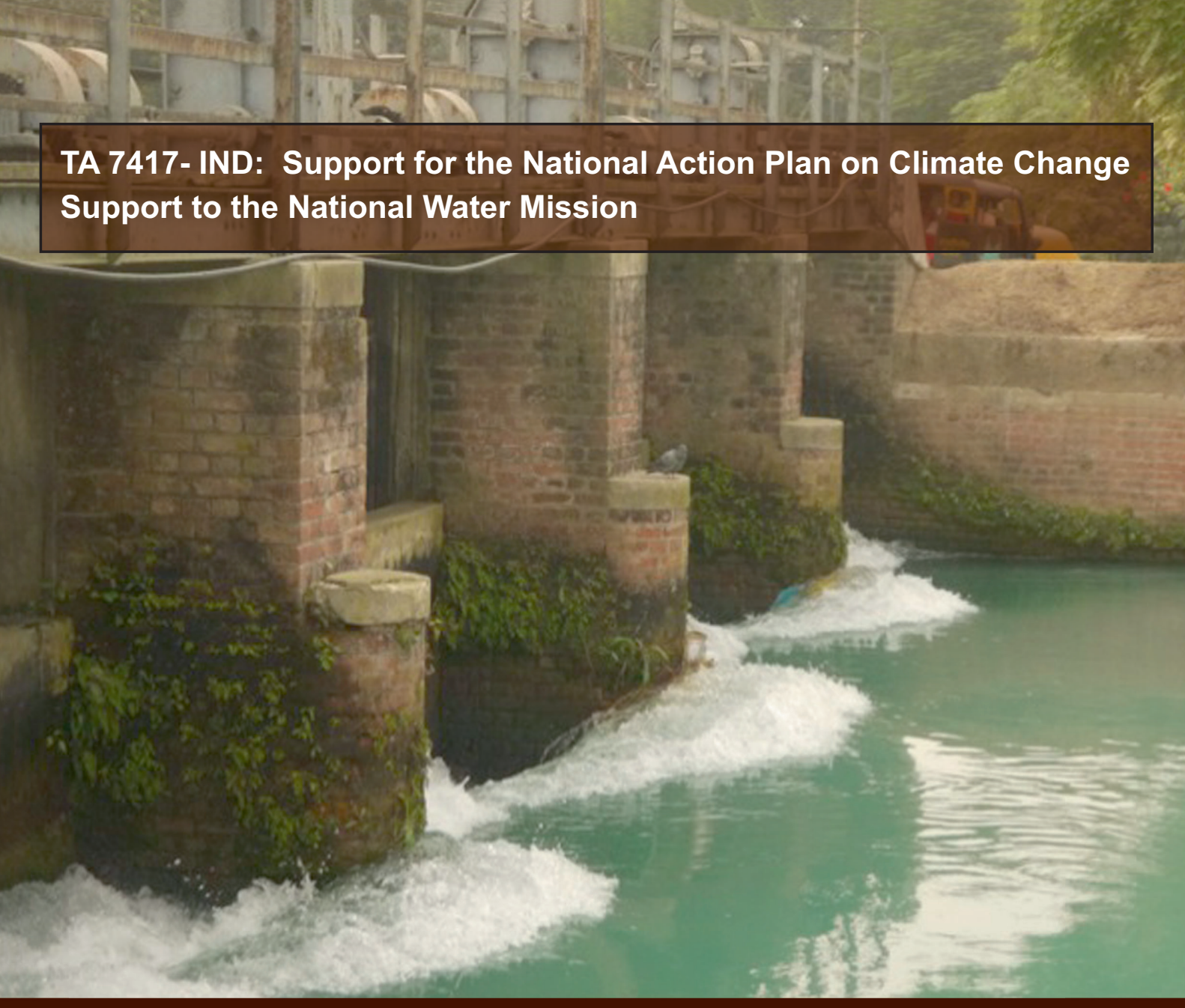
TA 7417- IND: Support for the National Action Plan on Climate Change
Support to the National Water Mission



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PREPARED FOR
Government of India
Governments of Punjab, Madhya Pradesh and Tamil Nadu
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EXECUTIVE SUMMARY

1. INDIA WATER SYSTEMS

India is a country which is and will continue to be severely impacted by climate variability precisely at a time when it is confronted with huge development imperatives For India, the focus of climate change action cannot just be emissions but must equally address the important issue of adaptation. India is already subject to high degrees of climate variability resulting in droughts, floods and other extreme weather events.

There still are large gaps in the understanding and projections of climate and hydrology at the basin level. As 'Business as usual' cannot continue new thinking and approaches are urgently needed.

The Technical Assistance to Support the National Water Mission (S_NWM) of the National Action Plan for Climate Change (NAPCC) was developed following a request[1] from the Department of Economic Affairs (DEA) on behalf of MOWR for ADB to assist towards the preparation of specific studies which would help to operationalise the National Water Mission (NWM) of the NAPCC. The study commenced in August 2010 and was completed end July 2011.

Project Rationale: The National Water Mission (NWM) to the NAPCC in 2008 produced a broad range of recommendations towards climate adaptation for the water resources and related sectors. The NWM identifies the main actions to be taken, appropriate mechanisms for coordination, and highlights the need for intensive capacity building and awareness raising. Although some parts have been taken up for study, there is only a limited strategy and mechanisms to implement the recommendations. Responding to this gap, the S_NWM study has identified core actions at the central and state levels to move the NWM recommendations towards a viable set of initiatives and investments.

The study's main outputs are strategic frameworks to identify and address the main areas of adaptation to climate change at two levels.

(i) **Strategic Frameworks for the India Water Systems:** Broad strategies for water resources related to climate adaptation and the establishment of Integrated Water Resources Management (IWRM).

(ii) **Strategic Frameworks for Three Pilot Sub basins:** Location specific strategic frameworks for the three pilot sub basins selected as focal areas for study and planning. For each sub basin, strategies were developed to address present issues and projected adaptation needs. These cover the scope for increased water efficiencies and other parallel measures to use water more sustainably and equitably.

Pilot Sub-basins were selected as shown in Table 1 based on the type and likely degree of sensitivity to climate change with specific reference to the three major areas of concern: (i) alterations of winter snow-pack dynamics from climate change likely to cause impacts on downstream areas; (ii) basins or sub basins where groundwater is an important water source with issues; and (iii) coastal areas where sea level rise will have impacts on surface and groundwater and increased flood risk.

Table 1: Sub Basins selected for S-NWM Study

	Category	Sub Basin	State
1	Snow fed	Sutlej	Punjab
2	Groundwater	Kshipra	Madhya Pradesh
3	Coastal	Cauvery Delta	Tamil Nadu

The study was implemented in close coordination with central and state Governments. It involved a high level of participation and consultation at all levels, including a detailed participatory rural appraisal with farmers and extensive consultations with stakeholders including civil society groups and researchers. The approach has been to assess the

[1]DEA request for assistance by ADB from the GOI (Ministry of Water Resources) through DEA, for support towards the operationalisation of the Implementation Plan of the National Water Mission of the NAPCC, was received on the 9 October 2009.

climate change issues and the hydrological response to them along with an in depth assessment and diagnosis of the specific problems of the three selected sub-basins. The approach is summarised in Table 2.

Table 2: Sub Basin Framework Planning

Sub-Basin Profile	ASSESSMENT OF CURRENT SITUATION AND ISSUES	
	Resource assessments, precipitation, surface and ground water resources and snow glacier, storages and sea	Assessment of surface and ground water resources identification of trends
	Agriculture, irrigation and drainage	Review of agricultural, irrigation and drainage issues
	Water supply/industry	Review and assessment of domestic and industrial water supply
	Environment	Assessment of environment issues
	Water Sector Communities and Stakeholders	Participatory rural appraisal with farmers and stakeholders
	Institutions	Institutional review and assessment
Strategic Frameworks for Climate Change Adaptation	STRATEGIC FRAMEWORK PLANNING	
	Strategies to Address Present Issues	Proposed approaches to meet development needs and sustainability
	Climate Change Scenarios	Assessment of projected climate changes temperature, precipitation, evaporation using PRECIS.
	Water Resources Response	Use of the SWAT model to analyse hydrological response to climate scenarios.
	Vulnerabilities to Impacts of Climate Change	Assessing vulnerabilities to and testing robustness of the planned strategy to impacts of climate change..
	Framework Plan for Climate Change Adaptation and Sustainability	Framework plan outlining objectives and the plan components. Plan discussed and endorsed by stakeholders

The India Water Systems assessment and proposals have been derived from the experiences in the pilot sub-basins as well as through consultations with government staff, and researchers at State and Central levels, as well as a review of relevant work nationally and internationally.

Summary of Findings

Water is a very critical element through which climate change impacts will be experienced. The Indian economy relies heavily on climate sensitive sectors like agriculture, water resources, energy and environment. Improved and more accurate climate assessments will have limited value unless the water resources agencies have the capacities and skills to absorb and apply such information. Achieving this requires systematic water resources planning. Approaches to develop strategic planning are proposed together with mechanisms to mainstream plans into water sector programmes and projects.

The National Water Mission (NWM) has identified five main strategies to combat possible impacts of climate change on water resources. These are; (i) formulation of comprehensive water database in the public domain and assessment of the impact of climate change on water resource; (ii) promotion of citizen and state actions for water conservation, augmentation and preservation; (iii) focused attention to over-exploited areas, (iv) increasing water use efficiency by 20%, and (v) promotion of basin level integrated water resources management. The studies have shown that before one thinks of any possible adaptation mechanism for future situations where there remains uncertainty; it is imperative to understand the capacities and procedures to address the very significant current issues, vulnerabilities and climate variability inherent in the water resources.

Climate Change: There are already good opportunities to improve the accuracy of climate assessments through multiple high-resolution climate projections. The Fifth IPCC Assessment Report (AR5), targeted for release in 2013, are likely to be more physically realistic and credible (as more processes are represented), with many at finer spatial resolutions than the CMIP3 versions. However, some scientists (e.g., Trenberth 2011) caution that there may be more inter-model variability (uncertainty) as a result. It is essential that the Indian Institute of Tropical Meteorology (IITM) and other climate research institutes are strengthened to keep India in the forefront as a world leader in climate change assessment and planning. Regional cooperation in climate change should be considered, with India playing a leadership role.

A strong partnership is required between IITM and MoWR/CWC to ensure the highest possible climate projections can be mainstreamed into water resources planning and management. MoWR and CWC and the State Water Resources Departments will play a key role to assess the implications of climate projections and incorporate necessary measures into the water resources planning and management processes.

Not all the possible consequences of climate change are fully understood. the study has incorporated climate projections using models designed to give the best possible estimates of the climate projections within the present level of knowledge.

The experience of this study shows that while climate change projections contain many uncertainties and in some areas are insufficient to concrete adaptation decisions, it is important however that development planning and design should incorporate the projections into the decision making processes as an early stage. Methodologies for this are proposed in the report.

Systematic Water Resource Planning: improved and more robust climate assessments will have limited value unless the water resources agencies have the capacities and skills to absorb and apply the information. To achieve this requires staff development programmes and systematic water resources planning.

Studies in the three pilot sub-basins have shown that issues are very location specific and actions must be tailored to meet specific needs. This calls for a systematic approach to the diagnosis of issues and development of appropriate measures. The three sub-basins currently have serious issues of water use sustainability which has significant implications to their resilience to climate change.

Conjunctive use of surface and groundwater is a major feature of many Indian water systems – when properly managed, it is a highly efficient system. Over exploitation of groundwater is however now becoming endemic in many basins. Conjunctive management requires a significant change in approach to water planning and management; current focus is mostly towards surface water systems. Demand management is critical in integrated surface and ground systems, which requires an integrated, multi-sector management approach. Effective demand management measures have also been recognized as priority water management issue.

Strategic framework planning incorporates a diagnosis of issues and broad proposals for the way forward. As issues and solutions are changing too fast, an iterative planning based on framework planning is proposed. Framework plans can be gradually refined, adjusted and updated as new and improved climate information systems are developed.

The proposed approach for the India Water Systems is directed to upgrade the planning and management processes and the development of strategic framework plans for sub-basins and basins. The recommendations of the NWM are appropriate to be incorporated into strategic planning processes. Without good planning systems climate information will be of limited value.

Improved water governance is needed at all levels. The issues and recommended approaches, including sub-basin and basin planning, require the adoption of integrated water resources management. At State and Central levels, water resources remain very sector-driven, with a lack of integration of various sectors; there is little coordinated management of surface and groundwater; there would appear to be more integration within the lower level organisations. Proposals are presented to strengthen IWRM at State and District levels through a IWRM unit within the state WRDs, a state level water resources steering committee and a new state water regulatory authority. District planning committees and stakeholder consultative groups are critical requirements to endorse and support the mainstreaming and implementation of sub basin and basin plans. Open data sharing is an essential pre-requisite of effective IWRM and climate adaptation strategies for water, as reflected in the NWM and the National Water Policy. A proposal for strengthening of CWC is presented to meet the needs of integrated water resources planning and management and climate change adaptation.

Strengthening of water resource planning is essential plans must be integrated and ideally at the basin level. There are however many institutional constraints to basin planning and it is proposed to initially instigate planning at the sub-basin level and gradually in stages integrate sub basin plans to basin level plans, once the appropriate institutional structures have been effectively established. Sub basin planning would be based on boundary conditions defined by the tribunals and other water sharing agreements. Planning must be a partnership of the state and centre, and basin plans would need to be developed based on sub-basin planning outputs. CWC must take a lead role to coordinate planning; strengthened regional CWC offices are proposed to help support the state-centre partnership; and also promote and develop empowered river basin organisations. A step by step approach is proposed with the a gradual convergence of CWC regional offices together with the states to create technically strong RBOs secretariats and representative river basin boards, empowered to make decisions. States need to be convinced of the advantages of basin level management. Stakeholders need to be properly represented at the sub basin as well as the basin level through stakeholder consultative groups and forums.

The proposed programme is to implement water resources planning and climate change adaptation in all sub-basins and states. The programme would be a partnership of the state and central governments initially working in the three pilot sub basins but gradually up-scaling to other sub-basins and basins. An eight component programme is proposed as below.

(i) **Specialist Climate and Hydrological Support:** Development and implementation of a systematic approach to climate change analysis for water resources to be implemented by CWC and specialist institutes including IITM.

(ii) **Sub Basin and Basin Strategic Planning:** Development of sub basin strategic planning for all sub basins, and later integration of sub basin plans into basin plans. Plans to be prepared as a partnership of central and state governments and the RBOs with specialist support. Plans to be participative involving stakeholders, plans to be endorsed by the district planning committees and stakeholder consultative groups at sub basin and basin level.

(iii) **Detailed Planning and Design of Sub Projects** will be implemented based on the strategic framework planning. Feasibility assessments will be undertaken to assess technical social and economic viabilities. Feasible projects will be designed as sub projects for implementation Planning and design would be required to incorporate resilience to climate change through design allowances and sensitivity assessments.

(iv) D**ata Management for Water Resources:** Implementation of a programme of data sharing and management including the development of web portals for open data sharing. Building and strengthening the present WARIS information systems

(v) **Capacity Building and Awareness:** Designing and implementation of an integrated programme of capacity building and awareness to meet the needs of integrated planning and management of water resources and climate adaptation

(vi) **Establishment of IWRM at State and District Level** Establishment of fully functional institutional organisations for IWRM at State and District and community levels

(vii) **Establishment of Enabled and Empowered River Basin Organisations** to support interstate basin level planning and management. Establishment will be in stages and will strengthen and empower the existing organisations and establish new organisations where considered necessary.

(viii)**Strengthening of the Central Water Commission :** A strengthened and more focused CWC and other attached MoWR organisations and empowered River Basin Organisations is proposed to effectively support holistic water resources management including surface and groundwater and multi sector water and environmental requirements. CWC in close partnership with the states has to take a lead role to coordinate and drive forward necessary climate change adaptation measures.

Road Map: The implementation of the programme is a major task, and requires strong coordination and management from the centre and the states. The broad approaches have been developed in the three pilot sub basins in the present study. The proposals need to be further refined and detailed plans and design of sub-projects prepared. An eight year planning and investment programme is proposed for each sub-basin.

Moving forward from the three pilot sub-basins, it is proposed to upscale the work initially focusing on Priority 1 sub basins which would be selected by the states based on complexity, issues, vulnerabilities. etc. Priority 1 sub-basins would be taken up for framework planning by specialist institutes and consultants including international specialists. Priority 1 sub basins would be then taken up for implementation in a manner similar to the three pilot sub-basins.

Priority 2 sub basins would follow the same methodologies. The teams of specialist consultants and institutes recruited for the priority 1 sub-basins would provide support and training for the state governments as well as the institutes and consultants who would implement the priority 2 sub-basins. The programme will require an implementation and financing plan, as well as project management consultants to support its implementation.

Responsibilities: The responsibilities to implement the programme would be shared by central and state governments. The complexities and scale of the programme will require significant outsourcing to institutes and consultants. Government at Central, State and lower levels will facilitate the programme and support data requirements as well as enable stakeholder and civil society participation to assess and review of the planning outputs.

2. LOWER SUTLEJ SUB-BASIN

The Sutlej River is the longest of the five rivers that flow through north-western India. It contributes significantly to make Punjab the breadbasket of India: a fifth of the country's wheat is grown in this state largely due to the combination of good soils, abundant water and skilled farmers.

Water resources are well developed: surface water irrigation from the Sutlej is supported by major storages of the Bhakra reservoir, groundwater, snow and glaciers. However, water resources are facing major problems of sustainability: groundwater extraction levels are significantly higher than their recharge; surface water resources can only provide a quarter of the irrigation demand, but they provide a significant portion of the groundwater recharge. There are issues of water quality.

In the long term, surface water flows are projected to be reduced due to a gradual loss of snow and glacier storage. Some benefit of projected increases in precipitation may occur. Projected increases in temperature will affect yields of certain crops. Pressures on water resources are increasing for agriculture as well as for domestic water supply and industry. Water quality is a major issue; saline groundwater in the southwest of the state is affecting productivity in that area.

The increasing cost of production and diminishing economic returns from farming are adversely affecting the socio-economic conditions of Punjab farmers. At the moment agriculture is heavily subsidised, which keeps farming viable, e.g. there is free electricity for pumping farm water. Farmers are well aware of the water sustainability issues but find it economically difficult to change their farming systems.

Agriculture in Punjab is moving rapidly to modern and mechanised farming systems, but yields currently remain quite low. Outside the south west nearly all farmers follow the government-supported rice-wheat cultivation system as they prefer secure returns albeit with high water requirements; in the south west the predominant crop is cotton. To adapt to climate change impacts and seek greater sustainability, farmers in Punjab need to achieve higher water use efficiencies and greater returns in their agricultural systems and a more balanced approach to water resource management including a very significant reduction in ground water abstraction. There is also need to address water quality issues; saline groundwater in the south west is affecting production and contamination of groundwater is occurring in many parts.

Climate Change: There is variability between projections, depending upon the emissions scenarios assumed and models used. The PRECIS regional climate model, run with boundary conditions from the HadCM3 global climate model for three emissions scenarios indicates a temperature rise in the range of 1.7°C to 2.0°C.

No quantitative assessment of the change is surface water resources in the upper catchment has been possible due to the complexity of the water systems and the lack of data. Currently the decrease in snow melts are being compensated by increased melts from the glaciers; it is broadly estimated that this would continue with no significant change over the next decade;. The longer term however is not so clear; a number of interacting effects make it impossible to come up with definitive assessments of the magnitude and time scale of change. Whichever scenario unfolds, the need to conserve groundwater is critical now and in the future.

The framework plan presented is an outline and includes draft proposal towards sustainable water resources management. It sets out broad proposals to meet the needs of economic development, environmental sustainability and means to adapt to climate impacts.

The key objectives of the plan include:

- Strengthened agricultural productivity and marketing systems to support financial sustainability as a means to buffer against climate impact; increased productivity would be developed in parallel with water use efficiencies and conservation.
- A major reduction of net groundwater abstractions to ensure long term sustainability;
- Development of mechanisms to improve water quality including management of salinity levels in the south-western area and reduction of pollution levels from pesticides and fertilisers;

- o Improved and viable catchment management and artificial recharge to help replete groundwater;
- o Mainstreamed seed varieties and other measures to withstand increased temperatures and other climate impacts.
- o Improve the conjunctive efficiency of the surface and groundwater systems.

Programme Components: There is no single solution towards meeting the needs of groundwater conservation and a portfolio of different initiatives is proposed. The need is to develop improved agricultural production and marketing systems within a framework of water resource conservation and controls. Four components are identified:

(i) **Improved Agricultural Production and Marketing Systems:** Long term agricultural sustainability requires financially viable production systems to maintain incomes. Support for financial sustainability of the agricultural systems would be directly linked to the uptake of water conservation measures including power management. Increasing farm profitability will be required to balance potential loss of returns from water conservation technologies and water regulation.

(ii) **Upscaling Resource Conservation Technologies (RCTs)** to reduce agricultural water demands. The RCTs would include adjusted cropping systems, micro irrigation land levelling, and power management. These need to be evaluated in terms of impact on water use, farmer and market acceptability, and readiness for upscaling. Incentives to encourage the uptake of RCTs will be a key aspect and linkages with agricultural productivity will be important.

(iii) **Water Resources and Catchment Management** will focus on water supply management; including: water management to address salinity and water quality; improved surface water management systems; catchment management and artificial recharge; sustainable urban water management; and rehabilitation of wetlands and village ponds.

(iv) **Institutional, Regulatory and Support Measures:** Implementation of programmes to address productivity and marketing and water resource conservation and management require to be supported by the establishment of IWRM, a regulatory authority and improved and integrated government support systems. Parallel regulatory and support measures will be developed to help farmers move towards water conservation and reduction in water demands.

Road Map Lowe Sutlej: It is proposed to establish the 'Lower Sutlej Sustainability Programme' to address ongoing development, environmental and potential climate change issues of the Sutlej River Basin in Punjab. The programme would put into place wide-ranging initiatives and investments to meet the needs of highly effective agricultural productivity and marketing systems, resource conservation, water resources and catchment management and institutional reforms, support and regulation.

Operational Studies and Research: There are major gaps in the understanding of the Sutlej water systems including; the hydrological response to snow and glacier melts under climate change as well as the conjunctive surface and ground water systems. It is proposed to implement a programme of operational research improve the knowledge base for the Sutlej River using a water model such as WEAP. The model would assess the evolution of surface water and groundwater through a systems analysis incorporating supply assessments of glacier/snow and groundwater recharge and demand simulations including economic optimisation of agriculture and power and the operations of the Bhakra reservoir. The outputs of the operational research will be tailored to be directly applied to the design of the Sutlej Sustainability Programme and the various component and sub projects.

IWRM : The project would be based on an IWRM approach, with a focus to address the sustainable development of water resources whilst addressing issues of agricultural production, marketing and resource conservation. The water sector departments currently lack the flexibilities, capacities and level of integration required to meet the project objectives. An IWRM institutional framework would need to be established including the formation of a state water resources committee, a regulatory authority and empowerment of the district planning committee and district level sector agencies. The programme would be in two parts: (i) investment and support programmes in the Sirhind Command Area which is the main area supplied from the Sutlej river; and (ii) institutional, regulatory and support measures covering the whole state.

An eight year programme is proposed, to be implemented through a new IWRM framework. The programme would be integrated involving and working closely with the key water sector agencies, the district administrations and relevant private sector partners. The programme would work under the direction of the Water Resources Steering Committees but in close coordination with the sector departments at State and District level, District Administrations and the Panchayats. The programme is designed as an integrated programme with each component requires cross-cutting interactions from the other components so it is critical the programme incorporates all four components.

The programme would implement field level support measures within all the districts of the Sirhind command area. Parallel to this, the programme would address institutional reform measures over the water sector departments in the whole of Punjab, these would be implemented in stages. The establishment of IWRM and institutional reforms are critical for the long term sustainability of water resources in the State.

3. KSHIPRA SUB-BASIN

The Kshipra sub basin is located in the Malwa Plateau in western Madhya Pradesh. Water quantity is a major issue: with very limited surface water, there is heavy reliance on groundwater and its overexploitation in some parts is a key challenge. Although the total annual yield of water from catchment and groundwater exceeds the requirement, most of this water is unutilised and lost from the sub basin during the monsoon.

Rural water supply and sanitation are major issues especially during the dry season when many wells run dry. Less than half of rural households have access to safe drinking water; most rural households do not have access to toilets. The urban centres suffer from similar problems, which are exacerbated by gradually declining groundwater levels.

While the rapid expansion in groundwater irrigation has certainly benefited the communities, it has also created a high dependency on irrigated agriculture from groundwater for household incomes. The situation is however is not sustainable due to the over exploitation of groundwater.

Surface water systems contribute to about 5% of the irrigated area, largely to support the Rabi crop. A number of small surface schemes are under consideration; the flat terrain limits the potential areas for new storages. The water from the Narmada River offers a perennial source; however, the very high pumping head precludes this option for irrigation. Indore and Dewas draw their potable water from the Narmada but the associated operational costs are very high.

Water Quality: The tributary streams of Kshipra are heavily polluted with untreated urban and industrial waste. The Kshipra River goes dry for periods of the year which precludes dilution or removal of wastewater discharges. The decline of river base flows is largely due to lowering groundwater levels.

Climate Change: Under the HadCM3 A1B scenario downscaled with PRECIS:

- Both maximum and minimum temperatures are projected to rise significantly: mean daily maximums by about 2°C by the 2050s and by about 4°C by the 2080s.
- Rainfall is also projected to increase: mean annual rainfall increases by about 80mm by 2050s, and by about 175mm by 2080s. Most of the increase will occur in the monsoon period, with an increase of 100 mm to the 2050s. There is a slight decline in the October to February rainfall. Mean monsoon rainfall increases by 140 mm by the 2080s.

The forecast increase of 10-15% in precipitation under PRECIS A1B Q14 scenario is significant. This could improve the water resources situation, depending on the intensity and inter-annual variability of rainfall.

Framework Plan: Agriculture in the Kshipra basin is developing but agricultural intensities and yields are significantly lower than their potential. The framework plan is to support the state agriculture plan towards modernisation and intensification of agriculture but in tandem introducing new technologies and controls to reduce the abstraction of groundwater to sustainable levels.

Industrial development is increasing demands on water and also aggravating pollution. Drinking water problems were one of the most pressing issues reported in the rural appraisal surveys. Sustainability of water resources, especially

groundwater, is a critical issue. The potential for additional supply is very limited but small reservoirs, farm storage tanks, water harvesting and water reuse offer some opportunities to increase water availabilities. The strategic framework plan for potable water is directed towards supporting integrated water conservation to reduce groundwater abstractions, water efficiencies and measures for rain water harvesting and artificial recharge.

Strategies for Climate Change: While the current projections for climate change are not sufficiently robust to make concrete planning decisions, they can be taken as indicative of future climate conditions and used to evaluate strategies and the general direction of water resources development. The proposed adaptation approach is to capitalise on the opportunities of increased rainfall through water retention and storage including small surface water irrigation, small farm tanks, watershed management and groundwater recharge. Although precipitation is projected to increase, it will be concentrated during the monsoon; water retention, storage and drainage will all be key requirements. This is a valid strategy even without any increased rainfall. A substantial increase in hazards related to heavy rain is expected over central India in the future. Drainage and flooding from the increased rainfall will likely be issues that will also need to be addressed, drainage design should factor in the projected increased rainfalls.

Parallel to this, conservation of water demand, especially from groundwater would be achieved through small surface water irrigation and farm tanks; the latter could reduce dependency on tube wells. Research, development and mainstreaming of temperature-resistant crop varieties will be important. To reduce vulnerabilities, it is necessary to increase the financial viability and net returns to farmers. The framework plan is designed to improve agricultural productivity while also meeting requirements of sustainability and conservation of water resources. The plan will address the very pressing problems of water pollution as well as domestic water supply and sanitation. Implementation will require cross-sectoral coordination and institutional development within government as well the farming communities and other stakeholders.

Objectives for the Kshipra are to address the over abstraction of groundwater and reduce groundwater dependence through support to improve the agriculture productivity and marketing in tandem with initiatives to support conservation of groundwater; including micro irrigation, small surface water schemes, farm tanks, catchment management and artificial recharge. Support measures for increased productivity would be linked to uptake of parallel conservation measures including power management. and power charging mechanisms. Problems of water supply, sanitation and pollution control would be addressed, indirectly through reduction of the pressures on the groundwater to improve the base flows, as well as direct actions to reduce the levels of pollution and increase the efficiencies of water supply and sanitation.

Programme Components: There is no single solution towards meeting the requirements of development, sustainability and adaptation of the Kshipra sub-basin. To meet the objectives, five components are identified:

(i) **Sustainable Agricultural and Conservation:** Support for agricultural production systems to improve farmers' incomes together with mechanisms for water resources conservation. Financial sustainability of the agricultural systems will be essential to effectively address conservation measures and to provide robustness to climate impacts. The strategy is directed at introducing resource conservation initiatives in parallel with support for agricultural productivity and marketing.

