analysis the weather conditions of the present and future have been provided by the IITM Pune[53] at daily interval and at a resolution of about 50 km. Simulated climate outputs from PRECIS for present (1961–1990, BL) near term (2021-2050, MC) and long term (2071-2098, EC) for A1B SRES scenario Boundary conditions for the RCM were from one realisation of the Hadley Centre HADCM3 QUMP (Quantifying Uncertainty in Model Predictions) ensemble (Q14).

198. The SWAT model has been used to determine present water availability in space and time without incorporating any man made changes like dams, diversions, etc. The same framework was then used to predict the impact of climate change on the water resources with the assumption that the land use does not change over time. A total of 90 years of simulation was conducted; 30 years belonging to IPCC SRES A1B baseline (BL), 30 years belong to IPCC SRES A1B near term or mid-

[53] PRECIS (Providing Regional Climate for Impact Studies) is the Hadley Centre portable regional climate model, developed to run on a PC with a grid resolution of 0.44° x 0.44°. PRECIS simulation datasets is provided by the Indian Institute of Tropical Meteorology, Pune

century (MC) climate scenario and 30 years belong to IPCC SRES A1B long term or end-century (EC) climate scenario.

199. Projected changes in precipitation in the Kshipra catchment have been discussed as part of the climatic assessment reported in section III of this report. The detailed outputs of the SWAT hydrological model were analysed with respect to the two major water balance components of water yield and actual evapotranspiration. These are significantly influenced by the intensity and temporal distribution of precipitation, and by the weather conditions dictated by temperature and allied parameters. All the analyses have been performed by aggregating the inputs/outputs at the sub-basin level that are the natural boundaries controlling the hydrological processes.

200. **Analysis of Change in Water balance components**: the outputs have been analyzed with respect to the baseline considering possible impacts on the runoff, baseflow, actual evapotranspiration and ground water recharge to mid-century and end-century. Table 43 gives the summary of changes in water balance components as percentage of the change in precipitation from baseline to mid century.

201. The PRECIS A1B scenario indicates an increase in annual precipitation in the Kshipra basin of about 16% by mid-century. The model results indicate that around 83% of this increase in precipitation will get converted to runoff. Baseflow which contributes to stream flow during dry periods will increase by 4%. An increase in aquifer recharge of 17% is projected, and a decrease in evapotranspiration of 4% is projected.

202. **Figure 58** shows the distribution of the major water balance components expressed in terms of percentage change to mid-century. The figure also shows the change in water balance component averaged over the entire basin expressed as a depth (mm) in bar chart form.

203. Precipitation changes vary locally in magnitude, sign, and seasonal details for the Kshipra basin. Seasonal changes in precipitation and its effect on water balance components obtained from the SWAT model for the A1B scenario are included for JJAS (southwest monsoon) and OND (North east monsoon) in Table 43. There is an increase in JJAS precipitation in the Kshipra basin of about 23% by mid-century. The model results indicate that around 70% of this increase in precipitation will get converted to runoff and 4% to baseflow. Aquifer recharge increases by 29% and evapotranspiration decreases by 4%.

204. Figure 59 shows the change in the major water balance components expressed in terms of percentage for the JJAS season to mid-century. From Figure 59 it can be seen that most of the increased precipitation forms runoff and groundwater recharge. The indication is that in parts of the basin surface runoff would double under the A1B scenario. This should be treated as a very optimistic projection from a water resources perspective, but would offer opportunities for increased water harvesting and groundwater recharge. A concern should be the potential impact on drainage and on flood risk. Clearly this should be investigated further, and drainage design criteria reviewed. The bar chart depicts the water balance component averaged over the entire basin and expressed as a depth (mm).