(ii) **Water Resources and Catchment Management** will focus on water resources supply and management. Key areas include: expansion of small scale irrigation schemes including medium and small scale storage/ tank systems for irrigation; rehabilitation and expansion of farm and village tanks; and support for catchment management and artificial recharge.

(iii) **Water Quality Management and Pollution Control:** Major issues of surface and groundwater pollution will be addressed through surface and groundwater management, pollution control, improving water treatment, and reuse of waste water.

(iv) **Water Supply and Sanitation:** Upgrading of schemes, improving efficiencies and service delivery, integrated solutions to support water supply shortages including improving efficiencies in irrigation to free up scarce water for water supply.

(v) **Institutional Development and Support Measures:** Implementation of programmes to address productivity and resource conservation and management need to be supported by IWRM including establishment of a regulatory authority, a inter-sectoral steering committee and improved government support systems. Training and awareness in water resources management and climate change adaptation need to be provided to government and non-government stakeholders. Appropriate support measures will be provided to offset any impacts of regulation and control of groundwater of groundwater abstractions.

Road Map Kshipra: The 'Kshipra Water Conservation and Development Programme' is proposed to address ongoing development, environmental and potential climate issues in the Kshipra sub-basin. It would put into place wide ranging initiatives, programmes and investments to meet the needs of modern agricultural systems, water resources conservation, water resources and catchment management, water quality, pollution control, water supply, sanitation, institutional reforms, financial support measures and regulation.

The project would be based on an IWRM approach, with focus to address the sustainable development of water resources whilst addressing the issues of agricultural production, marketing and water resource conservation. The sector departments lack the flexibility, capacity and level of integration to meet the project objectives: an IWRM institutional framework would be required, including the formation of a state water resources committee, a regulatory authority and empowerment of district planning committees and district level sector agencies.

An eight year programme is proposed, and would be implemented through the new IWRM framework. The programme would be integrated involving and working closely with the key water sector agencies, the district administrations and private sector partners. The programme would work under the direction of a newly formed Water Resources Steering Committees, but working closely in coordination with the sector departments at State and District Administrations and Panchayats. The programme would implement field level support programmes within the three districts of the Kshipra Sub-basin. In parallel, the programme would address institutional and reform measures over the water sector departments in the whole of Madhya Pradesh. The establishment of IWRM and institutional reforms are critical towards the long term sustainability of water resources in the State. Institutional reforms would be implemented in stages, and would include the establishment of an independent water regulator.

The programme would involve a mix of studies and consultation, planning, sub project design, community liaison and participation, institutional development and reforms. The focus of investment would be the three districts of the Kshipra. However, wider institutional strengthening and reform would be taken up to the whole state involving all the water sector departments.

The issues of Kshipra are similar to the other districts in the Malwa Plateau and consideration could be given to expanding a follow on programme to some other districts outside the Kshipra basin. This could provide a wider base to the programme with a greater impact. Institutional strengthening and reforms at the state level would benefit from a larger programme.

4. CAUVERY DELTA SUB BASIN

The Cauvery Delta consists of four parts: Lower Coleroon Anicut, Cauvery, Vennar and Grand Anicut. The issues of water resources in the Cauvery Delta are complex. There is very limited surface water availability during the south-west Monsoon; the erratic but the intense north-east Monsoon causes flooding. There are issues of saline intrusion; with some low lying lands unable to drain. Groundwater is extensively used to supplement the lack of surface water, but there are issues of overexploitation and salinity intrusion. Coastal erosion in areas is threatening coastal communities while some river mouths block causing problems of sea access for fishing boats and also flooding.

Historically, the Cauvery Delta was a major agriculture production area of India. The highly fertile soil, good rainfall and surface water flows were well suited to rice production. Today, the delta suffers from water shortages and uncertainties of climate. The water allocations under the tribunal award are less than earlier availability of water, and agriculture production systems have declined in recent years. The Cauvery Delta modernisation report in 2008 presented a series of proposals to address the decline in agriculture[2].

[2]Commissioned by the Tamil Nadu Water Resources Department

Climate Change: There is no statistical evidence of climate change, but farmers report increased levels of salinity, reduced freshwater flows and some changes in the timing of the seasons. Climate change will likely have significant impacts on the delta region including:

- **Temperature:** Under the HadCM3 A1B scenario downscaled with PRECIS an increase in mean annual temperature of about 2°C by mid century is projected.. By end century, the increase could be close to 4°C.
- **Rainfall:** The PRECIS projection is that, by mid century, although the annual rainfall would likely remain unchanged, the south-west monsoon would decline by about 10% over much of the basin. For the north-east monsoon, an increase of about 10 - 20% is estimated. The change in the upper catchment is less significant.
- The combination of higher sea levels and increased north-east monsoon precipitation will exacerbate existing drainage problems in the lower delta.
- **Sea Level Rise:** In the short to medium term, IPCC AR4 upper envelope projections indicate a 0.3 metre rise by mid century. Many researchers however consider this estimate to be too low as it does not give consideration of the ice sheet dynamics of Greenland and Antarctica.
- The Cauvery Delta experiences occasional cyclonic events: the INCAA 2010 report considered projected changes in cyclonic activity and storm surge, although there appears to be a decreasing trend of cyclonic storm activity in the Bay of Bengal, the report forecasts increased storm surge heights north of Visakhapatnam of 15 - 20% for a 100 year event as a result of increased intensity. The increase in storm surge heights is greater in regions with a lower tidal range.

Adaptation Requirements: Three key areas of adaptation are identified for the delta: (i) improving efficiencies of surface water irrigation systems; (ii) accommodating all water supply needs through piped supplies sourced from the rivers inland; and (iii) ensuring the sustainability of the coastal area.

Vulnerability of the Coastal Zone: There is a need to improve efficiencies of irrigation and also improve water supplies over the whole Cauvery Delta; it is however considered that the main direction of the adaptation plan should be to support the long term sustainability of the coastal area. Sea level rise, increased rainfall during the north east monsoon and associated drainage problems together with increased salinity intrusion all make the coastal zone very vulnerable to climate change. It is therefore proposed to focus the climate change adaptation to the coastal area.

Climate change impacts on the coastal area include:

- **Ground Water:** The estimate for groundwater is an increase in the salinity issues; with no significant change in annual rainfall, groundwater recharge will be largely unchanged; sea level rise will increase salinity intrusion. Groundwater demand will likely increase to compensate for the estimated weakening of the south west monsoon. Efforts to support sustainability of groundwater as a means to mitigate the projected impacts of the reduction in the south west monsoon will be required. Over extraction of groundwater can exacerbate the natural settlement processes of the delta which could increase the impacts of sea level rise.
- **Flood:** Increased rainfall, rainfall intensities and sea level rise will increase flood risk during the NE monsoon. Flooding is already a problem and will likely become more significant in the future. Farm drainage to reduce crop damage must be balanced with the need for supporting recharge.
- **Sea Level Rise** will impact of flooding and drainage as well as increased vulnerabilities of coastal erosion. Already quite large parts have significant drainage problems. The higher sea levels will affect the flood levels mainly in the NE monsoon and crest levels of bunds, dykes and regulators will have to be raised to meet these increased levels. Sea level rise will affect natural habitats in the estuarine rivers, the changes will affect both water levels as well as the salinity-freshwater balance.
- **Shoreline Erosion:** The long sandy beaches of the Cauvery delta are currently suffering from slow levels of localised erosion, the problems are largely due to the lack of sustainable supply of sand from the rivers; dams and sand mining have over time seriously reduced the supply of sand to the coast. The effects of climate change and sea level rise are difficult to predict and the responses of different coastlines are very variable. The increased sea level may affect the equilibrium profile; as sea level rises the beach profile is likely to adjust by shifting landwards and upwards by removing sediment from the shoreline and depositing the removed sediment in the nearshore zone. Erosion risk may also be increased by increased frequency of storms and associated surges.

Coastal Area Sustainability Objectives: The coastal area is indicatively defined as the area subject to salinity intrusion and the main area of flood risk which would approximately be all the land below the 15m above mean sea level inside the sub basins of Lower Coleroon, Cauvery, Vennar and Grand Anicut. The Cauvery coastal area is shown in Figure 1. The

objectives of the plan will be to develop an integrated approach to address current and future water issues along the coastal area. The programme will have five main objectives:

(i) To reduce the impact of flooding through integrated flood management including flood protection, drainage and establishment of flood alleviation.

(ii) To reduce the impacts of salinity in the surface and groundwater systems including construction and rehabilitation of tail end regulators, increasing fresh water storages and groundwater recharge.

(iii) To develop sustainable agricultural systems through increased yields and robustness to climate and salinity impacts, reduced water use through crop scheduling, shorter period varieties, more water efficient cultivation systems and support for micro irrigation and small farmer managed lift schemes from ponds, drains and poldered flood alleviation areas. The component would also support for community fishing and aquaculture.

(iv) To develop sustainable and environmental appropriate systems for shoreline protection and management, to provide protection from erosion and also support shoreline management activities including river mouths.

(v) Improving the strength and capacities of the institutions and stakeholders including improved capacities and awareness at government and community level to support integrated water resources management approach to ensure sustainability and adaptation to climate change including development of mechanisms to operationalise effective maintenance.

Programme Components: There is no single solution towards meeting the requirements of development, sustainability and adaptation of the Cauvery Delta Coastal Area. A portfolio of different initiatives will be required. The plan will build on the proposals of the Cauvery Modernisation Programmes as well on-going programmes by the Water Resources Organisation, the Department of Agriculture, Clima Rice and other government and non government agencies. To meet the objectives, five key components are identified:

(i) **Integrated Flood and Salinity Management:** Flooding will be addressed through flood dykes, drainage, expansion of flood alleviation areas as well as tanks, farm ponds and natural water bodies to absorb floods. Parallel measures of salinity control will include tail-end regulators and improving ground water recharge.

(ii) **Sustainable Agricultural Systems** to support increased productivity systems to improve farmers' incomes and resilience to climate change impacts. The programme would include mechanisms for water resources conservation, and minimising impacts of floods and salinity. Farmer productivity would be supported by: appropriate crop varieties; improved cultivation systems to reduce water demands and labour requirements; optimisation of crop scheduling; support for small scale farmer managed lift irrigation; and support for infrastructure to promote marketing. Support for fishing, fresh and brackishwater aquaculture, fish processing and marketing would also be included.

(iii) **Shoreline Protection and Management** would address present and the likely projected impacts from sea level rise on erosion and other shoreline issues. The component will support the development of soft and environmentally appropriate mechanisms for protection, including addressing planning of coastal development which is major cause of erosion and coastal instability, and managing the river mouths to support access by fishing boats and reduce flooding risk.

(iv) **Institutional Development, Training and Awareness** would be provided to support the establishment of an integrated management approach. These would include the effective establishment of IWRM at state level as well as in the Delta area to support the necessary field programmes.

Road Map Cauvery Delta: The 'Cauvery Delta Coastal Area Sustainability Programme' is proposed to address ongoing development, environmental and potential climate issues of the Cauvery Coastal Area. The programme would put into place wide ranging initiatives, programmes and investments to meet the needs of ensuring the sustainability of the Cauvery coastal area through integrated flood and salinity management, sustainable agricultural systems, shoreline protection and management and institutional development, training and awareness.

The programme would be based on an IWRM approach, with a focus to address the sustainable development of water resources in the coastal area. An institutional framework would need to be established, including the formation of a state

water resources committee, a regulatory authority and empowerment the district planning committee and district level sector agencies. Institutional reforms would be implemented at state level in parallel with water sector investments and programmes within the Cauvery Delta.

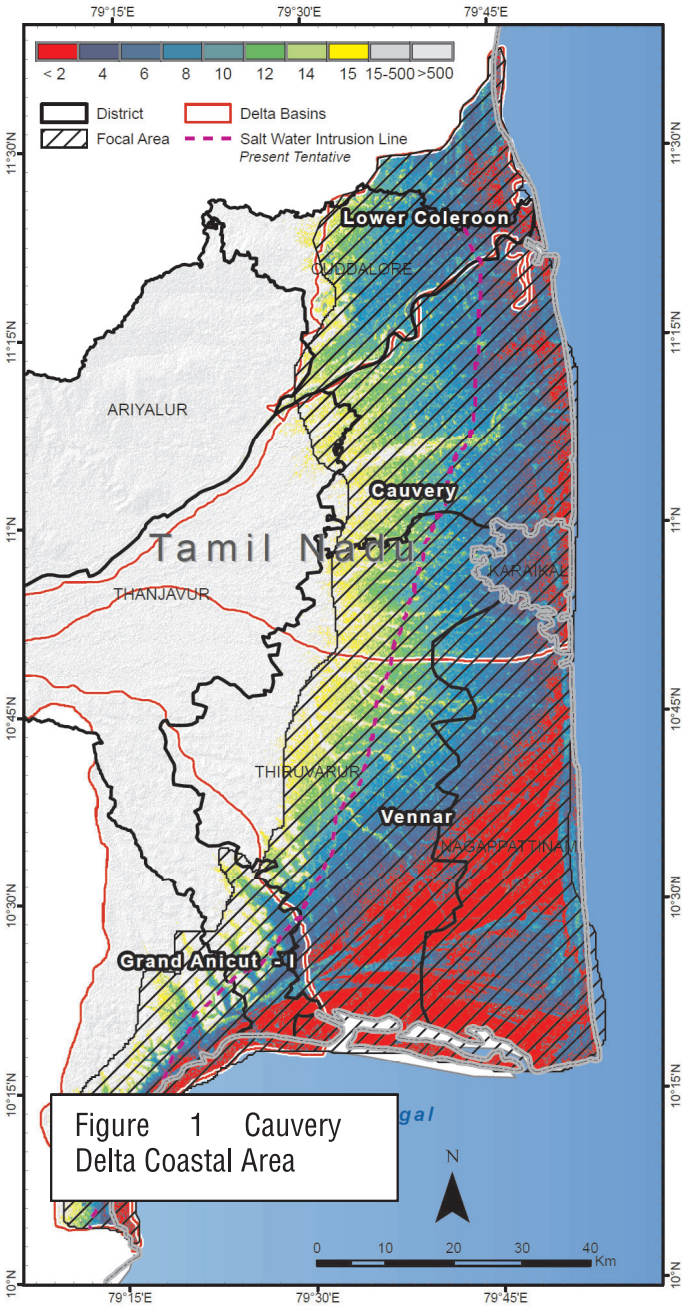

Figure 1 Cauvery Delta Coastal Area

Operational Studies and Research: The complexities of the water systems in the Cauvery Delta require the development of modelling systems to support planning including simulation of sea water rise, changes in precipitation in the south west and north east monsoon. Three modelling systems will be required (i) a hydrodynamic model of the surface irrigation network; and (ii) a coupled surface/ groundwater model to investigate groundwater systems including groundwater to different water management practices and (iii) a three dimensional hydrodynamic model of the coastal processes including facilities to assess sediment transport. The modelling would be incorporated into Decision Support System to review various development options for the coastal areas of the Cauvery Delta.

The 'Cauvery Delta Coastal Area Sustainability Programme' is proposed as an eight year programme and would be implemented through the new IWRM framework. The programme would be integrated involving and working closely with the key water sector agencies, the district administrations and private sector partners. The programme would work under the direction of a newly formed State Water Resources Steering Committees but working closely in coordination with the sector departments at State and District level, District Administrations and Panchayats.

It is proposed that the Vennar sub-basin would be taken up as a priority due to the more critical flood and salinity issues experienced in this part A second priority area would be taken up later. Shoreline management plans would be implemented for the whole Delta coastline and specific critical areas would be identified for further study and investment.

SUMMARY OF PROPOSALS INDIA WATER SYSTEMS

	Component	Description	Proposals Prepared	Three pilot Sub Basins	Priority1 sub basins	Priority 2 sub basins	Basin	India	Implementation	Specialist support institutes/ consultants
1	Specialist climate and hydrological support	High resolution climate projection scenarios and rainfall trend analysis for all sub basins	√	√				●	CWC working with IITM and IMD	IITM / IMD
2.1	Sub Basin Planning	Strategic plans for current issues and adaptation to climate change	√	√	●	●			To be upscaled to priority 1 basins and later piority 2 basins	Yes
2.2	Basin Strategic Planning	Compilation of sub basin framework plans to basin plans	√						Two pilot basins to be taken up once sub basin planning complete and RBO institutions and agreements in place	Yes
3	Detailed Planning and Design of Sub Projects	Refinement of strategic plans, feasibility studies andspecialst studies, design of sub projects	√	●		○	○		Initially in the three pilot basins and later upscaled to Piority 1 and 2 sub basins. Basin wide projects to be taken up at a later stage	Yes
4	Data Management for Water Resources	Integrated state and centre data management programme including development of web portals. Open data sharing	√	●	●	●	○	●	MoWR and CWC to manage and coordinate the programme. State government will agree to targets in return for investment support	Yes
5	Capacity Building and awareness	Comprehensive capacity building and awarenessfor IWRM and climate change to all levels	√	●	●	●			Requires training and awarness needs assessment. Training to be initiated 3 pilot sub basins and upscaling based on evaluation	Yes
6	Establishment of IWRM at State and District	Establishment of a fully functional institutional organisations for IWRM at State and District	√	●	●	○			Initial focus would be on the three sub basins but should quickly expand to other states. MoWR/CWC to support establishment	Yes
7	Establishment of Enabled and Empowered River Basin Organisations	Development of empowered interstate RBO to support basin planning and management	√				○		Development will be in stages. Two pilot RBOs to be taken up in advance. CWC and CWC regional offices to support establishment of RBO	Yes
8	Strengthening of Central Water Commission	Strengtheninag and rstructuring of CWC and other MoWR subsidiary organisations.	√					○	Requires detailed institutional analysis by management consultant	Yes

Notes: Work completed √
Priority 1 sub basin to be selected based on complexity, issues and vulnerabilities

● Activities to be implemented as a high priority

● Activities to be implemented as second priority

○ Longer Term Staged Activities

SUMMARY OF PILOT SUB BASIN ACTION PLANS

LOWER SUTLEJ SUSTAINABILITY PROGRAMME	KSHIPRA WATER CONSERVATION AND DEVELOPMENT PROGRAMME	CAUVERY DELTA COASTAL AREA SUSTAINABILITY PROGRAMMME
1.IMPROVED AGRICULTURE PRODUCTIVITY & MARKETING SYSTEMS	1.SUSTAINABLE AGRICULTURE AND CONSERVATION	1.INTEGRATED FLOOD AND SALINITY MANAGEMENT
Improved infrastructure for marketing Market Information Systems Support for mechanisation, diversification	Infrastructure for crop marketing and processing, marketing, access roads Market information systems training for marketing PPP initiatives to support production, marketing, conservation Micro irrigation and farm tanks Improved power supplies	Investments in drainage and flood dykes Construction/reconstruction of tail end regulators Development and rehabilitation of flood alleviation Retention of flood water for GW recharge & micro irrigation Maintenance of drains removal of weed Integrated catchment management over whole basin to reduce floods.
2.UPSCALING OF RESOURCE CONSERVATION TECHNOLOGIES	2. WATER RESOURCES AND CATCHMENT MANAGEMENT	2. SUSTAINABLE AGRICULTURAL SYSTEMS
Support to upscale and mainstream RCTs Support for private sector partnerships for RCTs Upscaling of micro irrigation Improved power supplies for agriculture	Investment for small medium reservoirs and projects for water supply irrigation and environment Catchment management and artificial recharge Waste water management Urban water management -water reuse rainwater harvesting, sustainable drainage and water reuse	On farm investment farm ponds, farm drainage, micro irrigation Increased mechanisation through cooperatives and private sector Infrastructure for marketing, post harvest processing storage, market areas, crop and fish processing, farm roads Support for low/non productive low lands including aquaculture and flood alleviation/ retention
3.WATER RESOURCES AND CATCHMENT MANAGEMENT	3. WATER QUALITY MANAGEMENT AND POLLUTION CONTROL	3. SHORELINE PROTECTION AND MANAGEMENT
Saline water management in south west zone Pollution control and water treatment Catchment management and artificial recharge Rehabilitation of water bodies, ponds and wetlands Investment in surface water systems focusing on water measurement and allocation systems Urban water management, leakage control, rainwater harvesting, drainage & water reuse	Pollution control and water treatment New initiatives for waste water management Urban water management	Beach and dune management Dredging of river mouths and beach nourishment Mangrove rehabilitation and management Support for other coastal infrastructure
	4. WATER SUPPLY AND SANITATION	
	Upgrading and increasing efficiencies of water supplies in urban and rural areas Urban water conservation	
4. INSTITUTIONAL REGULATORY AND SUPPORT MEASURES	5. INSTITUTIONAL DEVELOPMENT AND SUPPORT MEASURES	4. INSTITUTIONAL DEVELOPMENT TRAINING AND AWARENESS

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
BSL	Beas Sutlej Link
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
EA	Executing Agency for this project is MoWR
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	A three-dimensional finite-difference groundwater flow model developed by the United States 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
O&M	Operation and Management
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 , originally developed at the National Center for Atmospheric Research (NCAR), is maintained in the Earth System Physics (ESP) section of the International Centre for Theoretical Physics (ICTP), Trieste
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
TOR	Terms of Reference
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
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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I. INTRODUCTION

A. Background

1. The core focus of ADB's India Country Partnership Strategy (CPS) 2009 for the period 2009-2012, is to support India's efforts in the areas of inclusive and sustainable development, as emphasized in the 11th Five Year Plan (2007-2012). ADB's effort is therefore, to mainstream both, climate change mitigation and adaptation concerns into its India program.[3] Since 2009, ADB has held a series of consultations in India relating to the development of the South Asia Regional Climate Change Implementation Plan (CCIP). ADB has recently supported parallel IWRM and climate change scoping studies in Karnataka (2010), Himachal Pradesh (2009) and the Upper Sutlej River Basin Himachal Pradesh (2011). Discussions were held with senior officials of the Ministry of Water Resources (MOWR), reputed climate change experts and donor partners. This consultation process has continued to date with GOI. GOI believes that the maximum scope for adaptation work in India lies in the area of water resources management. The Department of Economic Affairs (DEA), Ministry of Finance, which is in some senses the "gateway" for all external agencies active in India, has been extremely supportive of ADB's efforts in this regard. It has been helping through the exchange of ideas to strengthen the design and implementation of TAs and loans, and also in liaising with state governments and impressing upon them, the need to mainstream adaptation concerns. A close working relationship has been developed with the Ministry of Water Resources (MoWR) and Central Water Commission (CWC) at the Central level and various Water Resources Departments (WRDs) at the state levels (e.g. Assam, Himachal Pradesh, Karnataka, Chattisgarh and Orissa).

2. The TA Project (S_NWM) has been developed following a request[4] from the Department of Economic Affairs (DEA) on behalf of MOWR for ADB to assist towards the preparation of specific studies which would help to operationalise the National Water Mission (NWM) of the NAPCC. Several meetings have been held with GOI and other counterparts during which possible approaches to support the NWM have been discussed and refined. A meeting was held with MOWR and representatives from a number of water agencies from the Central and State level on 28 October 2009 in New Delhi. At the meeting, a suggested approach to the support program was presented and discussed; comments and suggestions have been incorporated into the Technical Assistance Paper. Preliminary understandings and agreements were reached on the TA impact, outcome, implementation arrangements, cost estimates and consultants' terms of reference.[5] The ADB PATA: 'Support for the National Action Plan for Climate Change -support to the National Water Mission (S_NWM) was approved by ADB in December 2009.

3. The study is being conducted within a number of very relevant and parallel studies presently being implemented; these include amongst others, the initiatives of CWC to set up a water resources information system (WRIS), water use studies and other ongoing programmes relating to the NWM; the planning commission is supporting the establishment of state water regulator.

B. Overview of the Project

4. **Issues:** Adapting to climate variability and change has long been part of the water planning and management processes. The current pace of change in climate is unprecedented and experiences accumulated to date are unlikely to be sufficient to provide a fully acceptable way forward. While climate change projections on a global or regional scale are quite robust, there remain large uncertainties in the projections and associated impacts of climate and hydrology at the basin level. Water resource managers and planners urgently need information and direction to plan the way forward.

5. **MoWR** Request: In their request for assistance, MOWR has identified three areas of possible support: (i) integrated water resources management (IWRM) studies on selected river basins or sub-basins; (ii) strategic programs for pilot project demonstration of improved water use efficiency; and (iii) strengthened institutional strategies and capacity, including support from international experts for identified areas of climate change research and support for community mobilization and social awareness.

6. **Project Rationale:** The National Water Mission (NWM) to the NAPCC in 2008 has produced a broad range of recommendations towards climate adaptation for the water resources sectors. The NWM identifies the needs for long-term sustained efforts to develop and implement the identified activities and policies and enactment of necessary legislation

[3]Mitigation initiatives include increasing support for generation of renewable energy, reducing T & D losses, promoting energy efficiency, and tapping CDM opportunities and CDM-related capacity in various sectors.
[4]DEA request for assistance by ADB from the GOI (Ministry of Water Resources) through DEA, for support towards the operationalisation of the Implementation Plan of the National Water Mission of the NAPCC was received on the 9 October 2009.
[5]The TA first appeared in the business opportunities section of ADB's website on 20 May 2009.

through the state governments. The NWM identifies the foremost actions to put in place appropriate mechanisms for coordinated actions followed by intensive capacity building and awareness programmes; although some parts have been taken up for study, there is no overall strategy and mechanisms to implement the recommendations. The S_NWM study is designed to initiate the necessary actions at the central and state levels to move the NWM recommendations towards a viable and programmed set of initiatives and investments.

7. **Approach:** Strategic planning and the development of frameworks are critical elements to identify and articulate the issues, develop strategies and create a shared vision to meet the needs of sustainable and robust water resources systems to meet the needs of climate adaptation. Strategic planning is iterative and it is important to develop sustainable processes. The time frame and resources for the TA were limited and it was necessary to limit the scope of the study to key present issues and the main projected climate change impacts within the main water sectors. The work built on existing studies and ongoing national and international research outputs, with support and input by Government Agencies and Institutes. The study was executed at two levels; all India water systems and more detailed studies within the thee pilot basins.

C. Summary of Outputs

8. The outputs of the study are a set of strategic frameworks to identify and address the main areas of adaptation to climate change. Two categories of output are described below.

(i). **Output 1: Strategic Frameworks for the India Water Systems:** Broad strategies for water resources related to climate adaptation and the establishment of IWRM. The strategies would build on the outputs of the National Water Mission, ongoing initiatives under other ministries including MoEF, findings in the pilot sub-basins, new initiatives in other states, other related projects and research. The output includes recommendations for effective institutions, finance, training and awareness as well as an integrated strategy and road map.

(ii). **Output 2: Strategic Frameworks for Pilot Sub-basins:** Three pilot sub-basins have been selected as focal areas for study and planning. For each of the three pilot sub basins location specific strategic frameworks were developed to address present issues and projected requirements for adaptation. The frameworks addressed ongoing water issues as well as the estimated requirements for adaptation to future climate change at the sub-basin and state level. The frameworks quantified the present and projected future scenarios through climate and hydrological modelling. The scope for increased water efficiencies in the context of the necessary parallel measures to meet water sustainabilities have been examined. The output will include recommendations for effective institutions, finance, training and awareness as well as an integrated strategy and road map for each of the three pilot sub basins.

9. The report is arranged as shown in Table 1 below. For each sub basin, a sub basin profile has been prepared which examines the current situation and issues. The strategic framework analyses the issues and develops strategies towards addressing current issues as well as an examination of the projected climate impacts and how strategies require to be adjusted to incorporate the projected climate changes.

Table 1: Structure of the Final Report

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D. Project Implementation

10. The assignment was divided into key tasks based on the terms of reference which are shown in Appendix 7. A summary of the main activities is given below.

- Pilot Sub Basin Selection was based on the type and likely degree of sensitivity to climate change with specific reference to the three major areas of concern: (i) alterations of winter snow-pack dynamics from climate change likely to cause impacts on downstream areas; (ii) basins or sub-basins where groundwater is an important water source with issues; and (iii) coastal areas where sea level rise will have impacts on surface and groundwater and increase flood risk. The three pilot sub-basins are listed in Table 2 below.

Table 2: Selected Sub Basins

No	Category	Sub Basin	State
1	Snow fed	Sutlej	Punjab
2	Groundwater	Chambal Basin	Madhya Pradesh
3	Coastal	Cauvery Delta	Tamil Nadu

- **Data:** A review of data requirements was carried out and with the support of the CWC and the States nearly all the necessary data was sourced. A MOU was prepared with the Indian Meteorological Department (IMD) to share data and cooperate with CWC on various studies.
- **Central Level Consultations:** Extensive consultations were held within the Central Water Commission and other related Ministries within Central Government. Meetings were also held with MoEF and the departments of the Environment in the three sub basin states to ensure good liaison and coordination with the State Action Plans for Climate Change.
- **State and Field Consultations and Visits** were held in each of the three sub basins at three levels: (i) state discussion involving the main water sector departments; (ii) district, water sector departments, local administration and Panchayat; and (iii) village level local community representatives, farmers, fishermen and other stakeholders. Meetings held at each of these three levels in each sub basin were held at three stages: initial inception stage meetings were held in November 2010; interim stage meetings in February and March 2011 and the final stage June 2011. At each stage, meetings the proposals and outlines of the strategies were presented and discussed; adjustments have been incorporated into the reports.
- **Consultations with Indian Climate Change Research, other Research Programmes and Donors** were made. These included direct discussions with around thirty Indian researchers as well as sourcing of a wide range of relevant research papers specific to climate change and water issues.
- The team has carried out extensive review of the relevant studies and literature relating to the sub basins as well as the wider India water systems.
- **A Participatory Rural Appraisal (PRA)** has also been completed in each of the three sub basins. The PRA worked in selected communities and through a series of household and community interviews and focus group discussions prepared an assessment of the communities views and their perspective on the main current issues, and how they may be addressed, as well climate change.
- **Climate Change Impact Assessments on Water Resources:** An assessment of projected climate changes was carried out for each of the Sub Basins. A review of the glacier studies was completed for the upper Sutlej river. Modelling hydrological response to the projected climate changes was done with the SWAT model. The main aspects of hydrological and water resources assessments included:
- Preparation of PRECIS precipitation data, comparison of statistics of PRECIS baseline precipitation with those of the observed gridded data sets.
- Preparation of PRECIS temperature and ETo data and comparisons of statistics of PRECIS baseline temperature data with those of observed series.
- SWAT model calibrations on KShipra.
- SWAT model simulation runs on all three basins.
- Review of research relating to climate impacts on glacial and snow melts in the Himalayas and the Sutlej.
- Water balance studies to investigate alternative water management and cropping strategies that permit sustainable water use (surface and groundwater) for a selected distributory in the Punjab (about 10,000ha).
- **Workshops to** receive feedback and discuss on the proposals, workshops were held in Delhi at the inception stage (November 2011), Interim Stage (March 2011) and Final Stage (June 2011). These workshops were attended by Central and State Government representatives, other stakeholders and guest speakers. In addition state level workshops were held in each of the three pilot basins states in June 2011.

India Water Systems

II. INDIA WATER SYSTEMS

A. Introduction

11. The India Water Systems report examines the wider issues of Indian water resources and presents a strategic framework towards climate change adaptation. The report compiles general information on the overall Indian water systems as well as the lessons learnt from the studies in the sub-basins into a broad set of proposals that can be applied towards a strategy and policy primarily for the Ministry of Water Resources and CWC as well as general guidelines for the State Water Resources Departments.

12. The methodology includes: (i) compilation of lessons learnt conducting the sub-basin studies; (ii) examination of ongoing work being carried out within CWC including the water resources reassessment, water resources information systems and water resources efficiency programmes; (iii) lessons learnt from initiatives in other states and parallel water and climate change programmes; and (iv) examination of parallel climate change programmes and research in India.

13. Water is an important element through which global warming impacts will be experienced. The Indian economy relies heavily on climate sensitive sectors like agriculture which depend critically on the availability of water. Managing the water resources effectively through integrated planning for the extreme climate events is most important for adaptation planning and implementation. Therefore vulnerability assessment for the different regions in the country and exhaustive risk management strategies are critical to the development of sound adaptation practices for the country. Not all the possible consequences of climate change are yet fully understood.

B. Broad Climate Change Implications for India:

14. The IPCC AR4 reported climate change projections for South Asia are derived mainly from an ensemble of GCMs (CMIP3[6]), referred to as the MMD (multi-model-data) models. From the MMD models the reported change relative to the 1970s baseline was an increase in temperature under almost all the scenarios and above the global mean including:

- Warming under A1B Scenario: (i) an increase of 3.3°C by end 21st Century; (ii) more warming in DJF: about 3.6°C; (iii) less warming in JJA: about 2.7°C; (iv) northward increase within the region.
- Precipitation under A1B scenario (i) decrease in DJF; (ii) increase during rest of the year.
- Land-sea temperature anomalies would be less prominent in controlling the monsoon.

15. These results have been widely circulated and disseminated. Towards the end of 2011, the next generation GCMs (part of CMIP5, will be used in preparation of the IPCC AR5) will become available at higher spatial resolution. This will improve process representation, but may not reduce inter-model variability. The consistency of precipitation projections may improve with respect to the direction of change. No major changes in temperature projections are expected.

16. In the context of climate change, the term mainstreaming refers to integration of current and future climate change vulnerabilities or adaptation into government policy and implementation. The role of institutions is critical to ensure appropriate and timely adaptation responses to climate change impact in general and on the various water sectors in particular

C. Approach

17. The India Water Systems are extremely diverse and complex; their effective management requires a mix of technical, institutional and social interventions. The National Water Mission of the (NAPCC) provides a wide range of recommendations and proposals, and the report has built on these with a special emphasis on operationalising of the NWM proposals

18. The studies in the three pilot sub basins have shown that issues are very location specific and actions are required to be tailored to meet the specific needs of sub basins. This requires a systematic approach to the diagnosis of issues and development of appropriate remedies. All the three sub basins show there is a need to address the conjunctive management of water resources; surface water, groundwater as well as the related water systems; sea, snow and glaciers etc. The conjunctive use of surface and groundwater is common in many of the Indian water systems requires a significant change in approach to water planning and management. Present approaches directed to surface water management need to be

[6]Coupled Model Intercomparision Project

incorporate both supply and demand management. In the integrated surface and ground systems, demand management is critical; management of cropping systems is a key area to achieve increased water efficiencies and water conservation.

19. The approach proposed is to develop location specific planning through strategic framework planning. Issue assessment and appropriate strategies would be developed through strategic framework planning. Strategic framework planning is a methodology that incorporates a quick diagnosis of issues and broad proposals for the way forward. Framework planning is preferred over full basin planning which is a long process and requires very large resources to prepare. Issues and solutions are changing rapidly and an iterative planning based on framework planning is proposed. Framework plans would be gradually refined and adjusted.

20. The approach proposed for the India Water Systems is to address the planning and management processes and the development of strategic framework plans for sub basins and later basins. The recommendations of the NWM are in most cases appropriate to be incorporated into strategic planning processes. It is not possible to address all the recommendations of the NWM and ten key focal areas directed at operationalisation of the NWM are presented in Table 3 below.

Table 3: Focal Areas for the India Water System

No	Aspect	Description
1	Climate Change Analysis for Water Resources	A systematic approach to climate change analysis is required. This entails an integrated assessment of climate and hydrological information.
2	Planning Process for Climate Change Adaptation	Formal and workable planning processes need to be established. Planning has to be iterative locally applicable and endorsed at State and District levels.
3	Sub Basin Strategic Framework Planning	Strategic Framework Planning provides a quick approach to identifying key issues and is proposed for all sub basins. Mechanism to update, refine and revise the framework plans are required.
4	River Basin Planning and Management	Development of sub basin planning requires to be integrated with workable mechanisms for basin planning and management.
5	Water Use Efficiencies and Management Options	Water use efficiencies and water productivities remain very low with no significant change over the last few decades. Assessments of Water Use Efficiencies (WUE) are a key part of the sub basin planning process. Basins with significant groundwater exploitation are required to incorporate conjunctive water use assessment. Viable approaches need to be developed to refine and strengthen the programmes of WUE including development of workable and tested initiatives to be taken up for implementation.
6	Incorporating Climate Resilience into Planning and Design.	Systematic approaches are required to incorporate climate changes into planning and design.
7	Strategies for Water Resources Data Management	Effective water resources data management and data sharing is a critical part of climate change adaptation. An approach towards a staged development of data management and effective data sharing is proposed. The potential use and incorporation of emerging data capture techniques, including for example remotely sensed precipitation and evapotranspiration should be explored.
8	Capacity Building and Awareness	Implementation of climate change and the development of systematic planning is a major and complex process there will be significant requirements for capacity building and awareness for all stakeholders including civil society.
9	Template for IWRM at State and District Levels	The template presents a proposed approach to development of IWRM. The approach is primarily designed to build on the existing institutional structures. A water regulator is proposed for all states.
10	Strengthening of the Central Water Commission	The very changing requirements for IWRM, climate change and move to basin planning requires strengthening and restructuring of CWC and the other subsidiary organisations to MoWR

D. India's Water Systems

1. Introduction

21. The Government's 11th Five Year Plan (FYP) clearly articulates the impacts and implications of climate change noted in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports. There is a high level of vulnerability to the impacts of climate change. Present-day pressures on water resources are extremely challenging; variations and extremes of hydrology, population and poverty present major problems. To adapt to these anticipated climate impacts, it is essential to coordinate existing water management practices and optimize operation of water infrastructure consistent with sustainable development goals and availability of water. Of major issue for water resources are the non linear changes effects where changes in climate can be amplified in the water environment.

22. While reliable assessment of impact of climate change based on requisite data are still to be established, available predictions indicate that climate change may alter the distribution and quality of India's natural resources which may have a definite affect on the livelihoods of its people and therefore need to be addressed with utmost urgency.

23. The Government of India, with a view to address the climate change issues, prepared the National Action Plan on Climate Change (NAPCC), which was released on 30th June 2008. The NAPCC has identified eight National Missions namely; (i) National Solar Mission, (ii) National Mission for Enhanced Energy Efficiency; (iii) National Mission on Sustainable Habitat; (iv) National Water Mission; (v) National Mission for Sustaining the Himalayan Eco-system; (vi) National Mission for a Green India; (vii) National Mission for Sustainable Agriculture, and (viii) National Mission on Strategic Knowledge for Climate Change, to address the challenges of impact of climate change.

2. National Water Policy

24. The National Water Policy was adopted in September 1987 and was reviewed and updated in April 2002. The National Water Policy provides for some of the amendments needed in the ISWD (Interstate Water Disputes) Act. Some of the features of the new National Water Policy (NWP, 2002) are:

- The National Water Policy provides for the formulation of the River Basin organisations, it states also that the "scope and powers of the river basin organisations shall be decided by the basin states themselves" (Article 4.2). However, in the case of interstate rivers, such a move has never been made because of the mistrust and also due to the absence of a facilitator. This role may have to be entrusted to the Union government, if we want to manage the interstate rivers in the best possible manner. The Central Government constituted the 'National Ganga River Basin Authority' using the Environment (Protection) Act (1986) with the Prime Minister as the Ex-officio Chairperson for taking measures for effective abatement of pollution and conservation of the river Ganga.
- It provides for the creation of a standardised national information system promoting free exchange of data among various agencies (Articles 2.1 and 2.2). Here it might be mentioned that as per the Sarkaria commission recommendations , a data bank and information system at the national level has to be set up at the earliest and the states shall be required to compulsorily make the necessary data available. However the ground realities show that data accessibility is the major constraint for individual researchers as well as organisations, which leads them to take case studies of international water bodies at the cost of providing solutions using state of the art technologies for the Indian systems.
- It provides for "adequate safe drinking water facilities" without mentioning the quantity of water in LPCD which should be provided at the urban and rural levels for various densities of population (Article 8). Although there is no mention of the quality of drinking water, Article 14 recommends regular water quality monitoring of surface and groundwater against the national water quality standards.
- Article 27 states that "State Water Policies backed with operational action plans shall be formulated in 2 years". Some of the States such as Madhya Pradesh, Himachal Pradesh, etc., have come up with draft Water Policies but are not much different from the National Water Policy in terms of their implementation.
- The National Water Policy (NWP) also recognises that water resource development should be planned for in hydrological units, or watersheds.
- The National Commission for Integrated Water Resources Development Plan had recommended repealing the River Boards Act and enacting a new Act called the Integrated and Participatory Management Act. It is proposed that sustainability in the quantity and quality of water resources can be achieved by taking into accountmulti-sectoral factors such as groundwater, surface water and other environmental considerations. Although the Act has not been passed as recommended, it has been reflected in the National Environment Policy (NEP, 2006). The EP also addresses many other issues such as climate change and its impact on various sectors and the importance of exploring coping strategies.

25. Indian planning now has an emphasis on decentralised local planning. After the 1993 reform below the State level there are now District Panchayats, Block Panchayats and Village Panchayats. The most significant development is that the Panchayats have been assigned a wide range of functions with respect to the preparation of plans and implementation of schemes for economic development and social justice. Some of these functions include agriculture, land improvement and soil conservation, minor irrigation and water management, social forestry and farm forestry. The role of the Panchayats in watershed development has been enhanced with the recommendations of the Haryali Guidelines of the watershed development (Guidelines for Hariyali, 2003) and they have been recognized as the primary implementing agency of watershed planning and action. In principle there are committees such as the Watershed Committee, which are supposed to have technical members responsible for providing technical help in their domains. However, in actual practice such expertise is very rarely available in the rural areas, with the result that interventions are being made without any sound planning.

3. Watershed Management

26. A very large extent of development in land and water resources is also taking place through a parallel mechanism in the form of watershed management programmme. Although considered to be a benign development, it has far reaching consequences if not handled properly and must be linked with the water resources basin planning processes.

27. Watershed development in India has been managed by three central ministries: the Ministry of Agriculture (MoA), the Ministry of Rural Development (MoRD) and the Ministry of Environment and Forests (MoEF) (Panchayati Raj and Natural Resources Management, 2000). The Planning Commission of India, which is in charge of the development of Five-Year Plans for the effective and balanced utilisation of the country's resources, co-ordinates long-term policy development in this area.

28. The MoA has worked in watershed development since the 1960s and deals with issues including erosion prone agricultural lands, optimizing production in rainfed areas and reclaiming degraded lands. Until 1995, watershed development projects were officially co-ordinated by multi-sectoral programmes (with differing objectives) launched by the GoI. After review in 1999 by the MoRD and the MoA a common set of operational guidelines, objectives, strategies and expenditure norms were established for watershed development programmes in 2001. The guidelines encourage the active involvement of non-governmental organisations, semi-governmental institutions and private enterprises, universities and training institutions. Whilst these programmes have laudable objectives there remains the concern that the emphasis of many watershed development programmes is still firmly based on the belief that water resources remain unexploited and are still available for development through both groundwater abstraction and through the use of water harvesting techniques[7].

29. The MoRD has revised these guidelines through a recent initiative called "Hariyalli" (MoRD, 2004), which literally means greenery, and has among many other objectives, one objective that states "Harvesting every drop of rainwater for purposes of irrigation, plantations including horticulture and floriculture, pasture development, fisheries etc. to create sustainable sources of income for the village community as well as for drinking water supplies."

30. The intent to harvest every drop which falls over the area might be dangerous from ecological and environmental angle. If taken literally, this intent has the capability of bringing about biophysical changes to the extent that the total character of the existing hydrological regime is changed. There might not be any surface flow available any more to the downstream areas[8]. It must be understood that every area has a prevalent water balance and any intervention caused is bound to change its water balance, the extent of which is dictated by many factors including the local biophysical characteristics and weather conditions. It is unfortunate that the emphasis in watershed development programmes is still firmly based on the belief that water is essentially an infinite resource and can be managed through the continual development of groundwater abstraction together with the implementation of water harvesting techniques[9] (KAWAD, 2001).

31. The present implementation of the watershed management programmes; (i) ignore the connectivity of the watersheds and treating each watershed as a stand alone unit where activities within the watershed are considered independent of their impacts downstream, (ii) ignore the hydrological characteristics of the watershed while deciding on the possible interventions, and (iii) non-availability of any evaluation procedure to quantitative the possible impact of such implementation and any tradeoff whatsoever to address sustainability.

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[7]Gosain A. K., Calder, I.R., Amezaga, J., Rao, J., Batchelor, C., Saigal, S. 2007. Watershed Planning and Management Issues, Workshop on R&D Challenges & Strategies for Sustainable & Quality Water, Indian Institute of Science Bangalore, India

[8]Gosain, A.K. and Calder, I.R. Inter-relating Resource Management Issues. Presentation given in KAWAD workshop, Bangalore, India, 2003

[9]KAWAD, 2001. A Fine Balance: Managing Karnataka's Scarce Water Resources. Karnataka Watershed Development Society, Bangalore, India

32. Legislation promoting central and state adaptation of the programmes and the involvement of outside parties and autonomous agencies has led to a myriad of watershed development programmes and research initiatives at the state and district level. The difficulties in disseminating knowledge, experience, scientifically validated information and methodologies are made worse by the lack of any common framework between states and departments. This is accentuated further by the lack of any common set of agreed management strategies based upon validated scientific knowledge. This approach of compartmentalizing the functioning of the different ministry players is the exact opposite to the integrated approach that the country claims to follow.

4. Climate Change Impact Assessment

33. At the national level there has not been any significant work on climatic change impact assessment on water resources before 2004 except the NATCOM (NATional COMmunication) (2004). The general philosophy of the implications of climatic change on the water resources of India had been discussed by Lal (2001). A general projection of the water resource demand for 2050 has been worked out by the Central Water Commission and is provided by Thatte (2000). He has shown that even without considering climate change impacts the total water demand shall surpass the availability by 2050 even under a low consumption scenario.

34. In a recent unpublished work (Gosain et al, 2011) completed under the NATCOM Phase II, climate change impact analysis on water resources of India has been quantified using 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 (Q14 QUMP ensemble). The results obtained under the present exercise are appreciably different than those predicted for the NATCOM Phase I, because of the changes in the RCM scenario outputs. These uncertainties are going to persist because of lack of understanding of the complete physics of the atmosphere as well as the inherent assumptions in the developmental pathways. Therefore the onus shall be on the scientists, managers and the policy makers to keep the uncertainties in focus while taking adaptation decisions.

35. Forest, land and water policies have often aimed to maximise the pro-poor benefits that may arise from using forest, land and water resources, but generally they have paid less attention to the impacts that changing land use may have on water availability. As a result the changes in land use, which may be promoted as part of watershed development programmes, may reduce the availability of water for downstream users. In arid areas, where water is already scarce, this can have profound impacts on more vulnerable groups. Moreover, these land use changes can result in rivers drying out completely, having significant impacts on the functioning of aquatic ecosystems[10].

36. It is believed that many of these policy instruments, especially those being applied in association with other policies promoting irrigation and soil water conservation measures, may not be delivering the intended benefits either to the environment and water resources or to the livelihoods of vulnerable groups.

5. Irrigation

37. Irrigation is the oldest sector in India involved in the development of surface water resources projects, even before Independence. These projects are run of the river or storage projects of varied sizes and are categorized as major, medium or minor projects, depending on the area they command. Subsequently, another form of irrigation was added, namely groundwater or tubewell irrigation.

38. The total outlay on irrigation from Independence to 2000-01 has been estimated at Rs. 1,98,952 crores ($44 billion) at 1996-97 prices, resulting in an increase in gross irrigated area of 300 per cent, from 22.56 mha in 1950-51 to 75.14 mha in 2000-01 (DLR, 2006). This puts India at the top of the list of countries with irrigated agricultural area in the world.

39. India has constructed around 4,400 large, medium and small dams. The majority of the dams started in the 1960s and the 1970s, the peak construction period. By now most of the good potential sites are considered to have already been exhausted and also the construction of new dams face stiff challenges from environmental groups on account of environmental impacts and rehabilitation issues. There were 410 ongoing major and medium irrigation projects at the beginning of the Tenth Plan (2002) with some of them having started more than 20 years ago, the total spillover cost to the Tenth Plan being Rs. 1,77,739 crore ($39 billion). As against this the total allocation for irrigation and flood control for the Tenth Plan was somewhat less, at Rs. 1,03,315 crore($23 billion).

[10]Calder, I.R., Amezaga, J., Bosch, J., Fuller, L., Gallop, K., Gosain, K., Hope, R., Jewitt, G., Miranda, M., Porras, I. and Wilson, V. 2004a. Forest and water Policies – The Need to Reconcile Public and Science Perceptions. Acta Geologica. Volume 2 - Issue 2

40. This situation of shortage of resources also has a direct impact on the poor maintenance of the existing projects because of the reduction of funds required for maintenance and rehabilitation. This in turn has a very major impact on the water use efficiency of our irrigation projects. Most of the projects are running at an efficiency of about 35 per cent which is very low by international standards (about 55 per cent is achievable). Poorly maintained and managed projects also result in many ill effects. The Ministry of Water Resources puts the area affected in the irrigated commands to the tune of 1.6 mha under waterlogging, 3.1 mha under salinity and another 1.3 mha under alkalinity (NCIWRD, 1999).

41. The majority of the recent addition to the irrigated area is on account of groundwater development. Presently about 60 per cent of the irrigation in the country is from groundwater. Out of the 25.7 mha of the irrigated area added during 1970-90, about 85 per cent has been on account of groundwater. The share of tubewell irrigation in India has dramatically increased from 1 per cent in 1960-61 to 37 per cent in 1990-2000, the largest source of irrigation. At the global level also India attains the top position by having an annual extraction of over 150 billion cubic metres of groundwater (Shah, 2000). The groundwater developments in many states is now unsustainable. The situation is now serious in the alluvial parts of the country with plentiful groundwater as well as the hardrock areas. The major causes of the groundwater woes include many factors such as free or highly subsidized electricity, water pricing, and lack of any policy/ legislation on groundwater abstraction. The pity is that it is the poor who are the worst affected on account of groundwater mining by the powerful. There is very limited integration of surface and groundwater management, this is a historic institutional arrangement; there is now an urgent need to plan for surface and groundwater conjunctively requiring integration of the surface and groundwater departments at the centre and in the states.

6. The Way Forward

42. Under this background the steps that have been recommended by the NWM to tackle the age old problems are no different. Therefore what is the guarantee that these shall work this time around with hardly any change in the strategy.

43. Within the watershed development programmes the implementation of soil and water conservation measures, forestry and groundwater-based irrigation schemes have generally all been promoted to local communities and NGOs as "good things". In the right circumstances these interventions can indeed be hugely beneficial. The problems arise when these "good things" are implemented, in excess or in combination, such that the total evaporative loss from a catchment becomes close to the amount of rainfall input and the catchment approaches what is termed a "closed" or no-runoff condition. A particular feature of closure is a long-term trend towards lowering of groundwater tables, resulting in dry wells and boreholes and seasonal water shortages.

44. A "sanctioned discourse" is developing within government and donor circles which are leading to watershed activities being promoted as benign technologies that are at the very least "poverty neutral". There is evidence to indicate that the "sanctioned discourse" is pursued even when circumstances change radically, as happens when a region moves from water surplus into water deficit. In water deficit conditions there is overwhelming evidence to show that many present water-related policies and practices are doing little to benefit the poor - and little to achieve the relevant Millennium Development Goals.

45. The major players that influence the policy which in turn influences the water ecosystems are the ministries and organisations involved in planning, implementation and management of the big water-related projects. Most of these projects be they a major irrigation project or a hydropower project, have been in the realm of the government or at the most public sector domain. It is only recently that the private sector started participating, there are many big projects which are coming up with private investment. However, there is less clear policy on environmental flows. If consideration of environmental flows is imposed on a project which had not considered them during the design phase, then the whole profitability of the project might change and it might be difficult for a private investor to absorb.

46. Furthermore, there are many policies that may influence the ecosystem services but are never addressed. The case of interlinking of rivers is another case where despite being a mega project -the size of which has never been implemented - has not been looked at from its impact on ecosystem services. There are numerous other cases where decisions have been taken independently by the respective ministry or organisation, without looking at the possible implications. Some of the examples are:

- The intent of the MoEF is to cover 33 per cent of the country with forest cover:
- The recent intent of the government to cover 40 million hectares of wasteland with Jatropha plants to produce bio-diesel:
- To let the Special Economic Zones (SEZ) to come up on agricultural land
- To let farmers extract any amount of groundwater free of cost with free electricity or subsidised diesel.

47. Integrated watershed/water resources management does not merely imply the amalgamation of different activities to be undertaken within a hydrological unit. It also requires the collation of relevant information so as to evaluate the cause and effect of all the proposed actions. The watershed is the smallest unit where the evaluation of man-induced impacts upon natural resources becomes possible with respect to the water balance approach. As the impacts resulting from actions taken at the watershed level will be experienced at a lowers level within the drainage basin, the assessment of these impacts will require the availability of a framework which enables the mapping of such units to the higher catchment level in the hierarchy of River Basin at the highest level of drainage system. Such a framework will need regular maintenance and updating to reflect fully the most accurate ground-truthed data or the infrastructure requirements for planning and management of the natural resources collected by the relevant departments. This framework, once available, could be used by all the line departments and updated by the relevant departments which have designated areas of jurisdiction over the data entry. The format should be made consistent with local to state and national level structures as well as the corresponding watershed, catchment and basin level structures. Such a framework shall also be used to enumerate the freshwater ecosystem services each system is serving.

48. The research priorities of the country in the context of improving the use and sustainability of the freshwater ecosystems may be categorized under various related issues of policy, governance, and infrastructure. What has been observed in the past is that we have very good policies in position but when it comes to implementing the same policies, either the process is incomplete and faulty or the administrative and technical infrastructure is inadequate and/ or insufficient. Research is needed to address the loopholes identified in these issues so that it can supplement the intended purpose whether it is policy, governance or infrastructure.

49. Support for policy improvement: The policy, being an intent put together by domain experts and policy makers, is invariably a very good document that addresses all the concerns of a very wide cross-section of stakeholders. The same situation occurs with the National Water and Environment policies in India. These are very good documents in their own right. However there are few issues that are either not adequately addressed or are altogether missing. Some of these issues are briefly discussed below and might need research outputs for further support in bringing home the point.

- The National Water Policy (NWP) does talk of a river basin approach to manage the water resources effectively. It somehow does not explicitly emphasize that the same drainage area based approach should also be continued for the sub-areas of the basin, namely catchments and watersheds, that shall make it possible to address the equity and externality issues effectively
- There is no provision in the NWP for a feedback mechanism on the implications of actions taken in the policy instruments of other sectors such as Environment, Forest, Agriculture, Watershed Development, Energy, etc. Slogans of the kind ‘Stop the water where it drops’ are made as part of some policies without even thinking about the repercussions. Intents of the kind ‘foresting 33 per cent of the geographical area’, and ‘cultivating Jatropha on 40 million hectares of land’ are made without bothering about the implications on ecosystems
- The NWP does not even mention climate change impacts on water resources, in spite of the fact that it has been revised as late as 2002, when the general awareness of the issue was there and one of the ministries (namely MoEF) was already involved in making India’s Initial Communication to the UNFCCC
- The NWP does not attempt to tackle equity issues and other societal issues connected with water. It only stops at providing rehabilitation to those people uprooted by big projects but is not concerned when local level interventions (many times implemented by other ministries and departments) are made and are potentially capable of creating bigger impacts on the drainage basins.

50. Even with the NWM many of the above concerns still remain intact. It is very important to take stock of these concerns if the objectives set forth under the NWM are to succeed. It is not true that policy makers are not aware of these issues; it is more on account of lack of initiative and also many times due to the complexity of these issues. The initiative can also come from research organizations. To help bridge the apparent gap between the policy and research communities and to ensure that recent research findings and policy developments can be communicated between policymakers, it is proposed that greater use be made of research networks within and between countries. These networks would aim to incorporate advocacy and promotion techniques, and to connect and disseminate new knowledge of the biophysical and socio-economic outcomes of land and water interventions to policy makers through a number of mechanisms. These would include peer-to-peer networking of policymakers, the use of interactive workshops and the use of innovative media including e-fora and websites.

51. Solution to the problems and perverse outcomes identified above in relation to land and water policies and watershed development projects rests primarily in the realm of governance. In this context governance is considered to be the range of political, social, economic and administrative systems that are in place to develop and manage land and water

resources and the delivery of water services at different levels of society. The core challenge in Integrated Land and Water Resource Management (ILWRM) is that of land and water governance, particularly in relation to the deeper political and societal foundations on which day to day decisions and courses of action rest. It is also recognised that difficult ILWRM decisions will have to be made if both poverty reduction and environmental sustainability are to be addressed effectively. The NWM and this report promotes sub basin and basin planning; an iterative process that allows research findings to be mainstreamed.