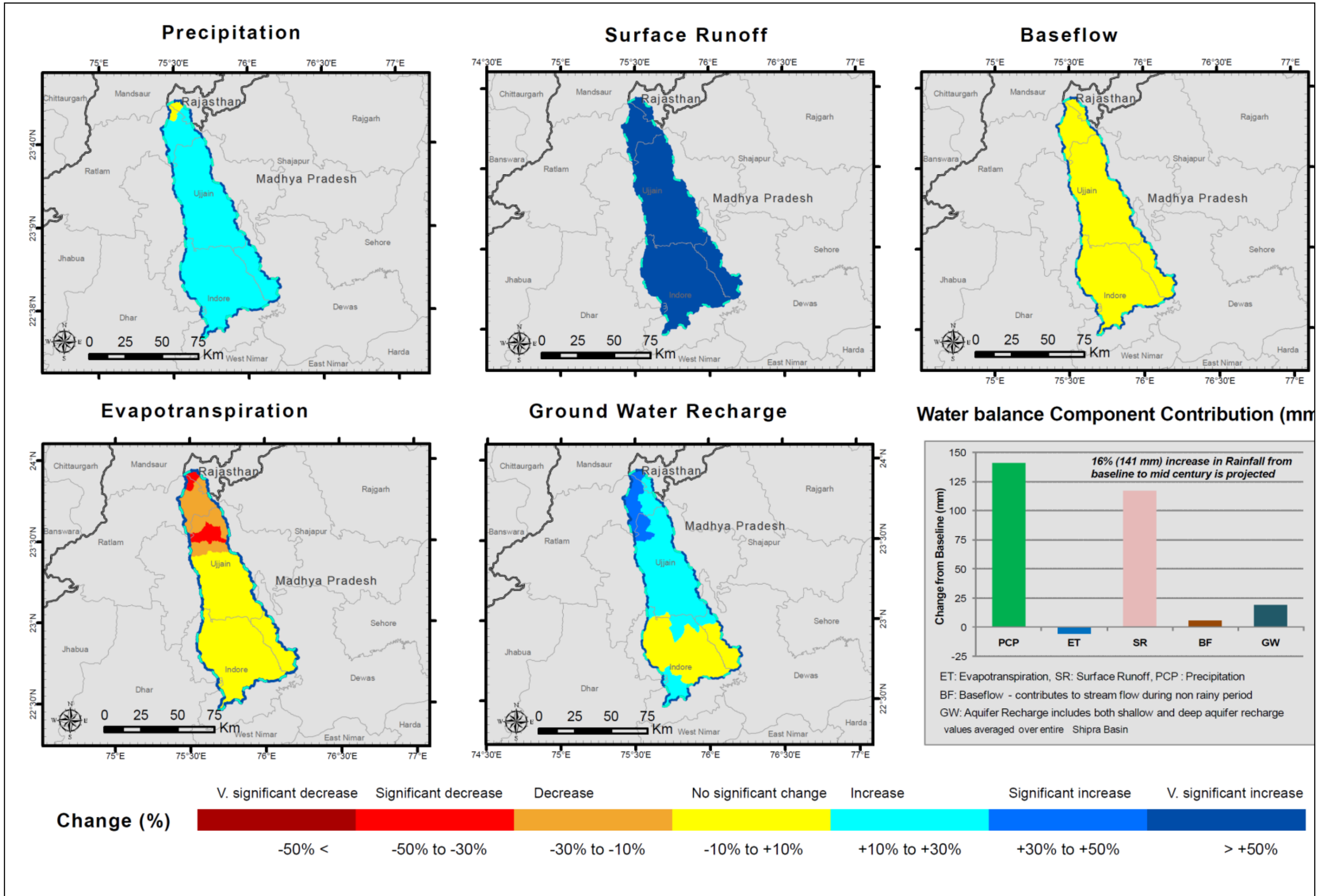
Table 43: Summary of Change in water balance++ expressed as percent change in precipitation

Scenario/Season	Precipitation	Evapotranspiration	Surface Runoff	Baseflow+	Total Water Yield*	Ground Recharge**
Avg Annual (A1B-Baseline)	883	699	180	42	222	354
Avg Annual (A1B-Mid Century)	1023	694	297	47	345	378
Percent Change in precipitation	16					
Net change (mm)	141	-6	117	6	122	25
Change (%)***		-4	83	4	87	17
Avg JJAS (A1B-Baseline)	745	274	155	17	173	311
Avg JJAS (A1B-	918	266	275	25	300	362

Mid Century)						
Percent Change in precipitation	23					
Net change (mm)	173	-7	120	8	128	51
Change (%)***		-4	70	4	74	29
Avg OND (A1B-Baseline)	68	120	19	19	38	12
Avg OND (A1B-Mid Century)	55	133	20	22	42	3
Percent Change in precipitation	-19					
Net change (mm)	-13	13	1	3	3	-9
Change (%)***		-100	-6	-20	-27	67
+: Baseflow: contributes to stream flow during non rainy period * Water Yield (streamflow): surface runoff+baseflow+lateral flow ** Groundwater Recharge: shallow and deep aquifer recharge ***Distribution of water balance components as percentage of change in precipitation						