52. Another segment that shall require maximum research initiative is to create infrastructure that shall be able to encapsulate the majority of issues described above and which shall act as a facilitator to provide a framework for integration, planning, monitoring and assessment. A typical framework, incorporating the Integrated Water Resources Management Cycle shall include the following methodologies which can be operated in conjunction with support tools[11] Some of the components and functionalities of such a system are:

- Hydrological assessment of all water uses and users within a catchment
- Catchment Stress Assessment to determine to what extent the catchment is approaching 'closure', or not meeting aquatic ecosystem requirements
- Strategic Environmental Assessment to identify the economic returns and employment opportunities that arise or potentially could arise from water use in the catchment
- Methodologies for contextual analysis (forest and water narratives, beliefs underlying policy)
- Web and GIS based dissemination tools, incorporating Blue and Green water integrating methodologies
- An 'Allocation Equity Guide', providing guidelines to support stakeholder negotiations
- Environment impact assessment methodologies, primarily in relation to biodiversity and water quality
- Poverty reduction impact assessment methodologies, addressing the questions: who are the winners and losers of these policies? Will the outcomes of the policy instruments benefit key poor and vulnerable groups?
- Monitoring and evaluation. The impact assessment methodologies outlined above will also provide the basis for monitoring and evaluating the socio-economic, poverty and water resource outcomes of manmade interventions
- Such a framework should be able to effect convergence of scales to encompass the interventions being made at various levels. The effective adaptation measures to climate change impacts shall only be possible through reliable simulation of the future conditions which such a common framework offers.

E. India's Climate Systems

53. India has a very complex climate system, dominated by the southwest monsoon and the major physiographic features including; the Himalayas, the oceans surrounding the country, the Eastern and Western Ghats and the Central Plateau. The Himalayas influence the climate in a number of ways providing shelter from the cold winter air mass of central Asia, keeping India warmer in winter and also acting as a barrier to the moisture laden south-west monsoon airflow in summer, resulting in heavy precipitation in northern India.

1. Climate Trends

54. **Temperature:** Various analyses show trends of increasing temperatures. Analysis by INCCA 2010[12] shows that the annual mean temperature has had a significant warming trend of 0.5°C per 100 years during the period 1901–2007 (Kothawale et al., 2010). Accelerated warming has been observed in the recent period 1971–2007, mainly due to intense warming in the recent decade 1998–2007. This warming is mainly contributed by the winter and post-monsoon seasons, which have increased by 0.80°C and 0.82°C in the last hundred years respectively. The pre-monsoon and monsoon temperatures also indicate a warming trend. Mean temperatures have increased by about 0.2°C per decade for the period 1971–2007, with a much steeper increase in minimum temperature than maximum temperature. In the most recent decade, maximum temperature was significantly higher compared to the long-term (1901–2007) mean.

55. **Precipitation:** A study of regional trends of precipitation patterns by Guhathakurta from IMD[13] reveals that, while there is no overall trend in precipitation in India, there are statistically significant trends at the regional level, with some areas showing an increase in precipitation while other regions exhibiting a drying trend. The patterns differ for different months and for the monsoon season, and the authors found decades with predominantly dry or wet monsoons. This is a manifestation of climate variability (at the decadal time scale).

[11]Calder, I.R., Batchelor, C., Quibell, G., Gosain, A., Jewitt, G., Amezaga, J., Hope, R., James, P., Garratt, J., Simpson, E. 2004b. Global Governance of Water and the Blue Revolution - Can we achieve better outcomes from land and water policies? International Symposium: Global Governance of Water - Water and Human Security, Tokyo, Japan

[12]INCCA Indian Network for Climate Change Assessment November 2010

[13]Trends in the rainfall pattern over India International Journal of Climatology 2007 P. Guhathakurta* and M. Rajeevan India Meteorological Department

56. Some research suggests a weakening trend of monsoonal rainfall, e.g. Naidu, et al [Naidu, 2008]. They conclude that "in the global warming era (1970–2005), 19 out of 30 meteorological subdivisions showed negative tendencies in summer monsoon rainfall. This decrease in summer monsoon rainfall is associated with a weakening of the Southern Oscillation and relaxation of the meridional temperature gradient over the Indian Ocean." However, this could be a multi-decadal variability rather than a long-term trend.

57. In contrast, the overall strength of the summer monsoon is projected to increase by up to 10% by end 21st Century, However, in the latest downscaled models for South Asia[14], given regional trends this may play out very differently in different river basins. There is less certainty in the projections for the winter monsoon. The all India monsoon rainfall series based on 1871 to 2009 shows the mean rainfall 848mm with a standard deviation of 83mm. The Indian monsoon shows well defined epochal variability with each epoch of approximately of about 3 decades, there is however no evidence of any significant trend.

58. **Rainfall intensity:** Studies by Goswami show that there are also trends in the intensity of rainfall, with a marked increase in heavy (above 100mm/day) and very heavy (150mm/day) rainfall events.[15] Using IMD's daily rainfall data set, the study showed that, in spite of year to year variability, there are significant rising trends in the frequency and magnitude of extreme rain events and a significant decreasing trend in the frequency of moderate events over central India during the monsoon seasons from 1951 to 2000. A substantial increase in hazards related to heavy rain is expected over central India in the future.

59. Studies by Krishnamurthy et al[16], generally support the findings of Goswami et al. Their study also made use of the IMD gridded daily rainfall dataset, but considered changes in the frequency of events above threshold percentiles of the daily rainfall distribution, and intensities, rather than fixed threshold values. There were many grid cells with no statistically significant trends, but the indication was of generally decreasing trends in frequency and intensity of extreme rainfall in the north and central parts of the Indian sub-continent, while coastal regions and the region immediately wet of Bangladesh have experienced increasing trends.

60. Dash[17] has carried out a similar study for both precipitation and temperature extremes at the regional level; the findings were that in the last half century, the numbers of moderate rain days averaged over the whole of India have significantly decreased during the summer monsoon season. Similar significant decrease is noticed in the number of low rain days. The number of heavy rain days considered over the entire country shows some indications of increase, though the trend is not statistically significant. Significant decrease in the number of long spell rain events and simultaneous increase in the short and dry spells are observed over India. Short spells of heavy intensity rain over the entire country are increasing whereas long spells of moderate intensity and low intensity are decreasing during the summer monsoon season. The seasonal contribution of moderate rainfall to total rainfall has decreasing trend in all India, west central India, northwest India, northeast India, central northeast India, Uttarakhand, Gujarat and Telangana, but has increasing trend in Himachal Pradesh.

2. Climate Change Scenarios

61. The IPCC scenarios provide a mechanism to assess the potential impacts of climate change. Global emission scenarios were first developed by the IPCC in 1992 and were used in global general circulation models to provide estimates for the full suite of greenhouse gases and the potential impacts on climate change. Since then, there has been greater understanding of possible future greenhouse gas emissions and climate change as well as considerable improvements in the general circulation models. The IPCC, therefore, developed a new set of emissions scenarios, published in the IPCC Special Report on Emission Scenarios (IPCC SRES, November 2000). These scenarios provided input into the Third and Fourth Assessment Reports and were the basis for evaluating climatic and environmental consequences of different levels of future greenhouse gas emissions and for assessing alternative mitigation and adaptation strategies. These scenarios refer to the projections made for future conditions mainly related to precipitation, sea level rise and temperature changes, based on 'storylines' of the alternate greenhouse gas emissions. There are four storylines (A1, A2, B1 and B2) identifying alternate states of future economic and technological development that takes place over the next few decades as summarized in Table 4.

[14]Krishna Kumar
[15]Increasing Trend of Extreme Rain Events Over India in a Warming Environment B. N. Goswami, V. Venugopal, D. Sengupta, M. S. Madhusoodanan, Prince K. Xavier
[16]Changing Frequency and Intensity of Rainfall Extremes over India from 1951 to 2003 Krishnamurthy 2009
School of International and Public Affairs, Columbia University, New York, New York
[17]Dash 2010

Table 4: Summary of IPCC SRES Scenarios

IPCC SRES Scenarios	
A1 World: Market Oriented Economy: Rapid economic growth. Population: Peaks in 2050 and then gradually declines. Governance: A convergent world - income and way of life converge between regions. Extensive social and cultural interactions worldwide. Technology: There are three subsets to the A1 family A1FI - fossil-fuels intensive. A1B - balanced on all energy sources. A1T - non-fossil energy sources.	**A2** World: Divided World Economy: Regionally oriented, lowest per capita income Population: Continuously increasing population. Governance: independently operating, self-reliant nations Technology: Slower and more fragmented
B1 World: Convergent Economy: service and information based, lower growth than A1 Population: Same as A1. Governance: global solutions to economic, social and environmental stability Technology: clean and resource efficient technologies	**B2** World: Local Solutions Economy: Intermediate levels of economic development Population: Continuously increasing population, but at a slower rate than in A2. Governance: local solutions to economic, social and environmental stability Technology: more rapid A2, less rapid more diverse A1/B1
Source: IPCC 4th Assessment Report (2007)	

62. Climate models are mathematical models used to simulate the behaviour of the climate system. They incorporate information regarding climate processes, current climate variability and the response of the climate to human-induced drivers. These models range from simple one dimensional models to complex three dimensional coupled models.

63. The latter, known as Atmosphere Ocean Global Circulation Models (AOGCMs), incorporate oceanic and atmospheric physics and dynamics and represent the general circulation of the planetary atmosphere and ocean.

64. The AOGCMs are usually run at very coarse grid (about 3° X 3°) resolution whereas the processes that are of interest for studies such as this one, such as precipitation, are highly influenced by the local features - namely orography (study of the physical geography of mountains), and there can be significant variation over small distances. These local characteristics are not properly represented at the coarse scale of a GCM and contribute to projection errors on the impact of climate change at the sub-grid scale. Therefore, these GCMs are strengthened with the incorporation of local factors and are downscaled, in general with a grid resolution of about 0.5° X 0.5° or less. The downscaling can be of dynamic or statistical type. Dynamic downscaling models are referred to as Regional Climate Models (RCM) and improve the quality of climatic prediction for specific local areas.

65. A RCM is a model of the atmosphere and land surface which has high horizontal resolution and consequently covers a limited area of the earth‘s surface. A RCM cannot exist without a 'parent' GCM or AOGCM to provide the necessary inputs. The RCMs provide an opportunity to dynamically downscale global model simulations and to superimpose the detail of a specified region. RCMs can provide climate information with useful local detail including better representation of extreme events and also they simulate current climate more realistically.

66. PRECIS (Providing Regional Climates for Impact Studies) is an atmospheric and land surface regional climate model of limited area and high resolution which is locatable over any part of the globe. Dynamical flow, the atmospheric sulphur cycle, clouds and precipitation, radiative processes, the land surface and the deep soil are all described. Lateral boundary conditions (LBCs) are required at the limits of the model's domain. Information from every aspect may be diagnosed from within the model (Noguer, et al., 1998[18]). While it is possible to get finer details from techniques such as dynamical downscaling by using regional climate models (RCMs), it is important to realise that if the parent model providing the boundary conditions is not skilful in replicating important features of the regional climate, then down-scaled results will reflect this lack of skill.

[18]Noguer M, Jones R, Murphy J (1998) Sources of systematic errors in the climatology of a regional climate model over Europe. Clim Dyn 14:691–712

3. Regional Climate Scenarios for India Using PRECIS

67. Indian RCM PRECIS has been configured for a domain extending from about 1.5°N to 38°N and 56°E to 103°E. PRECIS has been run at IITM Pune for time slices of the A2 and B2 SRES scenarios (baseline and 2080s), and for three members of the Hadley Centres QUMP (Quantifying Uncertainty in Model Projections[19]) ensemble with the IPCC SRES A1B Scenario.[20]

68. The QUMP ensemble is a seventeen-member perturbed physics ensemble (PPE) produced using the HadCM3 GCM by the UK Met Office Hadley Centre. The QUMP simulations comprise 17 versions of the fully coupled version of HadCM3, one with the standard parameter setting and 16 versions in which 29 of the atmosphere component parameters are simultaneously perturbed (Collins et al. 2006[21]). IITM Pune have produced 138 year simulations with PRECIS using the QUMP Q0, Q1, and Q14 member LBCs. (Lateral Boundary Conditions).

4. Validity of Models

69. Global circulation models (GCMs) with their relative coarse grid-cell resolution (several 100km) have reasonable skill in reproducing the temperature characteristics over the Indian subcontinent, however, the skill for reproducing precipitation varies considerably. A recent study [Kripalani 2007, 2010] has compared the skill of GCMs to reproduce quantitative and qualitative features of precipitation over India and in particular during the summer monsoon. It looked at the ability of the climate models that were used in IPCC AR4 to reproduce current climatology of the monsoonal precipitation - total amount and correct timing.

70. Average monthly rainfall (mm/month) depicting the annual cycle over the south Asian region for the observed climate was compared with that simulated by the 22 coupled models. Models were classified as follows:

- Category 1: Models simulating shape and magnitude well;
- Category 2: models simulating shape well but underestimating magnitude;
- Category 3: models simulating a shift in peak precipitation by a month; and
- Category 4: models unable to simulate the annual cycle properly.

71. It should be noted that neither of the Hadley Centre models used in dynamical downscaling models over India is in the first category. However, one was identified in subsequent evaluation as being worthy to take forward. In the global context, however, the Hadley Centre model, when evaluated over the whole globe and many climatic indicators, is considered as one of the best GCMs.

72. While it is possible to get finer details from techniques such as dynamical downscaling by using regional climate models (RCMs), it is important to realise that if the boundary conditions of the underlying GCM are not skilful, then the downscaled results will remain relatively poor.

5. Outputs of Projections Using PRECIS

73. **Temperatures:** From the recent INCCA study, the PRECIS simulations for 2030s indicate an all-round warming over the Indian subcontinent associated with increasing greenhouse gas concentrations. Relative to the 1970s baseline period, the annual mean surface air temperature rise by 2030s ranges from 1.7°C to 2°C as in the three simulations. The variability of seasonal mean temperature may be more in winter months. These findings are similar to the PRECIS assessment in the three pilot sub basins.

74. Precipitation

- The projections of precipitation[22] indicate a 3% to 7% overall increase in the all India summer monsoon rainfall in 2030s with respect to the 1970s.

[19]The basic approach involves taking a single model structure and making perturbations to the values of parameters in the model, based on the discussions with scientists involved in the development of different parameterization schemes
[20]PRECIS A1B, which is a mid path scenario, a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies, with the development balanced across energy sources
[21]Collins, W.D., V. Ramaswamy, M.D. Schwarzkopf, Y. Sun, R.W. Portmann, Q. Fu, S.E.B. Casanova, J.-L. Dufresne, D.W. Fillmore, P.M.D. Forster, V.Y. Galin, L.K. Gohar, W.J. Ingram, D.P. Kratz, M.-P. Lefebvre, J. Li, P. Marquet, V. Oinas, Y. Tsushima, T. Uchiyama, and W.Y. Zhong, 2006: Radiative forcing by well-mixed greenhouse gases: Estimates from climate models in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). J. Geophys. Res., 111, D14317
[22]INCCA 2010

- With the exception of the Himalayan region, all other regions were projected to experience a decrease in winter and pre-summer rainfall under the PRECIS A1B scenarios. The winter rainfall in the Himalayas showed no significant change.
- In the Himalayan region the PRECIS A1B scenarios indicated an increase in annual precipitation by the 2030s with respect to the 1970s, of 5-13%. The indication was for an increase in precipitation in all seasons, with the highest increase during the southwest monsoon. Only a small increase in winter precipitation was projected.
- In the west coast region, an increase in annual rainfall of 6-8% was projected for the 2030s relative to the 1970s. A small increase in southwest monsoon rainfall was projected, and a reduction in winter rainfall.
- In the east coast region, and smaller increase in annual rainfall of 0.2-4.4% was projected for the 2030s relative to the 1970s. The largest increase in precipitation was for the months of March, April and May. Winter rainfall was projected to decrease.[23]
- In the northeast region the indication from the PRECIS A1B scenarios was for an increase in annual rainfall of 0.3-3% by the 2030s relative to the 1970s, with a substantial decrease in winter precipitation.

75. Plots of changes in monsoon rainfall under each of the three QUMP scenarios shows quite significant spatial variations in precipitation changes, that are masked a little by the regional averages presented above. Figure 1 shows PRECIS results as presented in the recent INCCA report. the figure shows: (a) the observed summer monsoon rainfall climatology; (b), (c) and (d) are Q0, Q1, Q14 simulation of observed monsoon rainfall; (e) projected changes in summer monsoon rainfall in 2030s with respect to 1970s[24] (Source: INCCA, 2010).

76. In the four plots in the upper part of the figure observed southwest monsoon baseline precipitation is compared with PRECIS simulated baseline southwest monsoon precipitation for the Q0, Q1 and Q14 A1B scenarios.[25] The Q0 and Q14 simulations are similar and appear to underestimate precipitation in the western Himalayan region, and over estimate precipitation in the southwest of Orissa. The indication is that with the Q0 and Q14 scenarios, precipitation on the west coast may be over-estimated, while with Q1 it is under estimated on et west coast and in Karnataka. The patterns of changes by the 2030s under the Q0, Q1 and Q14 scenarios are presented in the lower part of Figure 1. There are clearly quite significant differences in some areas. In Karnataka and Tamil Nadu, for example, the Q1 scenario indicates increased monsoon precipitation while the Q14 scenario indicates a decrease. There are also changes in patterns over the central plateau and in the western Himalayas.

77. The PRECIS analysis carried out for the three sub basins as part of this study was based on the Q14 scenario (which was the only version available) and showed an increase in annual precipitation for the Sutlej basin (15%) and in the Kshipra (+23%), but no change for Cauvery. The increases are in the summer monsoon with some decrease in other months. For the Cauvery although the annual rainfall is largely unchanged there is an estimated drop in the southwest monsoon rainfall and an increase in the northeast monsoon rainfall. These results are consistent with what is presented in Figure 1 and demonstrate the need to consider a range of scenarios, and a range of climate models.

6. PRECIS Projections for Extreme Precipitation

78. The PRECIS projections with the A1B Q0, Q1 and Q14 scenarios indicate a reduction in the frequency of rain-days in most parts of India, except in the Himalayas, the northwest region and southern plateau. The projections indicate a corresponding increase in rainfall intensity. These findings are consistent with a continuation of trends observed in the historic record.

79. The PRECIS analysis in the three sub basin showed only a small increase in extreme rainfall events. In the Cauvery Delta there was an increase of 1 day per year of rainfall greater than 150mm.

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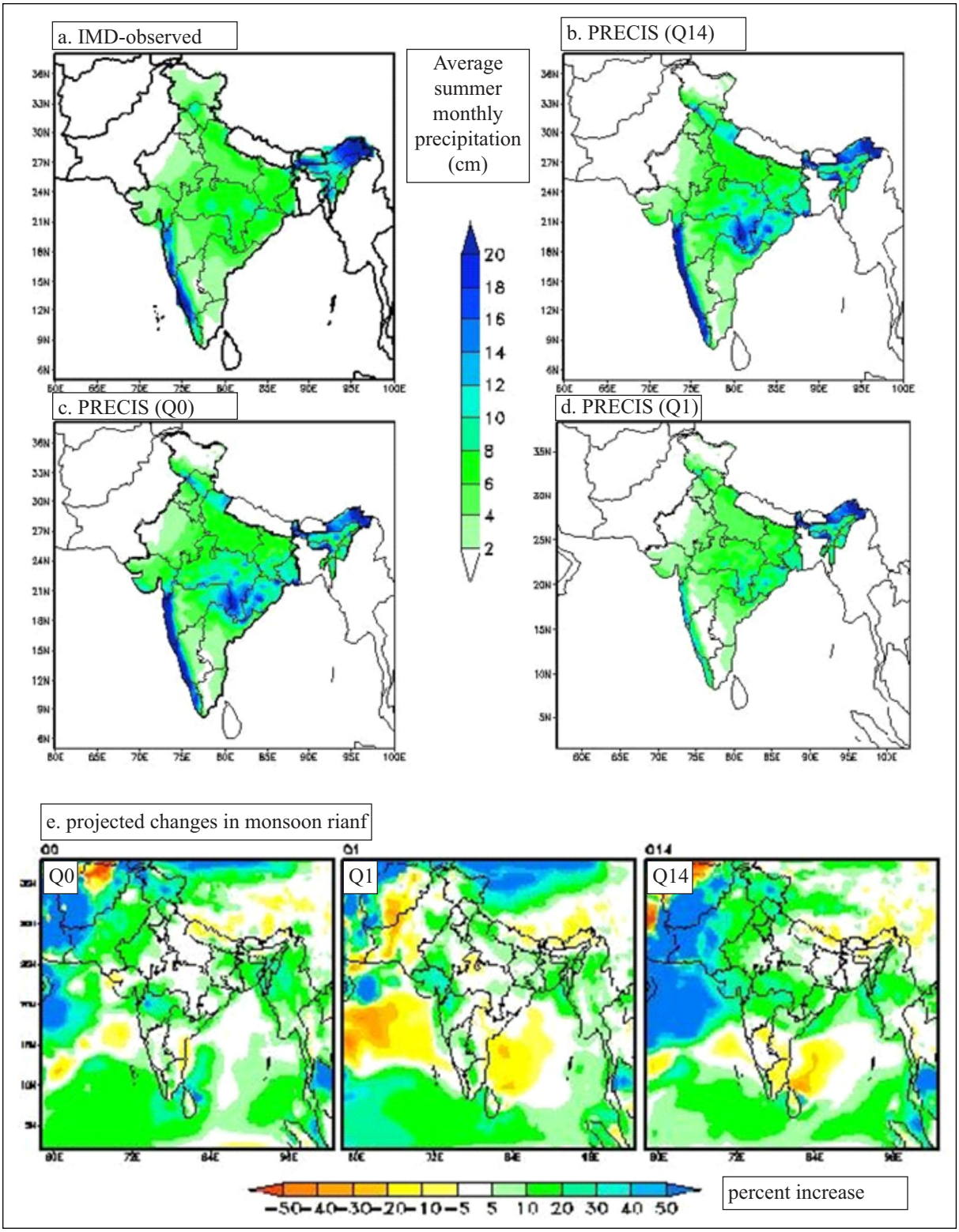
[23]The S-NWM study contrary to the INCCA study found that for the Cauvery Delta the summer SW monsoon would weaken but the North East Monsoon would strengthen

[24]INCCA Indian Network of Climate Change Assessment

[25]The QUMP ensemble comprises 17 runs of the Hadley Centre HadCM3 model. In each of these runs, there is a slightly different parameter set. Parameters that might be considered to be uncertain are adjusted within what is thought to be a feasible range to create the ensemble, and the identifiers Q0, Q1, Q14 etc., are simply identifiers for the model run. Each of member of the QUMP ensemble would be considered to be an equally likely realisation of future climate evolution. Q0, Q14 are alternative projections of climate evolution for the same SRES scenario. The QUMP approach is designed to account for inter-model variability, but to do so in a consistent manner be properly representing the uncertainty range for particular parameter that influence model results.

Figure 1 Observed and Projected Climatology



7. Projections for Sea level rise and Coastal Surges

80. Renewed research efforts into global sea level rise, especially into rise related to ice sheet dynamics is concluding that the IPCC AR4 projections (of some 0.6m in high-emission scenarios by end 21st century) are likely to be too conservative by a factor 2-3 (Rahmstorf, 2010), through other techniques an upper limit of 2m for end 21st century has been suggested (Church, 2008). The IPCC estimate is for a 0.3m sea level rise by mid century; although recently some scientists that express the opinion that a 0.3m rise is insufficient and will likely be exceeded. The figure of 0.3m however could be used for planning and design in the interim period.

81. In a 2006 study, [Unnikrishnan, 2006] investigated long term sea level changes (such as caused by thermal expansion of seawater, melting of glaciers and ice caps) and short term surges caused by storms. They used the HadRM2 model (similar to PRECIS) to show that under climate change storm surges with 2.5m or more will become more frequent than is currently the case. Of special concern is the strengthening of cyclones, a trend of which has already been observed in the Bay of Bengal, especially during November.

82. The PRECIS A1B Q0 and Q1 scenarios indicate a possible reduction in storm frequency by the 2030s, but as indicated above, this must be put in the context of possibly more intense storms.

8. Assessment of the Hydrological Response

83. The **Hydrological Response** to potential climate changes can be assessed using a rainfall-runoff model. Gosain, *et al* have used the SWAT model to study the potential impacts of climate change on water resources in India. The impact of climate change on the quantity of water resources has been predicted to vary between catchments as well as within catchments. Although there was an increase in precipitation in Mahanadi, Brahmani, Ganga, Godavari, and Cauvery basins for the climate scenario considered (A2), the corresponding total runoff for these basins had not necessarily increased. This was due to increases in evapotranspiration on account of increased temperatures. In other basins decreases in precipitation were projected. The resultant total runoff decreased in majority of the basins considered, but for Narmada and Tapi. The order of magnitude of changes in runoff response were not uniform since they are governed by many factors such as land use, soil characteristics and the status of soil moisture.

84. Further modelling studies have been undertaken with the A1B climate scenario the recent INCCA assessment of sectoral and regional climate change impacts in India. Four regions were considered: Himalayan Region, North-Eastern Region, West Coast Region, East Coast Region. The climate change assessment was for the 2030s, relative to the 1970s. The indications were for increased water yield in the Himalayan Region, but a decrease in water yield in the North-Eastern Region. In both of these regions an increase in sediment yield was projected. In the West Coast Region a reduction in water yield of up to 10% was projected for Karnataka and Kerala, but significant increases in water yield for the Gujarat and Maharashtra areas. There was variability in projections of water yield in the East Coast Region also, with some areas projected to experience a 20% reduction, while others were projected to experience a 20% increase.

85. SWAT modelling was carried out under the current study for the three pilot basins. The model was used with climate simulations from the A1B emissions scenarios from the PRECIS RCM with HADCM3 boundary conditions from the QUMP Q14 member. The model was calibrated using data from the IMD 0.5° precipitation and temperature data, and observed flow data from the Central Water Commission (CWC) and state gauging stations. In the Kshipra sub basin the calibration achieved with the model was considered to be acceptable, and river flow simulation with PRECIS input data matched reasonably well with river flows simulated with observed weather data. In the Sutlej basin calibration in the upper basin was very poor and no assessment was possible. For the Sutlej the SWAT analysis was restricted to the lower part of the catchment below Bhakra dam. For the Cauvery Delta the SWAT model was being run primarily for the catchment upstream of the delta, but considering only changes in natural runoff response. This project did not have the resources to model the complex water utilisation that takes place upstream of the delta. Because of this water use it was not be possible to properly calibrate the SWAT model. However, performance evaluation of SWAT hydrologic budget was made using the observed data for the period 1980-1989 at monthly scale for gauges upstream and downstream of Mettur dam. The long-term simulated monthly mean at all drainage area levels was over simulated as would be expected in the absence of water use in the simulation. In the lower Sutlej basin, an increase in both precipitation and potential evapotranspiration are forecast from the PRECIS scenario. SWAT simulated increased runoff from the middle part of the basin, no change in runoff in the lower part of the basin, but an increase in groundwater recharge in some areas.

86. In the Kshipra, increased precipitation was translated into increased runoff and groundwater recharge, but no change in actual evapotranspiration. In the Cauvery basin a much complex pattern emerged with some sub-catchments experiencing increased runoff and others reduced runoff and reduced baseflow and groundwater recharge.

9. Improving Climate Scenario Availability

87. At present there is very limited availability of future climate scenarios in India. Modelling capability exists at IITM and at TERI, and both of these centres are using PRECIS with HADCM3 boundary conditions. TERI are currently working on a very limited domain with a high resolution model. IITM on the other hand have been working with a domain that covers the entire continent.

88. IITM have produced simulations with the A2 and B2 SRES scenarios for the 2080s time slice as well as a baseline period, and have produced three simulations with the A1B scenario. The three A1B scenarios are alternative realisations using boundaries from the Hadley Centre's HADCM3 QUMP (quantifying uncertainty in model predictions) ensemble. The QUMP approach involves carrying out multiple model simulations with parameters adjusted within what are considered to be feasible ranges. The approach is designed to account for modelling uncertainties (and inter-model variability), and produces an internally consistent set of scenarios. IITM have thus far selected three of the 17 available QUMP ensemble members. They plan to carry out further simulations, and also intend to work with RegCM[26] in future. It is important that scenarios from a wider range of GCMs and RCMs become available.

89. At present there is no formal means of obtaining simulation results from IITM, although they do provide data to researchers on request. There would be advantage in making the data more widely available either through an ftp site or a web based portal, as exists for GCM data through the IPCC. For water resources investigations, the data generally required from GCM and RCM simulations are:

- precipitation;
- maximum and minimum daily temperatures;
- relative humidity;
- wind speed; and
- solar radiation reaching the ground surface.

90. These are a subset of the data produced by a RCM, and there is a good argument for creating a separate archive or repository for those data specifically required for water resources investigations. Data for the existing PRECIS scenarios (3 A1B scenarios plus A2 and B2) could be extracted and archived for the entire model domain used by IITM, and an interface set up to permit data extraction from the archive for any selected location and planning horizon. The archive could certainly be hosted and maintained by CWC (see section IX). It would also be possible to provide standard analysis and reporting routines that would make the data accessible to people with a wide range of skill sets. The repository could also include GCM data for the same domain as the PRECIS data.