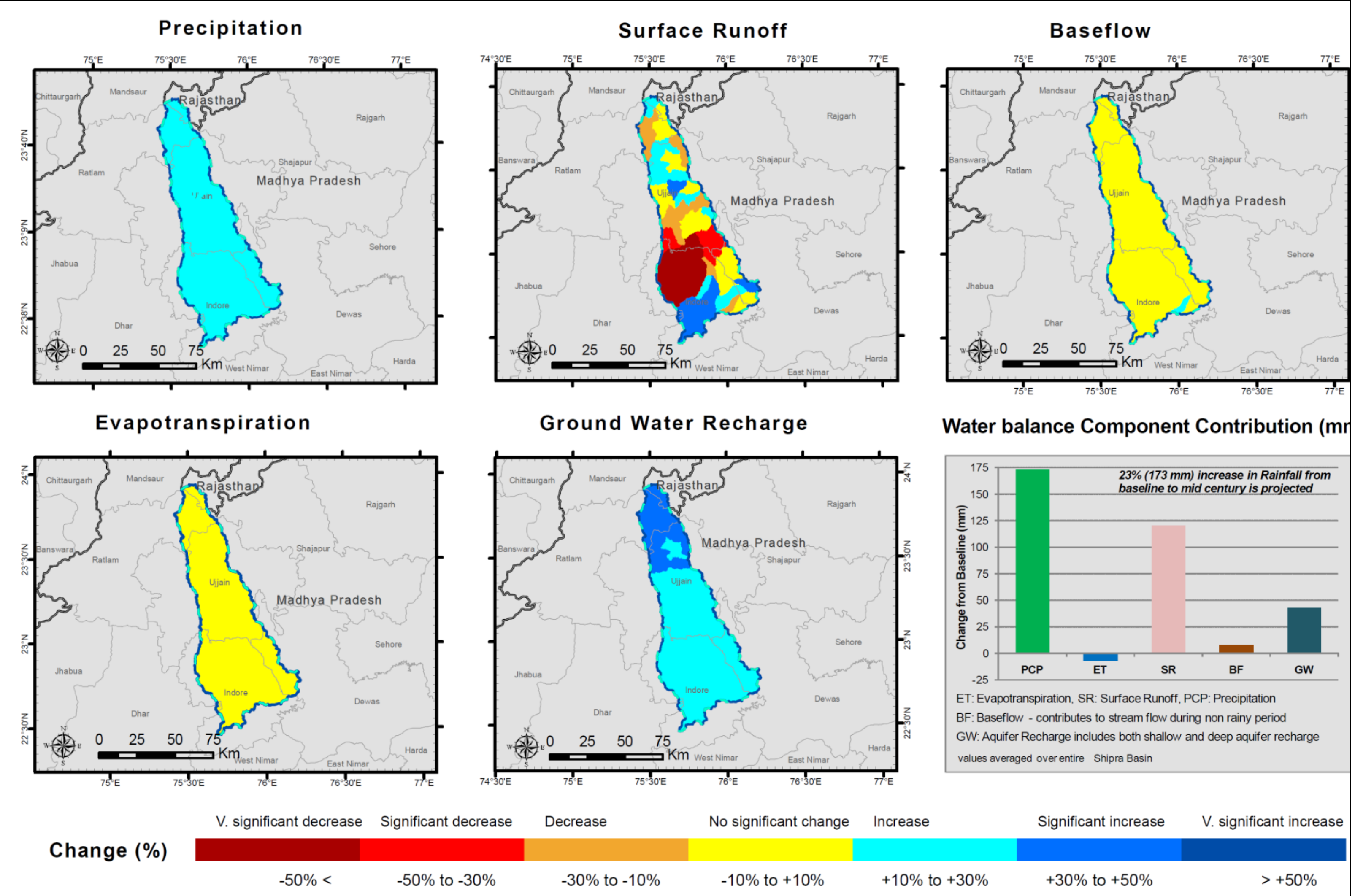
++ All units are in millimetres

Figure 58: Change in Annual Water Balance to Mid Century



SWAT hydrological model results simulated using PRECIS RCM IPCC SRES A1B daily weather datasets provided by the Indian Institute of Tropical Meteorology, Pune