91. Creation of the repository would provide a resource for all water resources studies in India, and would prevent duplication of effort in data extraction and analysis. It would be of assistance to both researchers and practitioners. Ideally the repository would also include access to other scenarios created by modelling centres outside of India.

[26]The Regional Climate Model system RegCM , originally developed at the National Center for Atmospheric Research (NCAR), is maintained in the Earth System Physics (ESP) section of the Internation Centre for Theoretical Physics (ICTP), Trieste. The first version of the model, RegCM1, was developed in 1989 and since then it has undergone major updates in 1993 (RegCM2), 1999 (RegCM2.5), 2006 (RegCM3) and most recently 2010 (RegCM4). The latest version of the model, RegCM4, is now fully supported by the ESP, while previous versions are no longer available. This version includes major upgrades in the structure of the code and its pre- and post- processors, along with the inclusion of some new physics parameterizations. The model is flexible, portable and easy to use. It can be applied to any region of the World, with grid spacing of up to about 10 km (hydrostatic limit), and for a wide range of studies, from process studies to paleoclimate and future climate simulation.

F. Focal Area 1: Climate Change Analysis For Water Resources

1. Requirements

92. Climate change analysis for water resources requires a partnership of State and Central government and National and State Institutes. At present, analyses are organised on a project basis and there is a need to develop a systematic programme and sub-basin approach for all states. New and improved data and climate projections need to be fed into the planning process as and when they become available.

2. Climate Projections

93. The need for climate projections and scenarios to guide project design and implementation in India has resulted in the use of projections that are: (i) developed on an ad-hoc basis; (ii) limited in the representation of uncertainties; (iii) of insufficient spatial and temporal resolution; or (iv) inadequately documented and evaluated with respect to scientific rigor and suitability for tasks. The underlying issue is a near-absence of well-documented high-resolution climate projections covering important geographic domains within the Asia and Pacific region.

94. The experience of this study shows that while climate change projections contain many uncertainties and in some areas insufficient to concrete adaptation decisions, it is important that development planning and design should factor incorporate the projections into the decision making processes at an early stage. Work on climate change scenarios needs to be further strengthened; this should include a better characterisation of uncertainties in the scenarios and associated hydrological analyses. Potential improvements could be made through using outputs from a wider suite of RCM runs, driven by different GCMs and forced by different emissions scenarios. This is an approach used in the USA for NARCCAP[27] or developing probabilistic scenarios using certain sampling techniques.[28]

95. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4, 2007) presented twenty three Global Climate Models (GCM). These have generated projections for a future climate that encompass the Asia Pacific region under a range of assumptions concerning the likely trajectory of greenhouse gas (GHG) emissions.[29] Three primary constraints limit the applicability of these model projections in the development of scenarios to guide impact assessment and adaptation planning within Asia and the Pacific: (i) model resolutions are typically too coarse (from 100 to 300 km horizontally) to provide projections of regional climate at resolutions required to support impact assessment (typically 50 km or below); (ii) many GCMs are not able to replicate important features of the climate of Asia and the Pacific, notably the South Asian monsoon and El Nino-Southern Oscillation (ENSO), at high levels of skill; and (iii) GCM outputs are not widely available to the community of end-users, and when available, often require extensive processing before they can be interpreted and down-scaled. These factors, along with others, have created barriers to wider and more effective use of GCM-based projections in adaptation projects and related work within the region.

96. Global climate modelling centres are currently engaged in performing simulation runs under the Coupled Model Inter-Comparison Project 5 (CMIP5) of the World Climate Research Program (WCRP). These runs will form the primary basis for updated analysis appearing in the Fifth IPCC Assessment Report (AR5) slated for release in 2013. While it is too early to determine if the CMIP5 generation of models will demonstrate improved performance in simulating the South Asian monsoon and other difficult features of regional climate, there are indications that higher model resolution may improve the model skill in these areas.

3. Strengthening and Coordination of India's Capacity to Prepare Climate Projections.

97. Recent evidence shows clearly that climate change (CC) is already affecting the Asia-Pacific region, and the impacts of Climate Change are projected to intensify in the decades to come. Analysis of trends in rainfall in the pilot sub basins do indicate that the projections in rainfall under the PRECIS A1B scenario are in line with the observed trends.

98. ADB has conducted a wide range of regional workshops and consultations since 2008, and has identified a strong demand for regional cooperation to complement in-country adaptation activities.[30] In many of these consultations, in

[27]North American Regional Climate Change Assessment Program; URL http://www.narccap.ucar.edu/)
[28]Such as the. Monte Carlo simulation etc; this is part of the approach used in UKCIP (UK Climate Impacts Programme) for the latest projections "UKCP09"; URL http://www.ukcip.org.uk/
[29]Model runs conform to specifications established by the WCRP Coupled Model Inter-Comparison Program (CMIP).
[30] ADB 2011 Draft Concept Note: Reference Climate Projection Library for Asia and the Pacific

particular those focused on the water sector, the absence of scientifically credible projections of future climatic conditions at a suitable level of resolution, and clear guidelines for their interpretation and use, have been identified as active impediments to the design and implementation of effective adaptation and/or development projects.

99. Opportunities already exist to improve the accuracy of climate assessments through multiple high-resolution climate projections. The Fifth IPCC Assessment Report (AR5) targeted for release in 2013 will further increase the opportunities for improved accuracy. Improvements in the resolution, skill, availability and documentation of such projections will significantly assist India to conduct climate change adaptation projects and improve the quality, effectiveness and scientific integrity of their adaptation efforts.

100. It is essential that IITM and the other climate research institutes are supported to keep India in the forefront of climate assessments. It is considered that regional cooperation of climate change could offer significant advantages both for India and the region. It is proposed that a strong partnership and memorandum of understanding (MoU) is developed between IITM and MoWR/CWC to ensure the most recent and advanced climate projections can be mainstreamed into water resources planning and management.

101. There are many organizations and agencies who are carrying out research on effects of climate change water resources, various scenarios and adaptation studies. Some very useful work has progressed on this under the Indian Network of Climate Change Assessment (INCCA) an initiative under the Ministry of Environment and Forests. For water resources it is important that the CWC and MoWR become more fully incorporated into the INCCA activities. Initiatives for water resources should build on the INCCA network.

102. MoWR and CWC and the State WRDs will play a key role to incorporate projections into the water resources planning processes. Improved and more robust climate assessments will have limited value unless the water resources agencies have the capacities and skills to absorb and apply the information. To achieve this requires systematic water resources planning. Currently this largely does not exist.

4. Mechanisms to Address Current Issues and Climate Impacts

103. The application of climate projections into the development of adaptation planning needs to be both cautious and pragmatic. Framework planning for the sub-basins has been based on three stages: (i) development of adaptation strategies for current issues and future development requirements; (ii) assessment of specific vulnerabilities to climate change; and (iii) preparation of a climate change adaptation framework.

104. The incorporation of the projected climate changes into the planning process will depend on several considerations, including: (i) the level of confidence of the projections (some are more robust than others - for example, projections for temperature and sea level rise are more robust than those for 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 initiatives can be designed to meet present climate variations; major long term investments based on low levels of projection confidence should be avoided; (iii) the scope for flexibility of the adaptation design, incorporating facilities wherever possible to upgrade adaptation designs step by step to meet progressive climate changes as well as incorporation of improved reliability of the projections into the planning processes; (iv) an assessment of the incremental costs to meet the projected impacts will be made - where such costs are low, these might be factored into the adaptation design, while major cost implications maybe left out in the interim. The aspects of safety and implications of delayed action would be assessed. The experience from the NAPCC sub-basins is that, in many cases, a ‘no-regrets approach for the short to medium term is indeed feasible. ‘No regrets’ is the implementation of adaptation measures that are still valid and worthwhile even if climate change does not occur.

5. Specialist Inputs to Sub Basin Planning

105. There is a need to move towards a systematic integrated approach to climate change projection and water resources planning. At the moment, such planning is ad hoc and various organisations are working in an uncoordinated manner; much of the climate change planning is currently unsupported and not sufficiently scientific.

106. It is proposed to develop climate change adaptation based on sub-basin planning. Sub-basin planning will be the responsibilities of the states who will be responsible for the preparation of the sub-basin plans and the interpretation of climate change information. States will require specialist support in key areas as indicated below. It is proposed that these specialists should be provided by the Central Government, in coordination with specialist institutes and consultants. It is also proposed that a logical and structured approach is followed as given in Table 5 below.

Table 5: Specialist Inputs to Sub Basin Planning

1.	**Climate Trends Analysis**	A rigorous analysis of actual trends in precipitation, maximum and minimum temperature and evapotranspiration would be carried out to support the climate projection assessment. It is proposed this is prepared by IMD in cooperation with CWC for all sub-basins with support from institutes as required.
2.	**River Flow Trend Analysis**	A long term trend analysis of river flows to be prepared by CWC, The analysis would incorporate state level data and be based on naturalised flows, preferably by removing the water resources development influences.
3.	**Climate Change Projections**	IITM would prepare climate projections for all sub-basins for all three A1B scenarios. When available, IITM would undertake preparation of updated scenarios under the fifth IPCC assessment report. The assessments will be for those climatic parameters of direct relevance to water resources investigation, precipitation, maximum and minimum daily temperatures, relative humidity, solar radiation, wind speed (the latter four being for ETo calculation).
4.	**Analysis of Hydrological Response to Climate Change**	Analysis to assess basin wide hydrological response using hydrological modelling - to be undertaken in coordination of the states by NIH or another suitably qualified institute.
5.	**Basin Wide Conjunctive Water Use assessment**	Assess and support the planning of water use in complex basins including surface and groundwater. To be undertaken by NIH or other institutes, using water resources systems simulation modelling.
6.	**Basin Wide Consultations**	Basin Wide Consultations – sub-basin plans should include interstate consultation of the planning - to be supported by CWC. Sub-basin plans should be made public on the state website. Stakeholder consultative groups and forums need to be established
7.	**Specialist support**	Specialist support for specific issues including snow and glaciers, coastal management, etc. - to be supported by specialist institutes with coordination through CWC.
8.	**Design Standards**	Incorporation of climatic change factors into design standards. CWC and NIH to advise on necessary adjustments to design standards under climate change.
9.	**Climate Change Data Repository**	Establishment of a data repository and website for all the data and analysis related to analyses above. The Climate Change data would be held in a repository by CWC together with the existing Water Resource Information System (WRIS) which is now web based. The repository will have a database of scenarios and the above parameters, covering the entire PRECIS domain for India. The database will be stored on a web server and have a web interface through which users can select their area of interest, the parameters of interest, and the time period of interest. It will permit files to be created for users on the server, and then compressed and downloaded. The repository will provide a basic software package that will assist users in routine analysis and reporting, and re-formatting of data for use in particular modelling applications; this package would be downloadable for use on a users own computer. The system will be designed to be directly linked to the will be designed to be directly linked to GIS systems In addition to the climate scenarios, the data repository would have the IMD gridded data sets of historic climate, and would permit those to be downloaded for a particular area of interest. It would also have some basic data processing routines for IMD data that could be downloaded to a user's computer. The outputs of the rainfall and river flow trend analysis would also be held on the repository.

G. Focal Area 2: Planning Processes for Climate Change Adaptation

107. Rationale: To address the potential impacts of climate change and develop appropriate adaptations requires a coordinated and effective planning process. Central and State Government have to work in partnership to prepare sub basin and basin plans; planning needs to be iterative, incorporating new and more accurate climate projections as they come available. Without well established planning and decision making processes climate change information and adaptation mechanisms will be of limited value. Currently there is very limited capacity and resources both at state and central government to meet these requirements, and outsourcing of specific tasks will be required.

108. Sub-basin planning should form the initial basis of water resources planning and management. Planning should incorporate the means to address current and development issues as well as potential impacts of climate change. Planning should be an incremental and iterative process and not a single plan. Once the institutional arrangements are established sub basin plans should be integrated to form basin plans.

109. Stages: Planning would be implemented in stages as summarised below. The starting point would be the State Action Plans for Climate Change (SAPCC) which encompass the wider aspects of the eight national missions. Sub-basin Strategic Framework Planning would build on the SAPPC plans and focus on the water resources aspects. Planning would be integrated and holistic, and involve the participation of a wide range of stakeholders. Detailed Planning and Design of Sub Projects would follow on from the strategic plans. Initially planning would be based on sub-basins, and would involve all water sectors. The sub basin planning processes are described in Figure 2. Once institutional mechanisms and agreements are established it is proposed to integrate the sub basin framework plans into basin plans as described in Focal Area 4.

(i) **Preparation of Plans:** The plans would be implemented by the proposed IWRM Unit within the Water Resources Departments of each of the states. The IWRM Unit would outsource the work as necessary to competent institutes and/or consultants. Sub-basin plans would be based on a 30 year planning horizon, with detailed five year plans. Plans would be reviewed and updated every five years; new and improved projections of climate change would be incorporated into such updating of plans.

(ii) **Framework Strategic Planning:** It is proposed to base planning on strategic framework plans which allow for a quick diagnosis of issues and broad proposals for the way forward. Issues and solutions are changing rapidly and an iterative planning based on framework planning is proposed. Plans would be gradually refined and adjusted. Planning would initially be implemented based on sub basins. The boundary conditions of sub basins would defined by the tribunal decisions or other existing water sharing agreements.

(iii) **Specialist inputs** to sub-basin planning would be required, covering aspects such as: climate change projections; assessment of the hydrological response at the basin level; basin level water balance; and support for trans-boundary consultations with neighbouring states. These specialist support areas would be directed at the basin level, and would be coordinated by MoWR/CWC/CGWB and implemented through outsourcing to specialist agencies such as the Indian Institute of Tropical Meteorology, National Institute of Hydrology, and other relevant institutes and specialist consultants.

(iv) **Detailed Planning and Design of Sub-Projects** would follow strategic planning after the strategic plan has been endorsed by the State Water Resources Steering Committee. The detailed plan would investigate only key specific parts of the strategic plan in more detail. Design of selected sub projects would be taken up as part of the detailed planning. The detailed plan would be based on the hydrological unit of the sub-basin.

(v) **Disaggregation of Sub-basin Plans** for implementing multi sector integrated sub-basin plans require to be broken down initially into: (i) departmental plans and projects; and (ii) district plans.

(vi) **Mainstreaming into the District Planning Process:** District planning works on an annual cycle. The five year water resources plans (disaggregated by district) would form the basis of water resources planning and management. The disaggregated water resource plan would be discussed with local bodies and stakeholders and incorporated into the District Vision Plan. The annual plan for water and other sectors would be agreed for implementation by the District Planning Committees.

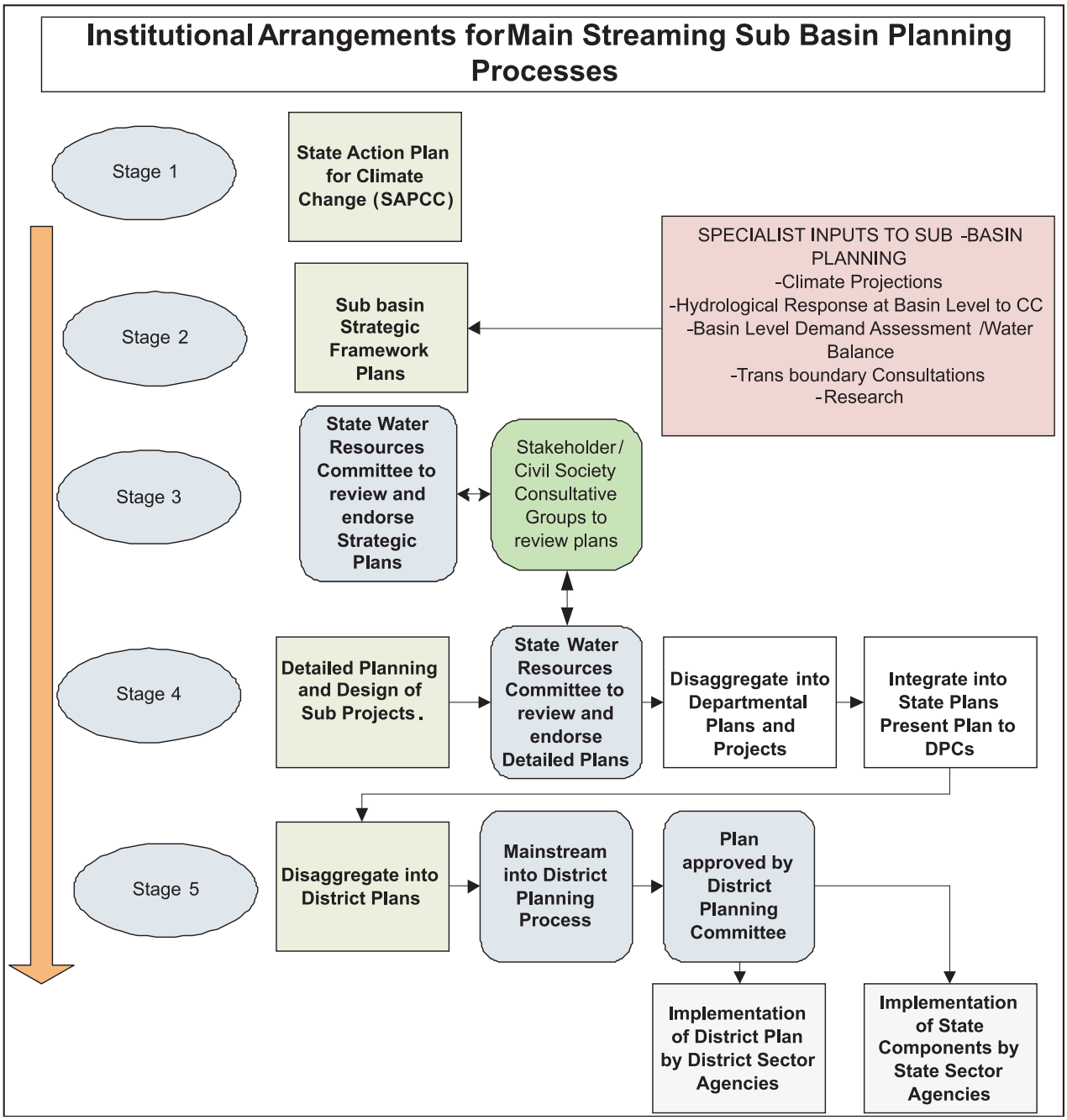
(vii) **Stakeholder Consultative Groups and Forums:** A lower level consultation process is required to support the sub basin and basin planning processes. To allow for a collective consultation at the sub-basin level; it is proposed that a 'Sub-Basin Consultative Group' is formed, the group representatives would be stakeholders and

members of civil society nominated by the various Panchayat Raj within the sub-basin with representation from the various stakeholders and civil society. The stakeholder consultative groups would have a role to advise and inform the Water Regulatory Authority on water issues in the basin. Sub basin consultative groups for the sub basins would later form the basis of the basin level consultative groups.

(viii) **Publication of Plans:** Sub-basin plans should be made public for a period of one month and posted on the Water Resources Department website for comment and feedback prior to endorsement by the State Water Resources Steering Committee.

(ix) **Basin Level Planning:** Sub-basin framework plans would developed based on the agreed water allocations between states which would define the boundary conditions. Sub-basin plans would be integrated and compiled into Basin Plans working through empowered interstate river basin organisations (RBOs). Opportunities or issues with the sub basin plans would be identified and modifications made as necessary. Basin planning requires the basic institutional arrangements and agreements to be in place; data sharing and open consultations are pre-requisites for basin planning.

Figure 2: Sub Basin Planning and Mainstreaming Processes



H. Focal Area 3: Sub Basin Strategic Framework Planning

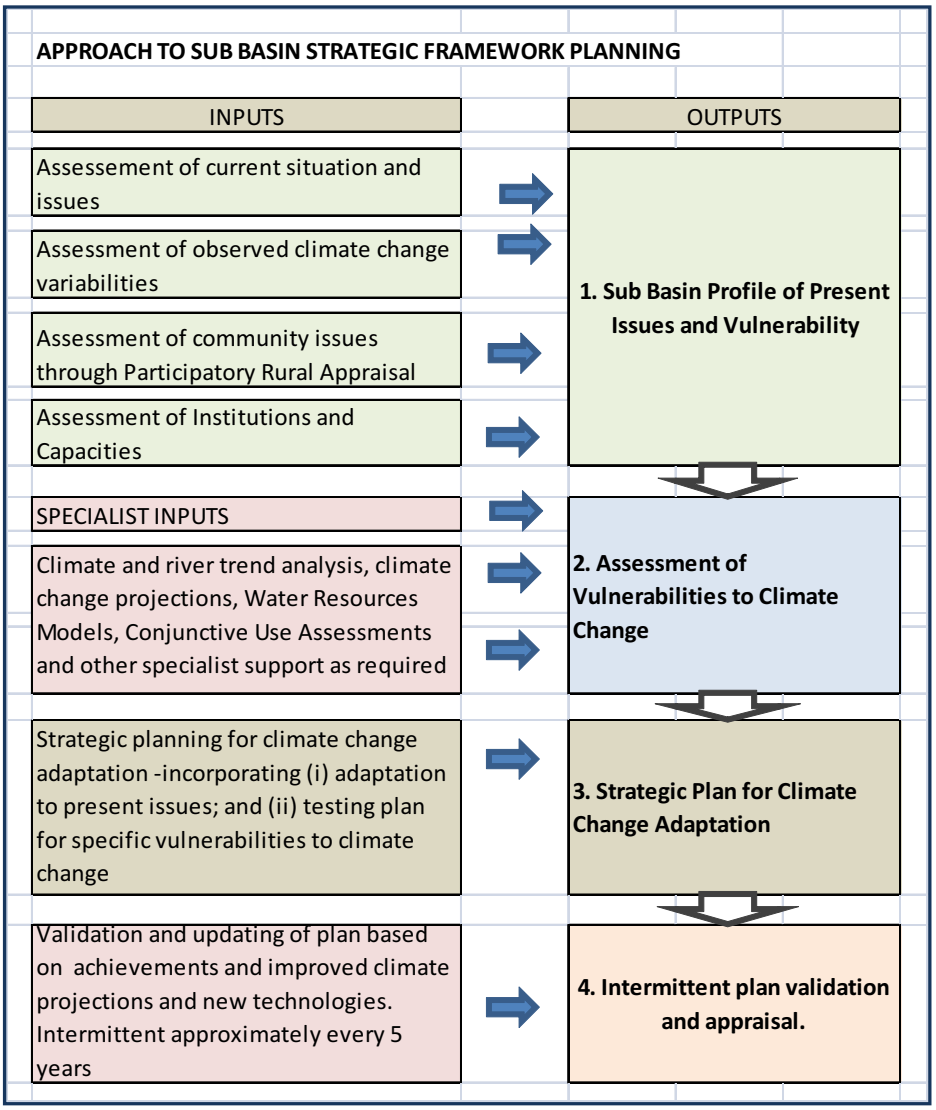
110. River basin planning needs to be directed at developing new and better ways to ensure sustainability, protecting and improving the water environment and increasing the efficiency of water use and levels of service delivery of water services. Good water resource planning and management practices at the basin level with links to state and national level water resources management strategies and decisions with local actions ("top-down" meeting "bottom-up"). Ideally planning needs to be based on basins and this remains the target but the initial planning should be based on the sub basin with the objective of integrating the sub basin plans to basin plans once the basic institutional arrangements and agreements are in place.

111. There is a need to strengthen the water resources planning processes which are currently lacking coordination. Water resources management needs to move towards an integrated approach that includes surface water, groundwater, catchments and land use. Social and institutional aspects also have to be incorporated. Water resources planning should form the basis of meeting present development needs as well as enabling climate change adaptation.

112. **Strategic Framework Planning** is broad outline assessment of issues and a strategic framework plan for the directions and areas of follow on detailed planning and design. The proposed approach to Strategic Framework Planning is shown in Figure 3.

113. Detailed river basin planning is a major process; involving high levels of studies and a formal consultative process and a long timeframe. Planning for climate change involves 'planning under uncertainty'. The preparation of comprehensive basin plans takes too long, and with rapidly changing conditions, plans can become quickly out of date. Strategic Framework Planning offers a relatively quick and more flexible approach to planning; strategic plans could be prepared in a period of about six to nine months for sub-basins. It is proposed that updates and refinements would be incorporated every five years to incorporate improved climate change projections and changes in demand..

Figure 3: Approach to Sub Basin Framework Planning



114. Strategic Framework Planning for sub-basins incorporates an analysis of current issues together with development needs and requirements for climate change adaptation. The frameworks will address ongoing water issues, as well as the estimated requirements for adaptation to future climate change. The frameworks quantify the present and projected future scenarios through climate and hydrological modelling.

115. Framework planning has been completed for the three pilots sub-basins is based on three stages as described below;

- **Adaptation Strategies for Current Issues:** The sub basins have very significant issues that are affecting efficiencies and long term sustainabilities. The approach will be to develop an initial adaptation plan for present issues based on current climate variabilities. The strategy includes development needs of increasing population, increasing agricultural production and farm incomes.
- **Vulnerabilities Against Climate Change Impacts:** The resilience of the 'Adaptation Plans for Current Issues' were tested against projected climate change impacts.
  Preparation of a Strategic Climate Change Adaptation Framework Plan incorporating measures to provide resilience to climate change

116. The scope for increased water efficiencies in the context of necessary parallel measures to meet water sustainabilities will be examined. The output will include recommendations for effective institutions, finance, training and awareness as well as an integrated strategy and road map for the way forward.

117. **Incorporating Climate Assessments:** In the three pilot sub basin the studies have examined the current climate trends as well as preparation of projections of temperature, precipitation, evapotranspiration and from the Swat model runoff, groundwater recharge and baseflow. The sub basin studies have also identified development strategies based on current issues as well as additional requirements to meet the projected climate impacts. The vulnerabilities under climate change have been assessed based on:

- **Firm actions:** Firm actions are based on the level of confidence of the projections. Firm actions include temperature and sea level rise.
- **Indicators:** Indicators are of a lower level of confidence but have been used to support the direction of adaptation. The indicators can be positive or negative. Indicators include precipitation, evapotranspiration and the Swat Model assessments (runoff, groundwater recharge, **Negative indicators** are where the projections gave rise to a worsened more critical situation the effects were reviewed. Where the projections are supported by the trends more weighting has been given. Positive indicators which give rise to a potentially improved situation (eg increased precipitation may support agriculture)

118. **Detailed Planning and Design of sub projects** follows on from strategic framework planning and incorporates more rigorous and quantified assessments including feasibility studies and design of sub projects for implementation. Methodologies for ensuring planning and design projects incorporate resilience to climate change will be required; proposed approaches for this are described in Focal Area 6.

I. Focal Area 4 : River Basin Planning and Management

1. Introduction

119. Most of the existing River Basin Organisations (RBO) in India have specific functions, including operation of major structures (dam and reservoir), overseeing the allocation of water according to the tribunal awards of the interstate agreement or development of water resources infrastructure. Functionally integrated river basin management (IRBM) functions are very much secondary and are largely restricted to overseeing or implementing the agreed interstate water allocation and accommodating the states water allocations according to their monthly requests.

120. There is limited support for basin level planning and management by the states; basin management is largely seen now in the context of tribunals as well as the legal processes to maximise the states share of the water and the states are understandably very defensive. Basin level planning and management is a key area for climate change adaptation as identified by the NWM. There is no consideration of climate change in the current water sharing or tribunal agreements.

121. This inherent lack of support of RBOs by the states is recognised and the initial focus of direction must sub-basin planning at the state level. Water resources planning and management is proposed to be implemented through the IWRM unit within the Water Resources Department at state level. Planning and management of water resources would be an integrated participative approach involving the various water sectors. Sub basin plans would work within the agreed and legal water allocations within the basin.

122. Many but not all of the water resources planning and management activities can be implemented within the sub basin; the sub basing boundary conditions are largely defined by the tribunals or other water sharing agreements. Sub basin planning however cannot address the many issues and opportunities of basin planning and must be seen as an interim and compromise solution. Independent state level water resources management wherever possible should be encouraged and established within the sub basins. Such organisations can then form the foundation for basin planning and management.

123. Integrating sub basin planning and management into basin level planning is a fundamental requirement towards realising some of the potential opportunities for water resources development at the basin level that would not be viable at the sub basin; these could include:

- storages or catchment management in the upper catchment that would benefit various sub basins;
- actions in one sub basin that would impact on another sub basin;
- optimising of water resources to allow different parts of the basin the benefit from improved water management;
- identifying potential areas of joint investment to benefit upper and lower sub basins. and
- flood control and management
- incorporation of basin wide measures for climate change adaptation.