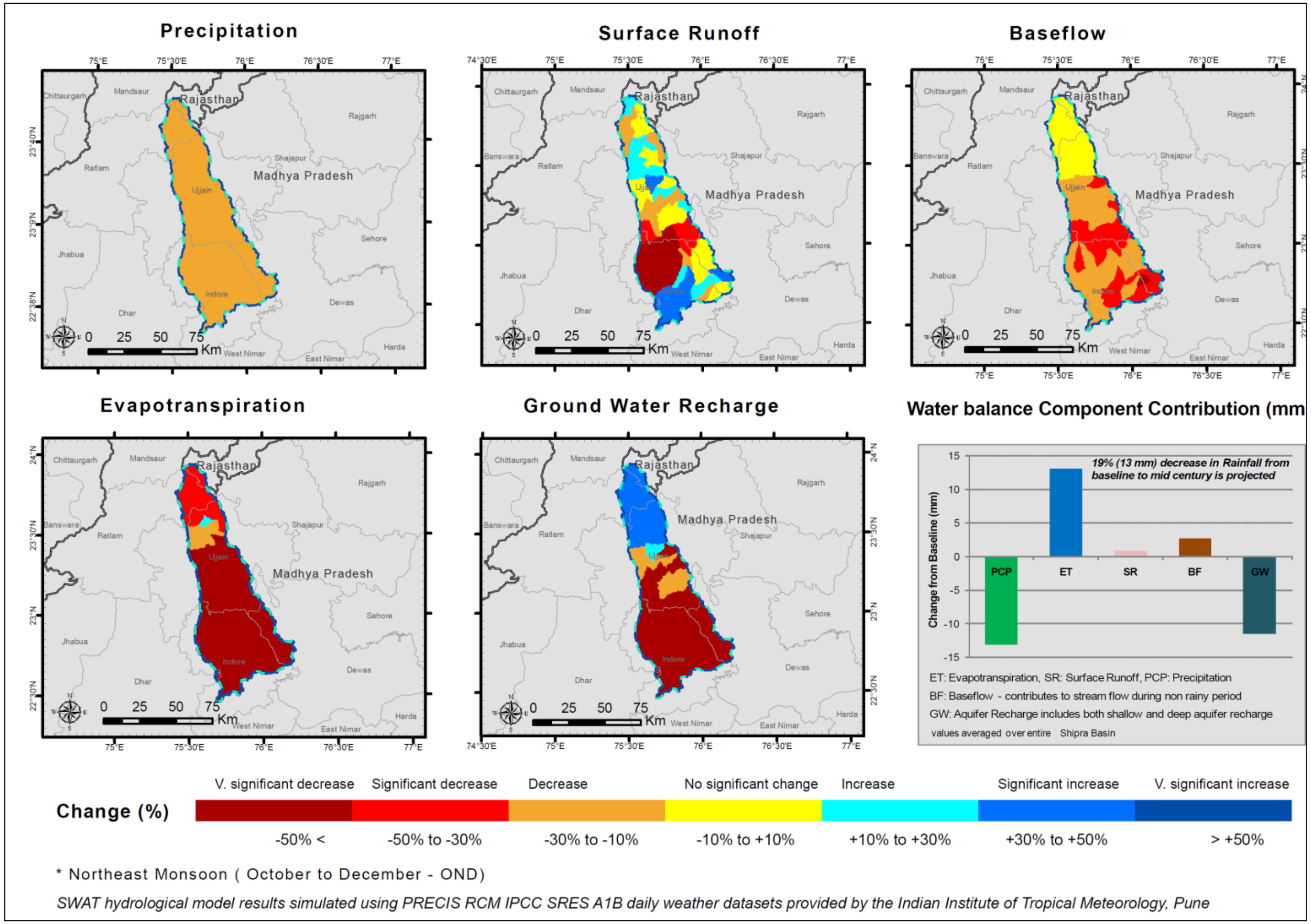
Figure 59 Change in JJAS Water Balance to Mid Century



* Southwest Monsoon (June to September - JJAS)

SWAT hydrological model results simulated using PRECIS RCM IPCC SRES A1B daily weather datasets provided by the Indian Institute of Tropical Meteorology, Pune

Figure 60 Change in OND Water Balance to Mid Century



205. During the Rabi season (OND), precipitation is projected to decrease by 13% by mid-century under the A1B scenario, resulting in a 67% decrease in ground water recharge. Evapotranspiration is projected to increase and base flow is projected to decrease. Figure 60 presents the changes in water balance components in percentage form. Average changes over the basin are included in a bar chart and expressed as depths (mm). During this season changes appear large when expressed in percentage terms, but the changes are to small numbers.

206. Annual average streamflow is projected to increase because of climate change, with the largest increase occurring in southwest monsoon period (JJAS). There is a reduction during northeast monsoon (OND). The disproportionate change in average annual streamflow relative to the increase in average annual precipitation, can be attributed to more precipitation falling on saturated soils. Increase in evapotranspiration is more during northwest monsoon period (OND). The bar chart depicts the water balance component averaged over the entire basin as depth in mm, as a result of decrease in rainfall by 13 mm

207. Drought analysis: Drought indices are widely used for the assessment of drought severity by indicating relative dryness or wetness effecting water sensitive economies. The Palmer Drought Severity Index (PDSI) is one such widely used index that incorporates information on rainfall, land-use, and soil properties in a lumped manner (Palmer, 1965[54]). The Palmer index categorize drought into different classes. PDSI value below 0.0 indicates the beginning of drought situation and with a value below -3.0 as severe drought condition.

208. A soil moisture index has been developed (Narasimhan and Srinivasan, 2005[55]) to monitor drought severity using SWAT output to incorporate the spatial variability. This has been used to focus on agricultural drought where severity implies cumulative water deficiency. Weekly information has been derived using daily SWAT outputs which in turn have been used for subsequent analysis of drought severity.

209. The severity of drought is proportional to the relative change in climate. For example, if a climate that usually has very nominal deviations from the normal even experiences a moderate dry period, the effects could be quite dramatic. On the other hand, a very dry period would be needed in a climate that is used to large variations to produce equally dramatic effects. In the current context scale 1 (Index between 0 to -1) represent the drought developing stage and scales 2 (Index between -1 to -4) represent mild to moderate and extreme drought conditions.

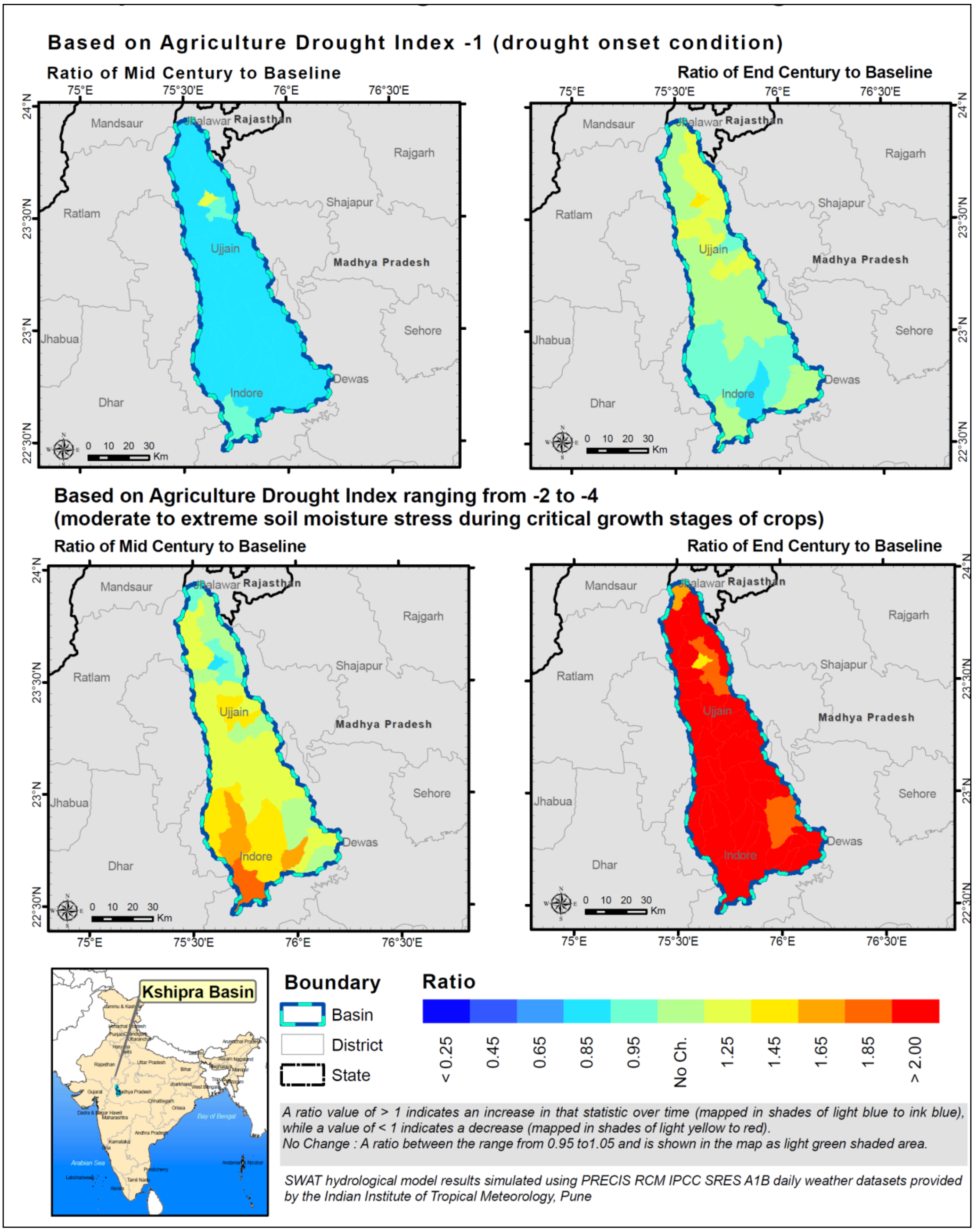
210. For the present study, the Soil Moisture Deficit Index (SMDI) was calculated for 30 years of simulated soil moisture data from baseline (1961-1990), MC (2021-2050) and EC (2071-2098). Weeks when the soil moisture deficit may start drought development (drought index value between 0 to -1) as well as the areas which may fall under moderate to extreme drought conditions (drought index value between -1 to -4) have been assessed and are shown in Figure 61.. The indication is that the number of mild developing drought weeks decreases over most of the area to mid-century, but then increases a little towards to end-century. The number of severe drought weeks on the other hand increases a little to mid-century, and significantly to end-century. This is indicative of greater variability in climatic conditions. Thus while on average the water resource situation is projected to improve under the A1B scenario with higher average rainfall, droughts will be more severe when they do occur.