An example is the Bhakra Beas Management Board which is presently undertaking a DSS to optimise the Bhakra reservoir operations to reduce flood risk and improve the use of available storage. This involvement of the RBO to support optimisation of water resources is of value to all the Sutlej sub basins.

124. Climate change; will impact at sub basin and basin level. The tribunal agreements include some allowance for stress situations and there is provision in the agreements for distress sharing; these provisions for the present seem reasonably adequate.

2. Integration of Sub Basin Plans into Basin Plans

125. **Integration of Sub Basin Plans into Basin Plans:** sub basin planning would be a participative bottom up approach prepared by the states through the state IWRM unit. The preparation of sub basin plans require specialist inputs including integration sub-basin plans into of basin planning. Planning must address technical, environmental and development issues and opportunities as described in Table 6 below.

Table 6: Integration of Basin Planning and Management Mechanisms

Climate Projections	Basin level climate projections to be prepared by IITM and made available on a CWC/IITM web portal
Data management and sharing	Open sharing of water resources data at basin level. River basin data to be made available through the WRIS portal and through the proposed parallel state levels portal under the WRDs.
Hydrological Response at Basin level to Climate Change	Hydrological model assessment for whole river basin to be prepared by specialist institutes or consultants
Basin Level Demand Assessments/ Surface and Groundwater Water Balance Assessments	Sub basin water demand assessments to be compiled into basin integrated demand assessments by specialist institutes or consultants. Assessment of basin wide environmental requirements-environmental flows, conservation, water quality.
Trans boundary consultations	Sub basin plans to be presented and discussed with basin wide stakeholders including civil society Sub basin consultative groups to be expanded to basin level consultative groups and forums.
Integration of sub basin plans into basin plans	Sub basin plans to be integrated into basin plans. Identification of basin level opportunities and issues. Basin level environmental assessments. Adjustments and refinements of sub-basin plans as required.
Research, information and awareness	Support for dissemination of knowledge and information Support for awareness and training in water and climate issues Support for basin wide research initiatives.
Investment	Promotion of integrated River Basin investment opportunities, through government, community initiatives as well as private sector partnerships.

126. Institutional Arrangements: Appropriate and workable institutional arrangements need to be established. The CWC working through its Regional Offices would support and coordinate the planning and management of the river basins in the country, nearly all of which are inter-state. CWC would be members of the State Water Resources Steering Committees in each state and would help and integrate the sub basin plans into the wider basin plans which would address basin opportunities and issues.

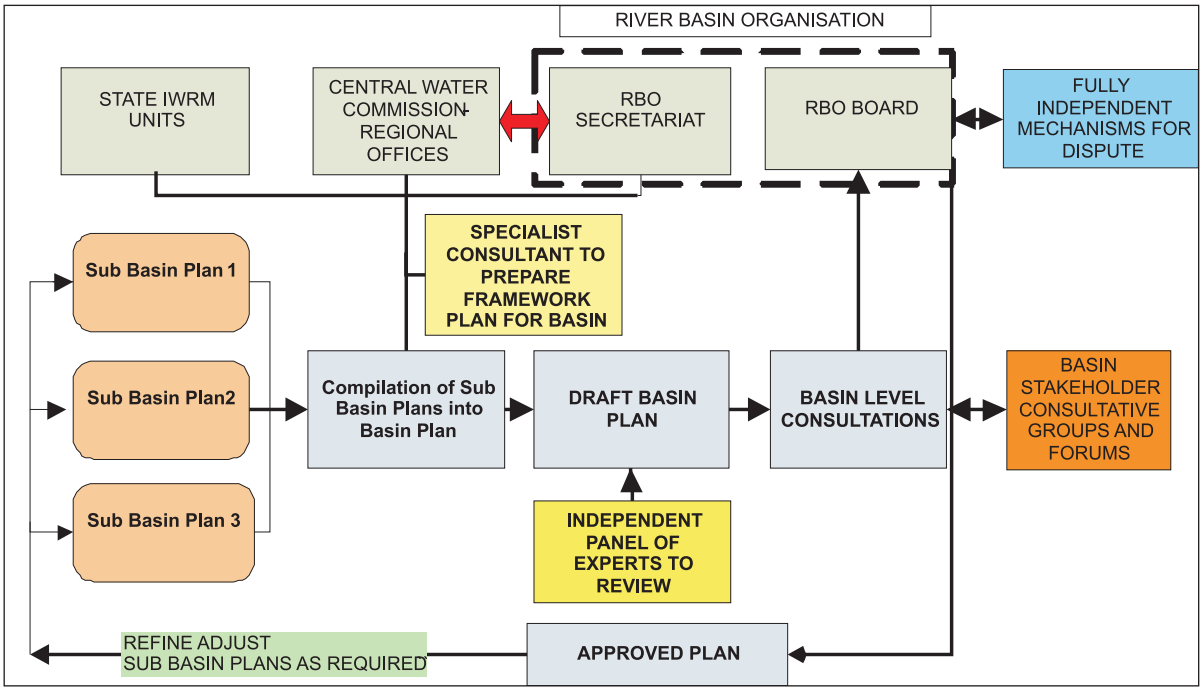
127. CWC is proposing the assignment of more senior officers, up to Chief Commissioner level, to be assigned to the regional offices in a move towards a more basin orientated management. The regional CWC offices would work very closely and support the State IWRM units to prepare the sub basin plans as well as support the River Basin Organisations to prepare the integrated basin plans. The preparation of water resources and water demand assessments at basin level would require specialist support from institutes or consultants which would be coordinated through the RBOs and CWC. Staff from CWC could be seconded to the RBOs or might chair the RBO.

128. Basin Consultative Groups and Forums will form a key part of the basin planning processes. Experience has shown that active involvement of stakeholders at an early stage is essential to avoid later stage conflicts. Good representation of civil society and stakeholder agreements are important to support the necessary state government agreements. Stakeholder groups for the sub basins would be nominated by the various Panchayat raj. Representatives from the various sub basin stakeholder groups would form the basin consultative groups.

129. Planning at the river basin level is extremely sensitive and it is proposed that the RBO and CWC have full access to an independent national and international panel of experts to support the basin planning processes. Adequate funding from central government should be made available to support the recruitment of highest possible levels of expertise.

130. Over and above the technical assessments, the RBO will require support to address disputes. In the first instance, disputes could be referred to CWC. Robust and workable mechanisms for solving disputes are required to be defined in advance; these would including agreed procedures to nominate independent dispute adjudicators and arbitrators as well as access to independent experts as required. The dispute processes should be defined and agreed by CWC, the States, and the RBO together with independent legal experts. The processes for basin planning are shown in Figure 4 below.

Figure 4: Processes and Organisation for Basin Planning



3. Proposed Approach for Enabled Interstate RBOs

131. The National Water Mission places emphasis on the creation of enabled river basin organisations. It is proposed that the focus should be primarily on interstate RBOs. It is felt that the functions of RBOs within states can be adequately managed by the state WRDs themselves with strengthened coordination of the line agencies. The establishment or enabling of existing RBOs should be bottom up, with a prerequisite to establish water planning systems at the sub basin level prior to moving towards basin level planning.

132. It is important to define what is an 'enabled RBO' and criteria for various stage of enabling will require to be developed. A preliminary definition on an fully enabled interstate RBO might include:

- A functional secretariat that can carry out basin planning and management. This requirement can be initially supported by CWC regional office and/ or outsourcing to specialist consultants
- Full support for the RBO from each of the member states.
- An IWRM unit to be established in each state.
- An agreed and representative RBO board including membership by government and stakeholders including representatives from civil society.
- An agreement with member states to share water, climate and other data
- Data and information needs available and supplied by the states and from CWC
- Completed sub basin strategic framework plans for each sub basin in the basin
- A water resource model set up showing present and future water demands including projected impacts of climate change
- A basin strategic plan endorsed by the RBO board
- Funds and mechanisms to update planning every five years
- An agreed basin plan developed from the strategic plan and agreed by the RBO board. The basin plan should include water allocations under conditions of low and flood flows.
- Mechanisms for disputes agreed and established.
- A basin level stakeholder consultative group and forum formally established, the stakeholder group would comprise of representative stakeholder groups from each sub basin.
- Meetings of the RBO board scheduled to be held at least 4 times per year
- Meetings of the stakeholder representative group scheduled at least twice per year
- Routine monthly meetings for discussions on water allocations and optimisation of the water use within the terms of the water tribunal (if any) and the basin plan.

- o Statuary binding for the basin states to accept and comply with the decisions and ruling of the RBO.and/or dispute resolution mechanism
- o Access to adequate funds

133. Establishing enabled RBO should be taken in stages; at each step state level support and endorsement should be obtained. RBOs should only be considered for very complex river systems or interstate rivers. There would appear to limited value of creating an RBO for issues within the state as most aspects can be better managed by the sector agencies. The proposed stages to establish the RBO are summarised below. For existing RBOs the requirement would be similar but with the emphasis on how to develop a fully functional and enabled RBO as shown in Table 7

Table 7: Stages to Establish River Basin Organisations

Stage	Activities and Benchmarks
1	• Discussions with states and stakeholders to identify the need and role of an enabled RBO. • MoU from the member states and MoWR on the proposed establishment of the RBO. The MoU would outline the objectives of the RBO and the necessary steps for the establishment. The empowerment of the RBO will likely require to be developed in stages; the first stage may not fulfil all the functions of a fully enabled RBO but would move the process forward. Open information sharing is seen as one of the key requirements for the first stage. • The MoU would include the proposed time frame and funding arrangements
2	• Establishment of state level planning and sub basin planning systems. These would include the establishment of a Water Resources Steering Committee, Independent Water Regulator and an IWRM unit. The proposals for the state level organisations are described in Focal Area 9.
3	• Preparation of sub basin strategic framework plans and compilation of the sub basin plans into basin plans
4	• Establishment of RBO Secretariat, Board and Stakeholder Consultative Group.
5	• Endorsement of the sub basin plans by the Interim Board. Initiation of regular interaction and information exchange.
6	• Establishment of a fully enabled and functional RBO

4. Basin Level Investments

134. A direct follow on from the establishment of the RBO and the basin planning would be support for basin level investments. Basin level investment should be directed at initiatives to improve the condition of the basin including catchment management to help ensure long term water and environmental sustainability.

J. Focal Area 5 : Water Use Efficiencies and Management Options

135. The Government, building on the recommendations of the NAPCC, is proposing a major programme to increase water use efficiencies by 20% by 2017. Water use efficiencies (WUE) are complex, and it is important to clearly define and understand the water systems to properly assess the appropriate mechanisms to increase efficiencies.

136. Water use efficiency will be defined very differently by the farmer, irrigation manager or a river basin authority. Sometimes project efficiencies, including canal systems and on farm irrigation efficiencies, may be low but substantial water losses may infiltrate the soil, recharge the aquifers, or flow into the drains for reuse. By recycling of infiltration losses, river basin efficiencies can actually be very high. In conjunctives systems, water use efficiency initiatives are largely restricted to savings of evaporative losses including reduction in wetted land areas and open water.

Assessment of water use efficiencies must be based on the sub basin or basin. Where there is significant or potential groundwater use, water efficiency assessments must address the conjunctive water use efficiency of the combined surface and groundwater systems.
Sub basin water efficiency assessments would be compiled to basin level assessments by the RBOs.

137. Economic aspects of efficiencies must also be addressed - different options to increase efficiency require a mix of capital as well as maintenance/operational costs. Assessment mechanisms are required to compare investment alternatives; for example, the high capital cost of lined irrigation canal and the lower capital cost of tubewell but with higher operational cost. Minimising energy use should also form a part of the analysis and assessment.

Economic and energy assessments should be incorporated into WUE assessments

138. Conjunctive Management involves the operation of groundwater in combination with a surface water storage and conveyance system. Conjunctive management involves the combined use of surface and groundwater systems and sources to optimise resource use and prevent or minimise adverse effects of using a single source. The approach to conjunctive use assessment is shown in Table 8 below.

Conjunctive water management must be incorporated into any sub-basin with significant groundwater use or potentials.

139. Most basins in India involve conjunctive water use to some extent; conjunctive assessments are required for both irrigation and potable water supplies. In irrigation groundwater use occurs:

- where canal are inadequately maintained and are unable to provide adequate supply to parts of the system (mainly the lower parts);
- poorly administered system with unauthorised excessive abstractions;
- in systems with low design duties and over stretched surface water resources;
- rigid canal water delivery schedules which are unable to respond to crop needs; and
- where excess water from the canals or groundwater flows into the drains.

140. In domestic water supply, many houses and industries use privately installed tubewells to either supplement their water supply or as their main source of water. The main reticulation systems are supplied either from river sources or government tubewells coexist with the informal private wells. An assessment of sub-basin type must be made to define the type of analysis to be used and the options for increasing water use efficiency.

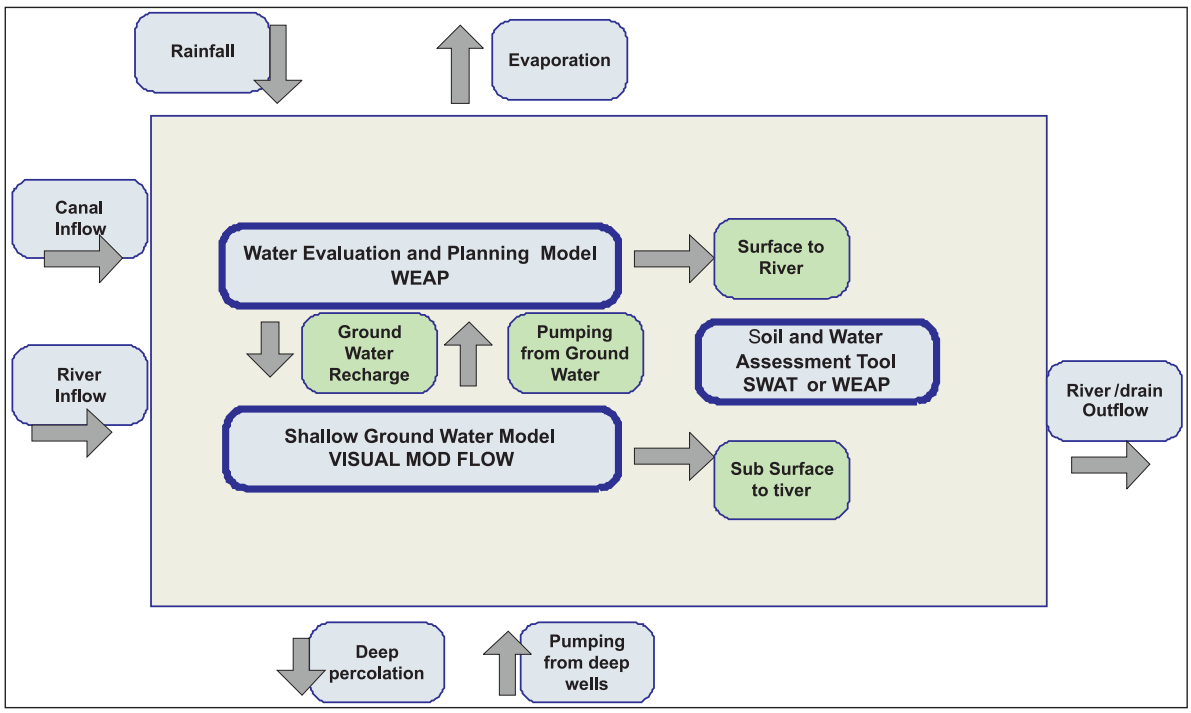
Table 8: Water Use Efficiency Options

	Sub Basin Type	Type of assessment	Management options	Conservation measures
1.	No groundwater availability	Surface use	Optimisation of the surface water system	Canal lining, improved water allocations, agricultural conservation methods.
2.	Minimal groundwater use	Surface but with simple assessment of groundwater use. Longer term demand assessments to evaluate likely future scenarios for groundwater.	Optimisation of the surface water system but considering possible future uptake of groundwater.	Improved water allocations canal lining.
3.	Recharge in excess of local groundwater balance	Conjunctive use	Check regional importance of local recharge. If feasible in regional context reduce surface water allocations and increase groundwater abstractions. Optimisation of surface and groundwater use.	Canal lining can improve surface water efficiencies but will reduce GW recharge.
4.	Recharge in deficit of local groundwater balance	Conjunctive use	Increase recharge using irrigation water and catchment management. Use of unlined canals	Reduce water demand through agricultural conservation methods.
5.	Groundwater quality issues-salinity	Surface use	Canal lining Mixing surface and groundwater.	Agricultural conservation methods
6.	High groundwater table	Conjunctive use	Drainage to reduce soil water logging and salinisation	

141. For surface use systems (with minimal or no groundwater use or saline groundwater) current methods to assess surface water efficiency can be applied. Irrigation efficiencies can be increased by canal lining, improved allocation systems, maintenance of canals, and improved farm level management through establishment of WUA. Investments to improve Water Use Efficiencies can be taken up subject to economic assessment.

142. There is quite limited financial benefit for farmers to invest in micro irrigation or other water saving systems. Farmers will see little reason to change to more efficient systems unless some yield benefit can be demonstrated, or significant subsidies are provided, or parallel controls/ regulation are applied as a disincentive for business as usual. WUE can have significant benefits for surface use systems but less tangible benefits for conjunctive systems. The parameters for conjunctive use assessments are shown in Figure 5 below.

Figure 5: Conjunctive Use Assessments



143. For conjunctive use systems, it is likely that overall efficiencies are already quite high. Improving the water use efficiencies is not easy and involves complex issues of conservation of the groundwater resources and demand management. Analysis of the conjunctive use requires assessment of different water uses, loss assessments including identifying proportion of losses to infiltration (reusable) and evaporation (lost). Modelling maybe required but simpler approaches should if possible be developed for smaller and simpler basins. While conjunctive use is primarily relevant to the large alluvial plains, it can occur in a wider range of hydro-geological settings.

144. Conjunctive use management requires merging the responsibilities for surface and groundwater as well as integration of agricultural and irrigation water saving initiatives. Effective integration requires institutional strengthening, and appropriate reform and support mechanisms. Agricultural conservation offers opportunities for reducing demands through a number of resource conservation measures, these would require some level of financial support/ subsidy and/or regulation.

145. Regulation or controls could include direct controls of cropping, for example restricting the number of tubewells, or area planted or indirect systems such as charging for power. Water or power charging would encourage farmers to invest in more water-efficient farming systems. One idea would be to "exchange" ongoing electricity subsidies for power (at a time when India faces chronic energy shortage) with one-time grant assistance to invest in water-saving technologies that would have the impact of greatly reducing both energy and water use in groundwater and conjunctive-use systems.

146. **Central Water Commission has** recently prepared a guideline for evaluating the surface water efficiencies of irrigation projects and prepared a: 'Handbook for computing the water use efficiency of an Irrigation project'. CWC has also carried out studies for evaluating the efficiencies of about 30 irrigation projects in the country. Results show that surface irrigation efficiency in some projects is as low as only 13% (Naggal Lift Scheme, Andhra Pradesh) and as high as 58% in Tungabhadra project in Karnataka. On an average, irrigation efficiency in irrigation projects in India is considered to be in the range of 30 to 35%, and this range is supported by the results of the CWC study of 30 projects. The assessments are all related to project level surface water only efficiencies.

147. **Conclusion:** The approaches to water use efficiency needs to be further developed; the present approach of assessing surface water efficiencies is only valid in basins with limited or no groundwater or poor quality groundwater. From the government perspective of resource management the need is to examine the overall water resources of surface and groundwater based on sub basins and basins. Water use efficiency studies and planning form an important part of the sub basin planning process; the outputs of the efficiency studies would form an important input to the sub basin/basin plans. Financial returns from water use efficiency initiatives are likely to be higher in areas of no or minimal groundwater.

148. The importance of cropping and cropping systems requires to be incorporated into the assessment; especially for the conjunctive use assessments where reducing evaporative losses is most critical. There is also a need to undertake comparative analysis of different options which should include assessments of costs and benefits including capital and operational costs. For pumped schemes some analysis to reduce energy requirements for pumping is important. r. A three stage approach is proposed.

(i) Review and recommendations for different approaches to assess water use efficiencies building on the lessons learnt in the sub-basins. The study should address how to incorporate conjunctive use and the incorporation of cost-benefit and power assessments.

(ii) Undertake a number of pilot studies in selected sub-basins with detailed analyses including economic assessments of different options.

(iii) Based on the review and pilot studies, develop simplified approaches for upscaling to other sub-basins. There is a requirement to reduce the complexities of analysis and develop simplified assessment systems. The use of data bases of key parameters and issues can be applied to simplify the planning and reporting processes. Simple computer programmes could be developed which could be used to guide and support the upscaling of the water use efficiency assessments. The programmes could include simple decision trees to assist the assessment processes. More complex basin systems may require conjunctive water resource and demand modelling using a modelling tool such as WEAP.

K. Focal Area 6: Incorporating Climate Resilience into Planning and Design

1. Introduction

149. Climate modelling and research is now able to give projections of future climate trends down to sub basin level; at this point of time some of the projections are however more robust than others. The experience of this study shows that while climate change projections contain many uncertainties and in some areas are insufficient to concrete adaptation decisions, it is important that development planning and design should factor incorporate the projections into the decision making processes as soon as possible.

150. There is a very wide range of existing water issues and future climate impacts will likely create additional challenges. The National Water Mission of the NAPCC has presented a very comprehensive over view of the issues and possible initiatives to adapt to climate change. The application of climate projections into the development of adaptation planning requires to be cautious and pragmatic; mechanisms and approaches of how to factor in climate change impacts require to be developed.

151. To address the potential impacts of climate change and develop appropriate adaptation measures requires a coordinated and effective planning process. Central and state governments have to work in partnership to prepare sub basin and basin plans; planning needs to be iterative, incorporating new and more accurate climate projections as they come available. Without well established planning and decision making processes climate change information and adaptation mechanisms will be of limited value. Planning needs to be developed in stages with plans gradually refined and more detailed before moving into implementations.

152. Strategic Framework Planning is a broad outline assessment of issues and a strategic framework plan for the directions and areas for follow on detailed planning and design. Strategic framework plans have been prepared for the three pilot sub basins.

153. **Detailed Planning:** Subject to agreement and endorsement of the strategic plans; the follow on stage will be to implement a programme of detailed planning and design of selected sub projects and pilot projects. The initial strategic plans are preliminary and require technical assessments to define all the options, before moving onto detailed project preparation, subproject design and implementation. Detailed planning would involve feasibility studies to verify the technical and financial viabilities of the proposals including extensive consultation and participation at all levels to ensure acceptability. Visits to other parallel projects would be important to discern the lessons learnt. Based on the outputs of the studies, pilot projects could be taken up to validate the proposals and make adjustments before embarking on up-scaling. Regular review of the strategy is proposed based on monitoring, studies and improved climate projections.

2. Operational Studies and Research

154. At present there are major gaps of the understanding in the current water systems as well as impacts of climate change. For some systems there maybe requirements for operational research will depend on the complexity of the issues in each specific sub basin. In some situations to fill the knowledge gap it may be necessary to improve decision making through operational research[31] involving advanced analytical techniques, including water resource modelling, socio-economic analysis, decision support systems and systems analysis.

155. Decision Support Systems (DSS) can be incorporated into the planning to address specific issues. A comprehensive DSS requires major inputs and significant time to prepare. The DSS (Planning) being developed under HP2 project uses sub-basins for the pilot areas, and seeks to develop tools that allow detailed estimates of water resources throughout the sub-basin, and to review impact of proposed planning decisions on the distribution and likely future availability of water resources. The experiences of the DSS studies under the HP2 project should be studied and lessons learnt taken to support future sub basin planning activities.

156. In the sub basins, two areas for operational Research have been identified that are proposed to be taken up as an integral part of the follow on programmes:

(i) **Sutlej River Water Systems Assessment:** There are major gaps in the understanding of the Sutlej water systems including; (i) poor information on the hydrological response to snow and glacier melts; (ii) limited understanding on the conjunctive surface and ground water systems and how water management and conservation can be applied to develop sustainable water systems. An operational research study is proposed

[31]Operational research (OR) encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improveddecision-making and efficiency. Some of the tools used by operational researchers are optimization, decision analysis, modeling and simulation. Because of the computational nature of these fields, OR also has strong ties to computer methods of analysis

to improve the assessment of the medium and long term hydrological response to changes in glacier and snow melt and implement conjunctive water use studies including; surface and groundwater modelling, agriculture studies and community consultations to assess alternative cropping and other water saving initiatives. Socio economic and institutional studies would be implemented to assess the viabilities and appropriate mechanisms for meeting water sustainabilities. An integrated water systems analysis for the Sutlej River would be carried out using a systems simulation model such as WEAP to represent the evolution of surface water and groundwater supplies under climate change based on simulated hydrological processes and incorporating the outputs of the glacier/snow and conjunctive use studies.

(ii) **Cauvery Delta Modelling and DSS studies:** The Cauvery Delta is a very complex water system of fresh and saline water. There are presently problems of saline intrusion, flooding, coastal erosion and drainage. Sea level rise and increased rainfall and runoff during the north east monsoon will worsen the situation. The processes are complex and it is proposed to implement a programme of operational research of the surface, groundwater and coastal water and sediment systems.

3. Water Resources Modelling

157. As stress on water resource systems becomes more acute, the task of managing resources becomes more difficult, and will generally require the use of mathematical modelling approaches to support the planning and management process. The primary role of mathematical simulation models in water resources assessment is to assist in the evaluation of alternative resource management and development scenarios, and the evaluation of potential climate change impacts and adaptation strategies. This is achieved by simulating the effects that these management or development or climate scenarios would have on resource availability in various parts of a basin. Typically models are used in conjunction with statistical techniques to quantify impacts, and to permit other forms of analysis such as economic analysis to be carried out. Models permit the integration of complex processes and interactions, to aid understanding and provide insights to impacts that would not otherwise be possible.

158. The modelling approaches should be capable of representing the existing water resources infrastructure and water demands in a sub basin or basin. They should be capable of representing the interactions between surface water and groundwater, giving consideration to the water resource as a whole. The process of setting up such a model is in itself very informative, and can identify data gaps and deficiencies in the existing knowledge of a system. There are now new remote sensing technologies that can provide increasingly accurate estimates including real evapotranspiration and soil moisture as monitoring changes over time of glacier mass. These models will become increasingly important in short-term water resources decision-making.

159. There are now available a number of models that integrate a number of component models, and offer planning tools that can be applied to varying degrees of complexity. One such model is the WEAP[32] model, developed by the Stockholm Environment Institute (SEI, www.weap21.org). The WEAP model is now a very comprehensive tool. SEI summarise the relevant features of the WEAP model as shown in Table 9 below.

Table 9: WEAP Model Features

Integrated Approach	Unique approach for conducting integrated water resources planning assessments
Stakeholder Process	Transparent structure facilitates engagement of diverse stakeholders in an open process
Water Balance	A database maintains water demand and supply information to drive mass balance model on a link-node architecture
Simulation Based	Calculates water demand, supply, runoff, infiltration, crop requirements, flows, and storage, and pollution generation, treatment, discharge and in-stream water quality under varying hydrologic and policy scenarios
Policy Scenarios	Evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems
User-friendly Interface	Graphical drag-and-drop GIS-based interface with flexible model output as maps, charts and tables
Model Integration	Dynamic links to other models and software, such as QUAL2K, MODFLOW, MODPATH, PEST, Excel and GAMS

[32]Water Evaluation and Planning System-a water resource planning tool prepared by the Stockholm Environment Institute and is available to Government and research institutes in India without charge.

160. The strength of a model like WEAP is in the manner that water resources development and water allocation are handled, and in the capability to link with a distributed groundwater model. It permits a holistic approach to water resources planning and management, integrating surface water and groundwater, and water quality. The groundwater capability and linkage between surface water and groundwater is particularly relevant in many parts of India where conjunctive use of surface water and groundwater takes place and must be managed.

4. Incorporating Climate Change Information Into Planning and Design

161. Incorporation of climate change information into the planning and design processes requires more research and preparation of workable guidelines. The urgency to gradually include climate changes is stressed especially for new structures; for example new structures can be made climate proof for minimal cost where retrofitting could be extremely expensive. The embodiment of projected climate changes into the planning will depend on:

- **The level of confidence** of the projections: some projections are more robust than others; for example, projections for sea level rise are more robust than those of rainfall patterns.
- **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 require a sophisticated analysis.
- **Scope for flexibility of the adaptation design:** incorporating facilities wherever possible to upgrade adaptation design step by step to meet progressive climate changes.
- **Assessment of the incremental costs** to meet the projected impacts will be made: where incremental costs are low then these might be factored into the adaptation design whereas major cost implication may be left out in the interim. The aspects of safety and implications of delayed action would be assessed.

162. **Proposed Systematic Approach:** Approaches to incorporate climate change for detailed planning and design need to be based on a systematic analysis. A number of options exist, but the approach developed by the UK Government with adjustments as necessary would appear to be relevant to the India Water Systems. The approach incorporates the use of a 'Design Allowance' and a 'Sensitivity Assessment' as shown below.