211. The concept of a drought week is reflective of the change in the normal moisture condition of a location. In this sense, if a dry or desert area is analysed which has uniform conditions over a long period, it shall declare all the weeks to be normal weeks since there is no change in the character of the area on the basis of the conditions prevalent in the specific week of the year over a long period e.g., 30 years.

[54] Palmer, W.C., 1965. Meteorological drought. Research Paper 45. U.S. Department of Commerce, Weather Bureau, Washington, D.C. 58pp.

[55] Narasimhan, B. and Srinivasan, R., 2005. Development and evaluation of Soil Moisture Deficit Index (SMDI) and Evapotranspiration Deficit Index (ETDI) for agricultural drought monitoring, Agricultural and Forest Meteorology 133 (2005) 69–88

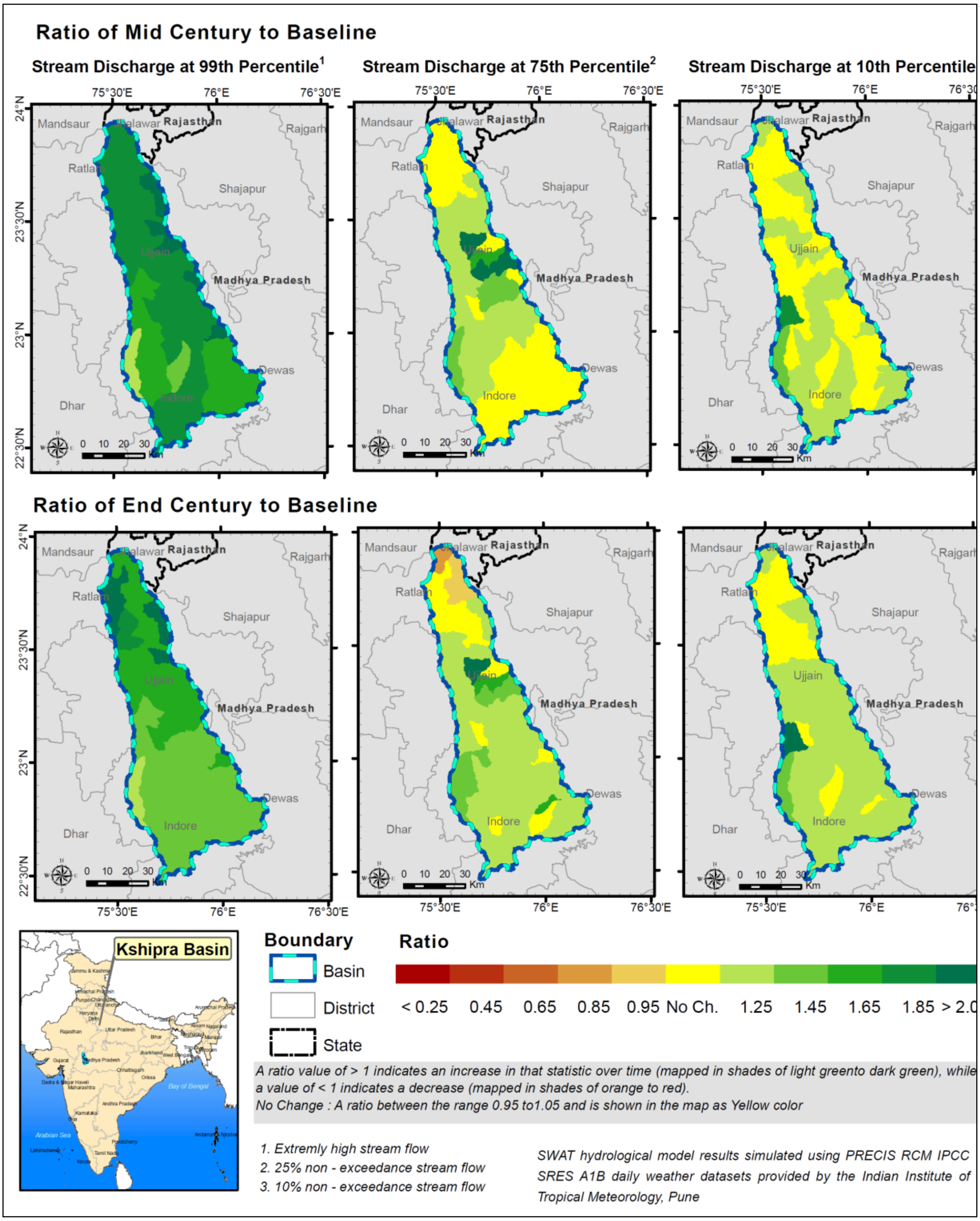
Figure 61: Change in Monsoon Drought Weeks with Respect to Baseline



212. **Changes in flood discharges**: An assessment has been made of changes in simulated maximum daily discharges for each sub-basin. Analysis was directed at identifying the basins where flooding conditions may deteriorate under the A1B scenario. Changes in the magnitude of flood peaks above 99^{th} percentile flow for baseline (1961-1990), MC (2021-2050) and EC (2071-2098) are shown in Figure 24. Very significant increases are indicated, with the majority of basins showing increases in flood flows of between 45% and 100%. This could have a significant implication for existing infrastructure such as dams, bridges, roads, etc., and will require appropriate adaptation measures to be taken up. The situation changes to certain extent towards the end-century where the extent of increase reduces to around 45 to 65% for the majority of the area. While these changes in runoff response are based on one climate scenario, it is clear that attention must be given to drainage design and flood mitigation design criteria.

213. Figure 62 also shows the changes discharge at non-exceedance probabilities of 25% and 10%, from baseline to mid-century and end-century Kshipra Flows at 25% and 10% non-exceedance probability show an increase, indicating increased flow reliability.

Figure 62: Annual Average Flow Dependability towards 2030s and 2080s with respect to 1970s



The National Water Mission (NWM) of the National Action Plan for Climate Change in 2008 produced a broad range of recommendations towards climate adaptation for the water resources and related sectors. Parts of the NWM are now being taken up; there are however major requirements for strategy and mechanisms to implement an integrated programme for climate change adaptation for water resources. Responding to this gap, the 'Support to the National Mission TA Study' has identified core actions at the central and state levels; building on the NWM recommendations as well as meeting requirements for sustainable water resources, the study has developed proposals towards a viable and workable set of initiatives and programmes for climate change adaptation.