(i) **Design Allowance:** Where the projection is to a sufficiently high level of confidence, then a design allowance should be applied. A design allowance is a design factor that should be applied to future planning and design decisions to incorporate projected climate impacts. At this stage only the projections of Temperature and Sea Level Rise are considered for adequately robust for consideration of a design allowance.

- *Projected Sea level rise:* From the Cauvery Delta studies, a sea level rise of +0.3m is projected by 2050 (note the 0.3m is generally agreed but there is ongoing scientific debate on the possible magnitude of global sea level rise above the 0.3m figure). Further research for all India is proposed to better define this figure with variations for different regions. Long term changes in the land movement would also need to be researched and factored into the assessment. Indications are that the rate of sea level rise will increase over time. Subject to more detailed research sea level rise allowance for all the coastal areas should be incorporated into planning and design of water resources projects.
- *Projected temperature increases:* there is a higher level of confidence in temperature projections than in projections of other climatic parameters. An allowance for increased temperature should be factored into planning, and specifically crop planning.

(ii) **Sensitivity Analysis:** This methodology is appropriate for projections where the degree of confidence is lower and further evidence and research is required. In such situations a climate sensitivity analysis can be used to test the base case as well as the options to determine how a decision making can incorporate indicative climate change. Planning and design should incorporate the results of the sensitivity analysis and a decision made the made on the most appropriate approach and scheduling of adaptation measures.

163. Defining the appropriate sensitivity factors for India still requires more research. For example the climate projections carried out for the sub basins show significant changes in precipitation by mid century as shown in Table 10. In this example a sensitivity assessment of +15% increase in monsoon rainfall might be applied to Kshipra, Sutlej and Cauvery when designing for drainage and flood management.

Table 10: Precipitation and Runoff Changes

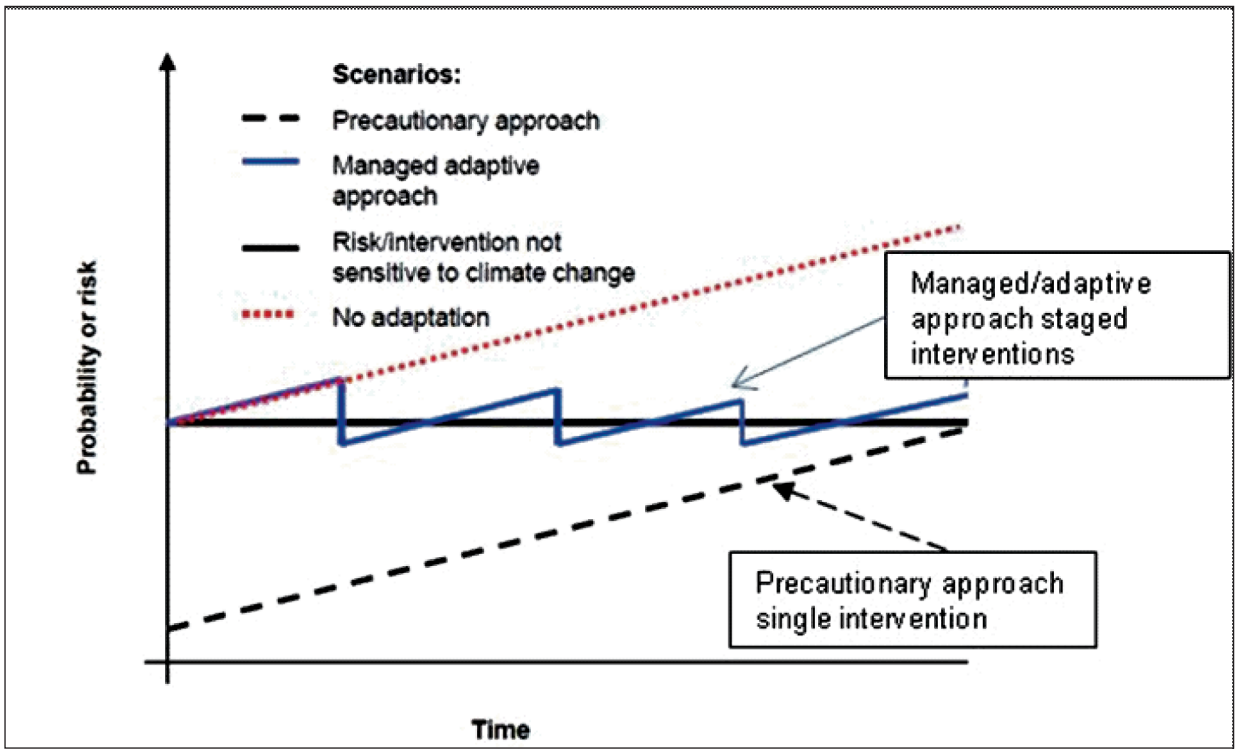
Sub Basin	Monsoon rainfall	Winter rainfall	Runoff
Sutlej	+15%	+20%	NQ
Kshipra	+15%	-5%	+65%
Cauvery	-10%	+15%	NQ
Notes:	NQ = Not quantifiable at this stage		

164. Under a sensitivity approach, projects would be designed for the base case with sensitivity factors applied to incorporate the potential impact of climate change. At the time of appraisal a decision would be taken to take whether to incorporate the climate measure immediately or at some later stage; risk should however remain unchanged.

165. For example; in Kshipra a new culvert might be designed for the 100 year flood plus a climate change sensitivity factor of say 15%. The incremental cost of incorporating the extra capacity into the design would be minimal and action now would be preferable; deferred action could be very costly. For other projects, a deferred approach or staged interventions may be more appropriate. Economic assessments can be applied to assess the relative benefits of implementing and building climate resilience now or deferring the action, possible risks of delayed action need to assessed.

166. Different adaptation approaches[33] are shown in Figure 6. From the figure, the increased risk of doing nothing is shown as red dotted line; the risk increases over time. The managed approach with staged interventions is shown as a saw tooth effect which keeps risk over time largely unchanged. The precautionary approach of a single intervention, initially gives an element of overdesign but in time the risk goes to the present level. For India the managed and staged approach is recommended except where deferred actions will be high risk and incur high costs eg. a new dam spillway where the precautionary approach/single intervention is appropriate and recommended.

Figure 6: Approaches to Adaptation



167. The United Kingdom government now provide firm guidelines for incorporation of climate change into planning and design. For example guidelines to incorporate design allowances for climate change include; (i) assume design rainfalls will increase by 30% by 2080; (ii) assume flood flows will increase by 20% by 2080; and (iii) assume sea levels will rise by 6mm per year. Whilst these projections still have a degree of uncertainty the need to take early action based on preliminary assessment is considered to outweigh the risks. The guidelines are aimed at project designers who have to ensure water resource projects are designed without increase risk from climate change.

[33]Flood and Coastal Appraisal Guidelines DEFRA Department of Environment Food and Rural Affairs UK

5. Incorporating Climate Allowances into Planning and Design

168. For the India Water Systems the regional variability makes it difficult to make country wide assessment and regional assessments will be required. Three alternative assessment approaches are shown below.

- **Design Allowance (DA) :** Projections with high degree of certainty should be researched and definitive guidelines produced. These would be incorporated into all planning and design decisions. Design allowances would be refined based on improved knowledge (DA1, DA2 etc) and eventually produced as a official standard by the Bureau of Indian Standards
- **Sensitivity Analysis (SA):** Planners and designers will be required to incorporate a climate sensitivity assessment and demonstrate how the climate impacts will be incorporated into the design. New investments with limited scope for later adjustment may need to incorporate an upfront investment whereas a staged process may be more appropriate for existing investments or where more adjustments can be staged. Sensitivity Analysis would be gradually over time be refined (SA1, SA2 etc) based on improved information and eventually upgraded to a firm Design Allowance.
- **Historic Data Sets (HDS):** should be used where data is poor and climate impacts are indicatively slow. HDS should be replaced by a Sensitivity Analysis (SA) or Design Allowance (DA) as new research becomes available.

169. **The risk of delaying** climate change effects into design may be quite high. These could include the very high financial costs of retrofitting as well as increased risk posed by inadequate design. The approaches are summarised in Table 11. The table shows the three proposed assessment options for the various climate parameters. Over time, improved climate projections will allow for refined assessments and staged process is proposed.

Table 11: Climate Change Decision Matrix for India Water Systems

Nr	Parameter	Quant itive assess ment possible	**Confidence level of estimates**		Estimated climate change to mid century	**Assessment stages**		
			Direction of Change	Magnitude of Change		2012-2014	2015-2020	2020 to 2050
1.	Temperature	yes	High	Medium	+2°C mean annual temperature.	DA1	DA2	DA3
2.	Precipitation annual	yes	Low	Low	Varies depending on the location & model / scenario	SA1	SA2	DA1
3.	Precipitation Summer Monsoon	yes	Low	Low	Varies depending on the location & model / scenario	SA1	SA2	DA1
4.	Precipitation-winter	yes	Low	Low	Varies depending on location & model / scenario	SA1	SA2	DA1
5	Snow Fall	No	Poor	Poor	No significant change in snow fall projected. Increased melt rates are now affecting river flows-both timing and quantity. Data is limited.	HDS	SA1	DA1
6	Snow and Glacier melt	No	High	Low	Increased glacier melts and reduced snow melts will change river flow regimes. Data is limited.	HDS	SA1	SA2
7.	Rainfall Intensities	yes	Medium	Low	Trends are indicating increased intensities. PRECIS projections indicate some increase	SA1	SA2	DA1
8.	Potential Evapotranspiration	yes	Medium	Medium	Varies depending on location	SA1	SA2	DA1

9.	Floods	yes	Medium	Low	Increased rainfall, run off and in coastal areas sea level rise will increase flood risk.	SA1	SA2	DA1
10.	Droughts	yes	Low	Low	Non quantified but estimated to increase	SA1	DA1	DA2
11.	Other Extreme events	no	Low	Low	Other Non quantified events all likely to increase-wind hail frost etc	SA1	SA2	DA1
12.	Groundwater	yes	Low	Low	Some small changes may occur due to change in precipitation	HDS	SA1	DA1
13.	Surface water flows	yes	Medium	Low	Varies depending on region	SA1	SA2	DA1
14.	Sea Level rise	yes	High	Medium	0.3m increase to mid century	DA1	DA2	DA3
15.	Storm Surges/wave heights	no	Medium	Low	Requires information on winds and currents.	SA1	SA2	DA1
Notes: Direction of change reflects whether there is an increase or decrease in the change parameter, magnitude is the quantification of the change DA -Design Allowance, SA- Sensitivity Analysis. DA1, DA2, DA3 , SA1, SA2 etc are gradual refinements of the assessments. HDS- use Historic Data Sets. The above are subjective assessments. As yet the quality and availability of RCM simulations for India is insufficient to permit a fully objective assessment. The above is intended as a guide for planning only.								

170. **Design Standards:** The Bureau of Indian Standards covers fourteen sectors including water resources. As water resources fall under the Water Resources Division Council (WRDC) which includes the Standardization in the field of Water Resources development to include the activities covering utilization of water resources for irrigation, drinking water as well as ground water development. NIH Roorkee as well as CWC are members of WRDC. For smaller catchments the design discharges are defined by the Hydrology of the Smaller Catchments which is presently being revised.

171. Currently there would appear not to be any initiatives to reassess design standards to meet climate change. The incorporation of climate change into planning and design for water resources requires to be mainstreamed and actions taken up as soon as possible. Institutional mechanisms need to be established as soon as possible involving MoWR/CWC, NIH, Bureau of Indian Standards and the state WRDs to ensure climate impacts are quickly mainstreamed into water resources planning and design.

L. Focal Area 7: Strategies for Data Management for Water Resources

1. Introduction

172. The development of a Water Resources Information System is a logical response to meet the specific information technology needs of the various line departments dealing with water resources. A water resources information system consists of an information database coupled with tools for acquiring data to fill the database and tools for analyzing and visualizing the data contained within it.

173. **WRIS:** The CWC released its web based Water Resources Information System (WRIS) in November 2010. The India-WRIS project was a joint venture between the CWC and the Indian Space Research Organisation[34]. The aim of the project was to make available water resources related data in standardized GIS form to the user community. The project scope included the generation and collection of data pertaining to thirty geospatial layers. This information can be accessed by the user through a web based geo-spatial application. WRIS incorporates a wide range of tools: map based display, data query and search, map based distance measurement, data presentation and analysis, and annotation and output. The spatial layers are grouped under the main headings of:

- watershed atlas;
- administrative layers;
- water resources projects;
- thematic layers;
- environmental data.

174. The watershed atlas layers are based on the SRTM90 DEM including the river networks, as well as basin, sub-basin and watershed boundaries. Administrative layers include international, state, district and tehsil / taluk boundaries, village boundaries, town and village locations and extent, major tourist attractions on river banks, major water sanctuaries and major waterfalls. Also included is an infrastructure layer with roads and railways.

175. Thematic layers include land use and land cover, wastelands, land degradation, snow cover areas, flood inundation maps, surface water bodies, waterlogged and salt affected areas in major and medium scale irrigation projects, soil analysis results in major and medium irrigation projects, numbers of minor irrigation projects by district / tehsil, groundwater depths and levels, lithological data with aquifer parameters, drought prone area maps, inter-basin transfer links maps, inland navigation waterways maps.

176. Water resources project information is accessed by project type: major and medium irrigation projects and command areas, hydropower projects, multipurpose projects, canal networks. Only limited information can be retrieved on water resources projects. It is not, for example, possible to retrieve dam and reservoir characteristics, or hydropower characteristics.

177. Environmental data include locations of CWC and IMD meteorological stations and mean monthly precipitation and potential evapotranspiration, hydrometric station locations, and pollution monitoring station locations. Basic meta data are provided. It would be helpful to extend the metadata to include stations owned and run by organisations other than CWC.

178. The India-WRIS is a significant achievement, providing an excellent overview of national and regional water resources, access to fundamental planning data and offering much potential for future development. A link between WRIS and the HIS[35] databases for data retrieval would for example be very useful, as would inclusion of additional characteristics on water resources infrastructure. It could in future also be possible to provide links to climate change scenarios and potential impact assessments, as well as to repositories of reports and design studies by basin and sub-basin.

179. The states have to various degrees have also developed information systems using GIS and remote sensing information; much of the work at the state levels is implemented through the State Remote Sensing Centres. Linkage with WRIS and the state information centres would offer a very significant benefit to the water information systems for quite minimal investment. Linkages would require some standardisation of the information systems.

[34]Details may be found at: http://www.india-wris.nrsc.gov.in/.
[35]Hydrological Information System Developed by HP2 project.

180. The IIT Delhi taken an initiative in this direction and formulated a GIS portal (http://gisserver.civil.iitd.ac.in/natcom), for the general users, the Web 'Mapping Application for Accessing Hydrological Information' is based on the SWAT hydrological modeling and other web based interface applications. This interface also provides the outputs of the NATCOM Phase I and Phase II projects quantifying the climate change impact assessment on the Indian water resources. The IIT portal demonstrates the potential to develop highly effective water resources information systems without major resources.

181. **Ground Water Information Systems:** The distribution of ground water in time and space is uneven and unlike surface water, that is often developed at a point on a river system, groundwater is developed and managed spatially. Web based GIS tools are particularly well suited for the development planning and management of distributed resources, such as groundwater. The CGWB has developed a "Web enabled Ground Water Information System (WEGWIS)" for users in the water sector. The system has been developed to provide a unified internet based access to water related information (spatial/ non spatial) for policy planning and management.

182. CGWB identified a need to create spatial and non spatial hydrological datasets that could be linked with various socio economic data for more holistic planning and management of water resources projects. Under HP-2 and an initiative by CGWB, a spatial database including various themes related to ground water was created for the entire country, utilizing source map data on 1; 250,000 scale. These datasets were also to be integrated with the dedicated software developed for ground water data processing under HP1.CGWB collated 1:250,000 scale topographic mapping, along with landuse, geomorphology, soils, geology, and geological structure mapping. These were digitised for inclusion in the GIS with the assistance of the National Informatics Centre (NIC).

183. WEGWIS is a web based GIS system that provides a functional internet based platform for accessing water related maps and data for decision making and planning. WEGWIS has been integrated with thematic data and dynamic data such as water level/water quality, other ground water related information and socio-economic databases. The information can be accessed at different and can be viewed at a user selectable zoom level. Responsibility for updating particular layers rests with the owners of the original data for these layers.

184. **WEGWIS Utilities:** It was envisaged that WEGWIS would be utilized for various purposes including (i) providing a National Framework of a water resources database and reference system; (ii) bringing together all spatial datasets related to water resources into one common platform; (iii) facilitating access to geospatial data and other related non spatial data and conducting queries for specialized analysis; (iv) providing a tool for decision makers & planners for effective management water resources.

185. WEGWIS is an internet based system having two mirror sites, one located at NIC Head Quarters, New Delhi and other at CGWB Head Quarters, Faridabad. Both the Mirror sites are connected by internet gateways through a 2 mbps lease line. Users have options to perform geographical queries and print visible information from the WEGWIS but do not have access to the vector data that underlies the system. The system has been launched at NICserver (www.gis2.nic.in/cgwb).

186. **The Department of Science and Technology (DST)** of the Ministry of Science and Technology and the Ministry of Information Technology provide science and technology inputs to the different ministries involved in land and water management. In particular, the Natural Resource Data Management Systems (NRDMS) programme of the DST is working to develop methodologies and technological tools to enable local bodies to prepare and implement plans. It is important that the WRIS information can link with ongoing initiatives by the DST; there is a need to closely align water resources and catchment management.

2. Proposed Approach for Data Management

187. The National Water Mission Document states that: "There is a need to review the restrictions on data access. The Ministries and their agencies should also take action to digitise data, maintain databases of global quality, and streamline procedures governing access." The importance of data management and access was clearly identified in the report of the National Water Mission (NWM, 2009), where the first of the five goals identified was "Comprehensive water database in public domain and assessment of the impact of climate change on water resource". Data access has been clearly identified as an issue. The data requirements are summarised in Table 12 below.

Table 12: Data Requirements for Water Resources

Indian Meteorological Department
Central Water Commission
Indian Institutes of Tropical Meteorology Pune (IITM)
Central Ground Water Board
Department of Agriculture
Environment and Forests at State and Central Level
State Water Resources Departments
State Statistics Agencies
State Departments of Agriculture
Urban Local Bodies (ULBs), Indusry, Rural Development-water supplies and indusry
Geological Survey of India
National and state remote sensing centres
Reservoir operators

Table 13: Data Organisations

Precipitation data
Climatic data from which potential evapotranspiration can be determined
River flow data
Tidal outfall conditions
Groundwater levels and aquifer characteristics
Land use
Soils characteristics
Underlying geology
Characteristics of water resources infrastructure
Operational records for historic water use (surface water and groundwater)
Crop characteristics and cropping calendars

188. Water resources data need to be accessible between central and state Government departments, researchers, and to organisations working on behalf central or state Governments, and indeed to any organisation that needs the data for design or operational purposes. The main organisations in India collecting data of relevance to water resources assessment are shown in .Table 13.

189. The **Data Manager** is responsible for collecting and compiling and quality control of the data. All the state water sector agencies and some of the central government agencies and institutes are data managers to some extent. The data managers have four main functions and responsibilities: (i) data collection of raw field data with basic checking for accuracy and error; (ii) preparation of validated data including quality control; (iii) data summaries including processed information and (iv) data sharing. The performance of the data managers should be based on an assessment of these four functions.

190. **Data Compilers:** There is some need to compile key water resources data into an integrated information system. Data compilers would source selected data from the various sector Data Managers and would compile and prepare an integrated water resource information system. The cost and resources to maintain and update compiled and integrated water resources data is significant. Two main data compilers are proposed; the Water Resources Departments at State Level and the Central Water Commission. Other sector departments may also compile information but there would be advantages to concentrate and limit the data compilation activities. In the longer term a networking system would allow data to be networked without the need for compilers. Data compilers would design the data system and ensure data compatibility and support moves to improve data access and data sharing.

191. **Web Based Portals:** A key element of the strategy should be that data are made openly available through web based portals, forming a distributed network or knowledge base. Each node of the network could contain links to other nodes. The longer term strategy should be to create a transparent system through which users can quickly assess data availability, and download data relevant to their needs. With a nodal system, nodal organisations would retain full responsibility for keeping their databases up to date, and for administering access. The existing CWC WRIS could be developed to provide a gateway to the databases of other organisations on the network, with perhaps with a single authentication. At state level it is proposed that the state WRDs would develop a state level equivalent to the WRIS which would access lower level more detailed data that would not be appropriate for the CWC WRIS. It is proposed to build on the ongoing data management initiatives by the HP2 project. An overview of how the network might be set up is shown in Table 14 below.

192. **Data Levels:** Central level data bases would be established with core themes building on the WRIS, WEGIS, HIS and other information systems. Parallel but not duplicating systems would be developed at the state level comprising of lower level and disaggregated data including district, panchayat and block information. State data should made available to the centre and other organisations through web portals the various state nodal organisations.

193. **Implementation** of the strategy will require a co-ordinated effort amongst the organisations involved in order to ensure that appropriate access provision is made in the independent databases. Fundamental agreement is required on data sharing, not only between concerned organisations, but with the public and organisations with a role or interest in water management. The data involved are collected with public money for the benefit of society as whole and ownership should be considered to be with the public and not with the organisation that collects it; they are custodians. There will also have to be agreement on user registration and authentication procedures. A preliminary road map for data management is presented in Table 15 below.

Table 14: Proposed Water Resources Data Access and Management Network

Data Type	Ownership and Management	Independent Web Portal	WRIS Portal Access
Precipitation and climate data	Data held and maintained primarily by IMD.	√	√
River flow data	Data held and maintained by CWC and by State WRDs for respective networks. Databases updated under HP-2	√	√
Water resources infrastructure	Metadata should be held by CWC for all infrastructures exceeding a certain size. Links to owners data.		√
Groundwater data	Data held and maintained centrally by CGWB. Links to GIS for mapping	√	√
Irrigation systems	State WRDs to create and maintain electronic databases accessible for basin planning.		√
Agriculture	State Departments of Agriculture hold and maintain state statistical and phenological (plant life) data		√
Climate scenarios	Repository created by CWC in collaboration with IITM for data relevant to water resources	√	√
Soils and land use	A central repository of state land use and soils date should be established at National Remote Sensing Centre.	√	√
Tidal data	Network of primary tidal stations to be established and maintained under CWC hydrometric activities		√
Glaciers	Basin wise inventory / database and remote sensing information to be established and maintained by IGS	√	√

Table 15: Preliminary Road Map for Data Management

1	**Define Data Requirements**	Data requirements have been estimated for the HP2 project for the 13 states under the project. The approach should be expanded to other states. The assessment approach has been defined by HP2 which should be applied for other states.
2	**Define Current Data Availabilities**	Current data availabilities from the various sector agencies-central and state level would be assessed.
3	**Workable Data Target to 2020**	A data plan would be developed; the plan would be based on the needs of IWRM management including the requirements for supporting sub basin planning, hydrological modelling, water balance modelling etc over the next decade. The 2020 plan would set into three year slices 2012 to 2014, 2015 to 2017, 2018 to 2020.
4	**Strategy to meet Workable Target**	Each of the state and central agencies would define how the data target would achieved; this would include focus on upgrading of existing systems as well as additional networks
5	**Information Sharing Strategy**	Sector departments at state and also central agencies would define their data sharing strategies. Data would classified as (a) full open sharing free on a web portal (b) restricted sharing to certain departments; (c) no sharing. Where data would be charged for, the charging system should be defined. Departments would present an action plan for free and open data access. The action plan would show a step by step move to increase the data available without charge under category (a) and also (b) where some restrictions would apply
6	**Financing and implementation arrangements**	Assessment of the financing needs and financing arrangements. Assessment of institutional requirements training needs and requirements and mechanisms for outsourcing. Financial support would be required. Financial support could be conditional on improved data sharing.
7	**Design of web portals and databases**	Specialist support would required to design the web portals, and databases.

M. Focal Area 8: Capacity Building and Awareness for Climate Change Adaptation

1. Introduction

194. Climate change adaptation creates a wide range of new issues that have to be addressed in parallel with existing water sector issues. Understanding these issues and mainstreaming of climate change adaptation requires a well planned institutional strengthening process.

195. Institutional strengthening is a key entry point to analyze, comprehend and provide solutions to the problems of adaptive responses to climate change impacts. Central to institutional strengthening, is the development and enhancement of capacities through training and awareness. At present central and state departments are working towards reducing the barriers and increasing the flexibility of employees and work teams to accomplish the department's mission. To meet these demands, there is a need for a well-trained, responsive workforce capable of meeting tomorrow's challenges: improving the quality of work and service to the public at large.

196. The concept of institutional strengthening and capacity building should be anchored in the institutional policy objectives. Knowledge and human capacity[36] are critical to implementing successful water resource development and management initiatives within the framework of Integrated Water Resources Management (IWRM) as well as Climate Change. New skills and capacities within water management institutions are critically important to meet the new challenges of systematic planning and management of water resources.

197. Capacity development should not be conceived as necessarily involving formal training or activities with specific capacity development objectives. Capacity development also takes place through learning by doing, participation, observation, comparison of experiences and other informal activities. The potential areas capacity development extends across a range from individual, through organisations to systems. The underlying assumption however is that the capacity building initiatives help towards new and stronger institutional capacity for management, service delivery, resource generation and management.

198. Building capacity at all levels is vital within government institutions, and within local communities to meet the targets of service delivery. Capacities do not only relate (as is commonly understood) to technical issues, but also a range of social, managerial and institutional issues. These can range from organizing effective community participation; building solidarity, vision and a sense of purpose within communities; and starting and running efficient community-based organizations to dealing with government procedures, legal requirements and conflict resolution within the community based organisations; all in conformity with the IWRM principles.

199. **Effective involvement of local communities:** Even after capacities have been enhanced, there is a need to develop institutional space and mechanisms for governments and local communities to interact effectively. Official consultations with local communities need to be judicious in choosing between full participation and participation by representation, using the formal or informal community organisations. Explicit mechanisms have to be drafted into government rules and regulations, explained to concerned officials, and 'back-stopped' by a capable body till it becomes accepted practice.

200. **Awareness:** Given the complexity and diversity of water uses across India, there is no single approach to awareness raising and communication. CWC and the state governments are required to formulate effective communication strategies in relation to climate adaptation in the water sector; these could include:

- Building upon the various information bases available at community level, rationalising them where necessary.
- Improving the dissemination and sharing of water related information at all levels, increasing access to real time data in formats and languages easily understood by local people.
- Increasing opportunities and platforms for multi-stakeholder dialogues on water use at state and district levels, carefully mediated by trained facilitators.
- Strengthening partnerships with relevant academic, civil society and media organisations for enhanced information sharing and communication activities.
- Conduct regular public perception surveys, and participatory rural appraisals to assess water users' awareness and concerns.
- Improving coordination and information sharing between officials whose work concerns different types of water use: irrigation, drinking water, sanitation, pollution monitoring, etc.

[36]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.

2. Training Context

201. The proposed training programme is designed to support the programme of climate change adaptation. The training is not proposed to be a comprehensive training programme for water resources which are reasonably well covered by ongoing programmes. The training programme for climate change adaptation would be a standalone but complementary programme to the ongoing water resources training through MoWR, the National Water Academy and the States.

202. The strategic framework to sustainably manage India's water resources for climate change adaptation is based on the concept of integrated water resources management (IWRM), which takes a holistic look at water resources as an integral component of the ecosystem. It treats water both as a natural resource and a social and economic good. The recommendations in this report place heavy emphasis on more efficient use of both surface water and groundwater. Considerable gains could be made through better coordination and by adopting more water-thrifty crop patterns. The study also advocates Conjunctive Water Management -- where the use of surface water and groundwater resources is well coordinated, so that together they produce better results than either could on its own. In the conjunctive surface and groundwater systems water use efficiencies are already quite high and demand management though crop planning, shorter duration crops, higher crop productivity become critical. The linkages of surface water, groundwater and agriculture is a key theme for training and awareness.

203. Implementing IWRM requires institutional reorientation, capacity development and building of stakeholder consensus through enhanced awareness and understanding of its benefits in the short and long terms. A crucial first step in pursuing IWRM is conceptual clarity, so individuals and institutions take the 'bigger picture' view, and understand how and where their actions fit in and impact the inter-connected water resources management process. For example, it would be necessary to arrive at a common definition of 'irrigation water use efficiency' as this could mean very different things to a farmer, irrigation manager or a river basin authority.

204. **Key topics/concepts:** successful awareness raising will involve clarity of message, focus in communications, and sustained engagement with selected audiences over a period of time. (Fleeting campaigns or messaging produces temporary results, but cannot accomplish changes in attitudes or behaviour.) In such a systematic awareness effort, it is necessary to define and agree on the key messages. The following is an initial, partial listing of such topics at all-India level, drawing from the areas of coverage of the present study:

- Meteorological studies, monsoon changes, glaciers, sea level rise
- Climate change impacts on water resources in the Indian context;
- Strategies for effective water resources management for climate change adaptation;
- Integrated Water Resources Management (IWRM) – concept and practices;
- Methods for improving Water Use Efficiencies (WUE), various resources conservation technologies
- Conjunctive Surface and Groundwater Use;
- Catchment/watershed management and artificial ground water recharge ;
- Specific key messages and topics relating to the issues in sub basins

205. The most successful training is training by doing and it is proposed, as far as possible to link the training to processes of planning, mainstreaming and implementation of climate change adaptation including sub basin planning measures as proposed in this report.

3. Training and Awareness Processes

206. Training and awareness for climate change requires to be a customized programme, the topics and approaches are largely new and training/awareness must be tailored accordingly. The programme needs address the key needs of climate change adaptation but also incorporate the requirements and expectations of the government, community organisations and training participants. The key stages are summarised below.

(i) Defining in detail the key components and requirements for climate change adaptation;
(ii) Identifying training needs through a process of dialogue and consultation with various stakeholders of the organization;
(iii) Identifying and training of trainers;
(iv) Preparing training and awareness proposals/ modules consisting of objectives, topics, sequence and timing, methods and expected outcomes in close consultation with the target organization;

(v) Pilot the training on sample groups;
(vi) Monitoring and evaluation through recap of learning, feedback about training and trainers, and assessment of the training;
(vii) Modifying and upscaling .

207. **Training Needs Assessment (TNA):** Identifying the training and awareness needs is required through a process of dialogue and consultation with various stakeholders. The purpose of a training needs assessment is to identify performance requirements or needs within an organization in order to help direct resources to the areas of greatest need, those that closely relate to fulfilling the organizational goals and objectives, improving productivity and providing quality products and services. The needs assessment is the first step in the establishment of a training and development programme.

208. The complexity of the training requirements for the India Water Systems requires holistic and extensive training needs assessments (TNA). It would not be realistic to implement a TNA in one stage so a step by step approach is proposed; working initially with sample groups in the three pilot basins, preparing material and evaluating them before they are upscaled. Parallel studies to assess awareness requirements and appropriate approaches are also required.

209. **Rotation of Government Staff:** Frequent rotation of government staff between the different departments, especially at state level is a major obstacle to development of capacities; staff trained in one speciality area are often transferred to another unrelated department. The lack of specialist staff is a major issue; the World Bank supported HP2 project has faced major problems of a lack of trained hydrologists; much of the hydrology at the state level is managed by non specialist staff. Rotation of staff and how to develop capacities within the system of rotations has to be incorporated into the training needs assessments.

210. **Identification of trainers:** The IWRM climate change strategy contains a significant amount of new material and ideas that will be largely unfamiliar to existing government trainers. The very large scale of the training will require a gradual expansion of the cadre of trainers; and a programme of training of trainers will be required. The capacities of the training centres will require to be reviewed. It is proposed to better network the water training including the central training centre at Pune, and the state centres including WALMI. Training facilities provided in the other missions should be networked by National Water Academy. Capacity building and training components provided in the missions including the National Missions for Sustainable Agriculture, National Mission for sustaining Himalaya Eco-system and National Mission for Strategic Knowledge for Climate Change should be suitably networked and collaborated.

211. **Private sector** can potentially fill the gaps where government institutes are not able to immediately meet the training requirements. For community training and awareness stakeholders from civil society can potentially offer a good pool of trainers; the WALMIs have specific expertise in this area.. Short term overseas specialist training may be required in certain specific areas including climate projections and adaptation and specialist modelling. Private sector can provide significant support where there is a potential marketing opening for example promotion of drip irrigation, use of fertilisers pesticides. Research into an Indian private sector extension services enterprise[37], showed that;

- Farmers were willing to pay for the delivery of an integrated set of services giving them access to quality inputs, credit and procurement services and field-based advice on technology use.
- Farmers registered with the private extension service provider were able to substantially increase their yields and income from farming in comparison to non-participant farmers.
- The increase in yields and income was attributable to field-specific technical advice from the private extension provider regarding the application of the right type of inputs at the right stage of crop growth.
- The private extension approach focused mainly on medium- and larger-scale farmers.
- This apparently successful private extension approach was developed through a learning-based approach.

212. Great care is required in the selection of the trainers: trainers should not be restricted to official trainers. Line agency staff and members of civil society at different levels who show interest and capacity for training should be given training responsibilities; the mix of real hands-on experience and an aptitude for training provides the best candidate for a trainer. Appropriate incentives should be given for line agency and external trainers.

213. Strengthening of the National Water Academy(NWA) and other water resources training centres is proposed under Focal Area 10 and the training programmes need to link with the proposed upgrading of the training facilities.

214. **Planning the training and awareness** is essential. Many training courses fail or do not fully achieve their targets due to lack of preparation and/or the use of irrelevant material. The type of training should be varied and not limited to

[37]Agricultural and Extension Network Effectiveness Of Private Sector Extension In India And
Lessons For The New Extension Policy Agenda Rasheed Sulaiman V, Andy Hall And Suresh N DFID 2005

classroom training; it should include lectures/class room, case studies, practical exercises, site visits, discussion groups and simulation exercises. Training for farmers and community groups needs special care.

215. **Prepare and test the programme:** The IWRM and Climate Change programme includes a wide range of topics many are new and testing and refinement is essential. It is proposed to pilot the programme on a selected sample of recipients in the three pilot sub basins. Constant Monitoring and Evaluation has to be taken up and the training adjusted based on evaluations.; independent evaluators should be used for evaluations.

4. Programme Organisation

216. The training programme would be implemented as a partnership of central and state government and the various training institutes. It should also be suitably networked with the other national missions for climate change and other ministries like MOEF, Ministry of Agriculture and Ministry of Science and Technology and other departments like IMD, ICAR, IITM, ISRO,NIOT,CPCB etc. The proposed arrangement is for a Central Training Hub, a State Training Hub and State Training consortium as described below.

(i) **Central Training Hub** would be a partnership of the CWC Climate Change and the Human Resources Units and the National Water Academy Pune and other related organisations. The Central Training Hub would be supported by specialist consultants during the initial planning and start up period. The Central Training Hub would be the overall coordinator and designer of the climate change adaptation training programme including implementing training needs assessments, organising pilot training, preparing modules and training of trainers and supporting the state training programmes. The hub would directly organise training and awareness at the central level including high level training for senior managers at state and central level in water resources planning and policy. Independent assessors would be recruited to monitor and evaluate the training programme.

(ii) **State Training Hub** would be consist of the state IWRM unit of the state WRDs in association with other water linked sector departments, together with representatives of non government stakeholders/civil society. The state training hub would be responsible for training and awareness at state, district and community levels. The state training hub would be supported by specialist training consultants especially during the initial stages. The initial design and development of the training programme would be the responsibility of central training hub but tailoring of the training/awareness to the local situations and implementation of the state and lower level training and awareness would be responsibility of the State Training Hub.

(iii) State Training Consortium would be responsible for implementing state and lower level training. Cadres of trainers would be identified and given training in methodologies and understanding of the training materials for climate change adaptation. In addition to the state training institutes it is proposed that trainers could be selected from within the WRDs as well as civil society. The state consortium would include specialists in information and communications technology.

217. Methods have to be developed to allow interaction with stakeholders to understand current issues, possible impacts of climate change and the needs to move from business as usual to long term and sustainable management systems. There are many and varied methods for awareness raising, outreach and stakeholder engagement. It is important to bear in mind that one approach or method does work with a multitude of audiences and stakeholder groups (in other words, 'one size' does not fit all). Possible approaches include:

(i) **Information and Communication Technologies (ICTs):** ICTs are now more user-friendly, affordable and can enable large scale deployment of information for training and awareness. ICTs can support a maximum outreach to stakeholder at signficantly lower costs than other training methods. Examples include; use of web sites and online social networking, television and radio documentaries and dramas, free software, electronic newsletters, interactive geographical information systems.

(ii) **Engaging with communities through Multi-Stakeholder Consultations:** Field surveys and consultations conducted in the three sub-basins have highlighted a significant degree of contentious issues and conflicting interests among different stakeholders. These are common in water stressed situations and can become more aggravated with declining water quantity and quality trends and rising uncertainties due to climate change impacts. The idea of multi-stakeholders consultation is that stakeholders must be aware of the fact that their needs for use of a finite resource may conflict with other users' needs and through participative discussion stakeholders will express their concerns and issues and through collective dialogue move towards addressing issues and finding solutions. Multi stakeholder consultations, facilitated by a neutral party, is a methodology that can be used in such resource conflict situations. The Multi Stakeholder consultations are required to be initiated very early in the planning processes to ensure the planning fits the needs of stakeholders and to allow modifications to plans as necessary; possible areas of dispute need to be identified as early as possible in the planning process. The consultation process needs to be repeated at all the critical stages; preliminary planning,

detailed planning and final design. The various consultations should be organised with as wide representation and participation as possible.

(iii) **Lectures/presentations**-formal lectures/presentations remain a key training methodology. For in service training and training of communities and farmers, concentration levels can be an issue. Introduction of case studies, practical exercises and discussion groups are useful to create variation and hold interest.

(iv) **Site visits** are generally very useful; follow on discussion to assess applicability can provide added value. Visits should be carefully designed and include interaction with different types of stakeholders.

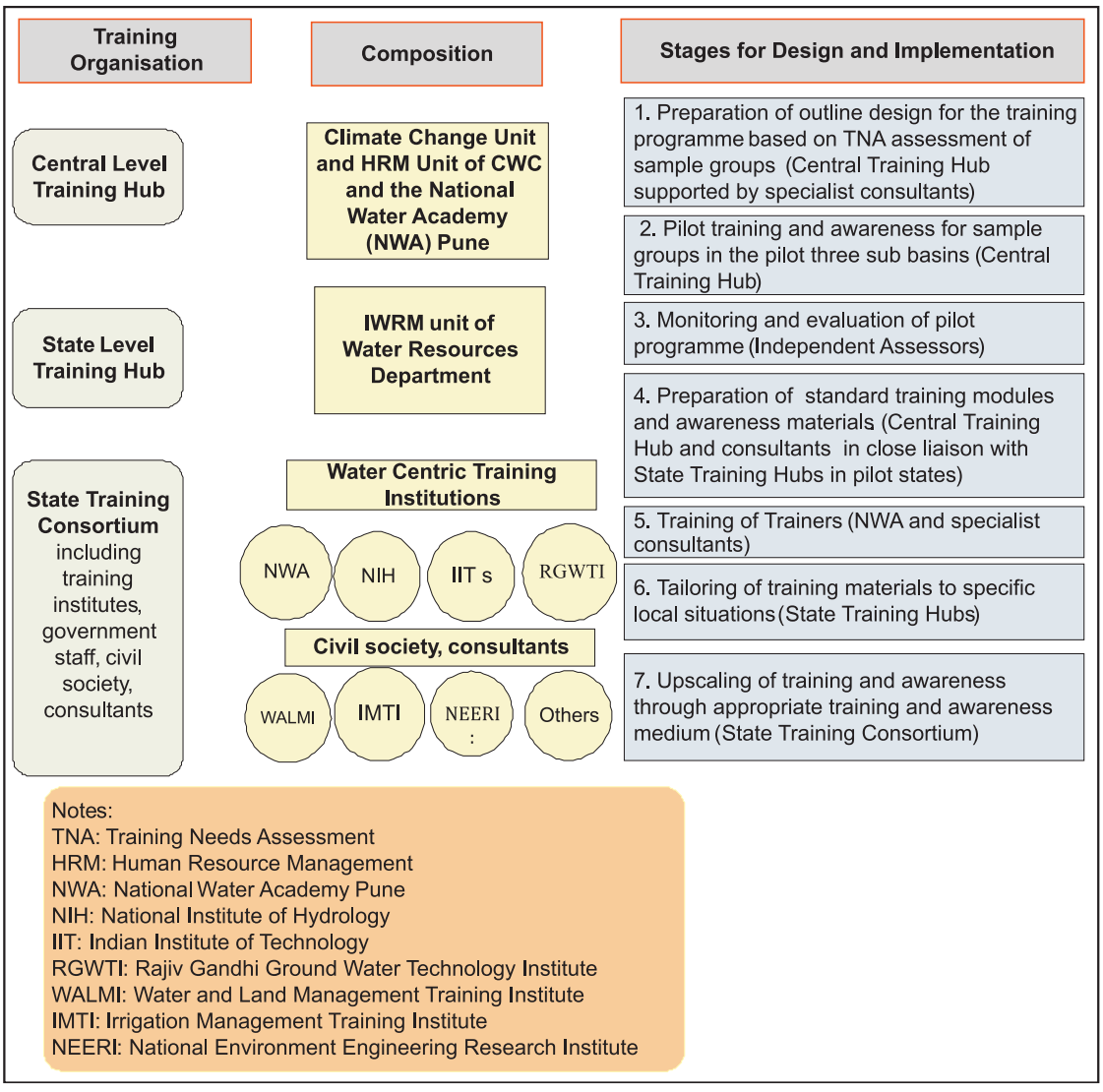
(v) **Simulation exercises** or games; these are very relevant to climate change where potential future scenarios of climate change can be simulated and impacts on water systems presented; groups can be tasked to design adaptation measures.

(vi) **Participatory Rural Appraisal** although designed to obtain information of stakeholder issues and perceptions, the appraisals can be orientated to be a two way appraisal and learning and awareness process. Field staff implementing the appraisal need special skills in training as well as community evaluations.

(vii) **Water campaigns** using printed, electronic media, large events with celebrities and logos to give identity to the campaigns.

218. The training organisation and stages is shown in Figure 7

Figure 7 Training Organisations and Stages for Design and Implementation



219. **Introducing Reforms and Change:** Many of the programmes for climate change adaption involve reform or change and a move away from 'business as usual'. Training and awareness programmes have to be carefully designed to promote understanding of the benefits of change and provide simple approaches to initiate change that provide will provide a clear benefit and minimum risk to change. Reform or change measures are more sustainable when accompanied by a communication campaign aimed at the public and all levels of civil servants to build public confidence in government and address the specific concerns of both public and civil servants

5. Outline Design of the Training and Awareness Programme

220. It is proposed to establish a 'Training and Awareness Programme for Climate Change Adaptation'. The programme would incorporate the wide ranging technical and institutional aspects relating to adaptation to climate change and water resources sustainability. The programme would be a customised for the MoWR/CWC, states and lower levels Training has been linked to the ten focal areas described in this report. An preliminary assessment of the training and awareness requirements are summarised in Table 16 below.

Table 16: Proposed Areas of Training and Awareness

Nr	Focal Area	Aspect	CWC	State	Districts	Other Stakeholders and Civil Society	Farmers and Community Organisation
1	1	Climate Change Analysis for Water Resources	A/B	A/B	C/D	D	D
2	2	Planning Process for Climate Change Adaptation	A/B	A/B	C/D	D	D
3.1	3	Sub Basin Strategic Framework Planning	A/B	A/B	C	D	D
3.2		Specific technical issues relating to sub basins		A/B	B	D	D
4	4	River Basin Planning and Management	A/B	A/B	B	D	D
5	5	Water Use Efficiencies and Management Options	A	A	B	C	C
6	6	Incorporating Climate Resilience into Planning and Design	A	A	B	D	D
7.	7	Strategies for Water Resources Data Management	A	A	B		
8	8	Capacity Building and Awareness	B	B	B	B	
9	9	Establishment of IWRM at State and District Levels	A	A	A	C	D
10.1	10	Strengthening of Central Water Commission	A	D			
10.2		Water Resources Planning and Policy for Senior Managers from Centre and States	B	B			

A: High End Skill- understanding in detail including technical aspects -*only key selected personnel would trained to this level*
B: Working Knowledge: good understanding of material and issues-*appropriate for most mid to senior staff*
C: Exposure Training: broad understanding of issues and approaches-*lower level staff/ communities*
D: Basic Understanding and Awareness: introductory material designed to meet the needs of the target group-*most appropriate for large/dispersed audiences*
A/B, C/D-a few selected personnel would be trained to the higher level, the main training/awareness thrust however would be to the lower level.

221. For each of the training/awareness areas training needs assessments are required to be carried out. The proposed training and awareness approaches are described in Table 17.

Table 17 Proposed Training and Awareness Approaches

Nr	Focal Area Title	Issues	Proposed Approach
1	Focal Area 1: Climate Change Analysis for Water Resources	Content is mainly technical and scientific information. Training has to be tailored to the capacities and job functions of the audiences.	Senior technical level training for senior state and centre officers by IITM and other specialists Training at state and district level by consultants/ institutes ICT information to wide audiences Use of simulation exercises to demonstrate potential impacts of climate change.
2	Focal Area 2: Planning Process for Climate Change Adaptation	There is a need to change approaches and methods-doubts and uncertainties require to be identified and addressed	Technical training to be supported by a communication campaign to stakeholders.
3a	Focal Area 3: Sub Basin and Basin Strategic Framework Planning	Training has to be directed at understanding the planning processes and approaches to mainstreaming the plans.	Multi stakeholder consultations Participatory Rural Appraisal Workshop to present/discuss findings Increasing the awareness and support for plans through water campaigns, and ICT.
3b	Focal Area 3: Specific technical issues relating to sub basins	Technical training requirements to be identified as part of the sub basin planning. Training would be given to help support the planning processes	Issues to be identified through multi-stakeholder consultations Training is specific technical areas relating to sub basin issues. Water campaigns and ICT to increase awareness of issues and solutions.
4	Focal Area 4: River Basin Planning and Management	This is a very sensitive issue and there is a need to overcome many years of dispute and distrust.	Study tours for senior officials to river basins in Asia, Australia, USA and others. Multi-stakeholder consultations to focus on issues and develop approaches. Support the understanding of legal and institutional options, Water campaigns to promote advantages of river basin management.
5	Focal Area 5: Water Use Efficiencies and Management Options.	New ideas of conjunctive water management need to be introduced. This is a significant change of approach and requires improved understanding of issues.	Technical training to be supported by a communication campaign to stakeholders. Study tours and site visits to see new initiatives. Awareness information through brochures' leaflets.
6	Focal Area 6: Incorporating Climate Resilience into Planning and Design	New concepts to factor in climate change into planning and design. Training should be based consultancy to review requirements and present options Training will be interactive with senior technical officers from centre and state with a consultant as a facilitator Output would be agreed guidelines for planning and design for climate change.	Consultancy assignment to review approaches and prepare draft guidelines High level international workshop to bring in international perspective Interactive discussions at centre and state levels Final guidelines for design under climate change conditions. Training in approaches to planners and designers at centre and state.
7.	Focal Area 7: Strategies for Water Resources Data Management	This topic covers three areas: Understanding needs and requirement for data sharing. Technical aspects of databases/gis. Design and management of web portals.	Data base management/GIS High level workshop to discuss agree data sharing policies and develop targets. Design of web portals
8.	Focal Area 8: Capacity Building	This part incorporates the planning design and preparatory work for the training programme .	Training Needs Assessments Designing of training programmes and identifying trainers Training of Trainers Pilot training and assessments
9.	Focal Area 9: Establishment of IWRM at State and District Levels	There is a need to change approaches and methods-doubts and reluctance to change have to be addressed Benefits of new organisational structures need to be presented	Multi-Stakeholder Consultations Distribution of awareness material Participative consultations to assess and agree strengthening and restructuring requirements.
10a	Focal Area 10: Strengthening of Central Water Commission	Series of short courses relating to water resources and climate change adaptation. Seminars and discussions relating to requirements of restructuring and strengthening of CWC	Data base management/GIS Management training Technical training in specific area Multi-stakeholder consultations and seminars to discuss and agree strengthening/ restructuring proposals
10b	Focal Area 10: Training in Water Resources Planning and Policy for Senior Managers from Centre and States	A series of intensive courses for senior management to bring in core aspects of water resources planning, policy and climate change adaptation. Key areas of training to be defined	Short intensive overseas management training/study tours/ technical training in climate change High level short intensive training in in India -with international and national presenters. Medium level training derived from outputs of high level training

222. Training modules have been identified to link with the key objectives of each of the focal areas. A preliminary summary of appropriate training modules is given in Table 18 below.

Table 18 Training and Awareness Modules

	Course	Main application-with reference Focal Areas described in Table 17 above.
1	**Institutional /Policy**	
1.1	Water Policy and approaches to implementing policy	10b
1.2	River management legal mandate, institutional approaches	10b, 4
1.3	Agricultural Support Policies to meet needs of water conservation	10b, 3a, 3b
1.4	Sustainable groundwater management	10b, 3a, 3b
1.5	Charging systems for surface and ground water	10b, 3a
1.6	Establishment of IWRM	10b, 2
1.7	Institutional requirements for mainstreaming climate change adaptation	10b, 3a
1.8	Participatory irrigation and water users	10b, 3a
1.9	Planning Processes for Climate Change Adaptation	10b, 3a
1.10	Role of private sector to support climate change adaptation	10b ,3a
2	**Management Tools**	
2.1	Application of GIS and Remote Sensing Tools	9, 10a,
2.2	Data bases management for water resources	7, 3a
2.3	Web portals for data and information sharing	7
3	**Climate Change**	
3.1	Disaster management under climate change	3b, 6
3.2	Safety of dams and hydraulic structures under climate change	6
3.3	Specific technical training according to identified issues in sub basins	3b
3.4	Impacts of temperature increases on cropping systems,	3a, 3b, 6
3.5	Land use planning for climate change adaptation and sustainability	3a
4	**Specialist Water Resource**	
4.1	Understanding of climate change projections	1, 3b
4.2	Numerical Modelling of Surface and Ground Water Systems	1, 3b
4,3	Modelling of Water Supply and Demand (WEAP or other models)	1, 3b
4.4	Decision Support Systems to Support Climate Change Adaptation	3a, ,6
4.5	Hydrodynamic Modelling of coastal water system	3a, 6
4.6	Incorporation of climate resilience into planning and design	6
5	**Water Resource Management**	
5.1	Water Resource Conservation	3b
5.2	Artificial Recharge For Groundwater	3b
5.3	Water use efficiency including conjunctive water use	3b
5.4	Improving efficiencies Water supply and sanitation; water reuse	3b
5.5	Saline water management	3b
5.6	Natural coastal protection/shoreline management planning	3b
5.7	Catchment management to support groundwater recharge	3b
5.8	Micro irrigation	3b
6	**Agriculture Productivity and Water Use Conservation**	
6.1	Cropping systems to reduce water use	3b
6.2	Crop production management	3b
6.3	Agricultural Marketing	3b
6.4	Post harvest technologies	3b
6.5	Agriculture options in saline, flood prone areas including aquaculture	3b
6.6	Agriculture systems to reduce water demand SRI, direct seeding mulching etc	3b

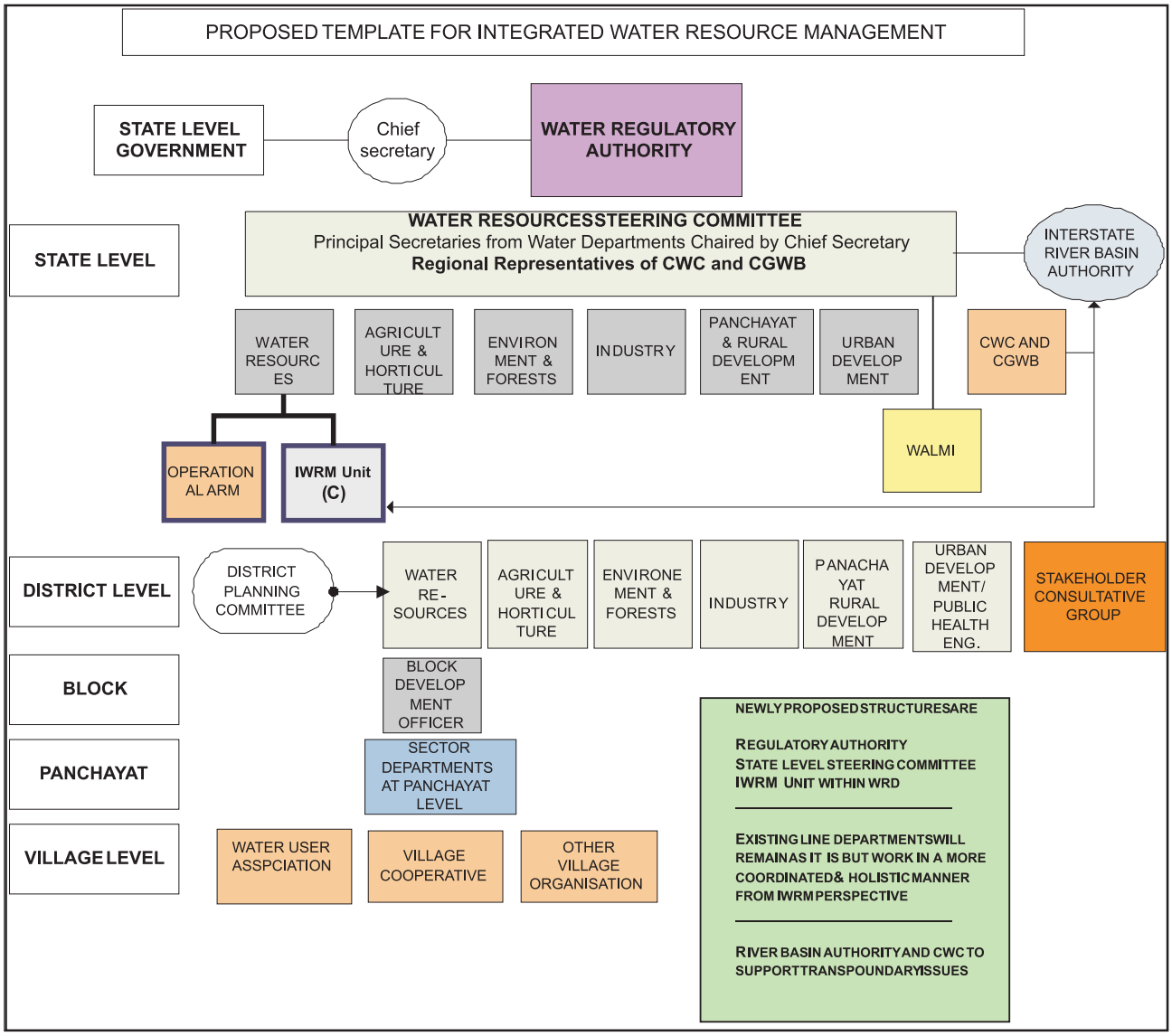
N. Focal Area 9: Template for Integrated Water Resources Management at State and District Levels

223. **Rationale:** In the context of increased pressure on water resources, lack of potentials for additional water resources and climate change, there is a need for improved and integrated water resources planning, management, governance and regulation.

224. A modern, successful water management organization must reflect the concepts of good IWRM but cannot be all things rolled into one. The roles of regulator, standard setter, resource manager and operator should ideally be separated. In the Indian situation it is not easy to completely separate these functions; most of the water department and agencies combine the function of 'resource managers' together with an 'operating/development' role.

225. There are a number of institutional options for water management organisations to be able to fulfil the need for separate disaggregated functions. The preferred model depends very much on the local institutional needs and conditions. The proposed organisational structure for IWRM at State and District is to build as far as possible on the existing institutional structures and keep IWRM very much within the mainstream water planning and management processes. The proposed arrangement is presented in Figure 8 below.

Figure 8: Proposed Arrangement for IWRM within the States



1. Proposed IWRM Institutions

226. The proposed IWRM institutions at State and District level would include:

(i). **State Water Resources Steering Committee (WRSC)** should be established at State Level to drive IWRM planning and management. The WRSC must include the various authorities and institutions involved in decision making in the water sectors, along with other key civil society stakeholders. The constitution of the WRSC must be carefully balanced and requires long-term commitment from the outset from all participating department and entities (government, the private sector and civil society etc). The regional officers of CWC and CGWB would be part of the steering committee to support wider basin coordination opportunities and issues.

(ii). **IWRM Unit within Water Resources Departments:** The present planning, data management and hydrology sections within the WRDs would be combined, expanded and strengthened with a new mandate and skills to become an "IWRM Unit". The present operational functions would be separated from the WRDs. The new 'water resources management unit' would include a role in water resource planning including providing guidance to the water regulator about water issues including advising on water licences and permits. The new IWRM management unit would encompass water resource aspects of climate change and would liaise with the Proposed Climate Change Centres being developed by DEST. Staff from the different sectors department would be seconded to work. The CWC and CWGB would provide support and guidance and monitoring support to the IWRM unit.

(iii). **Stakeholder Consultative Groups:** A lower level consultation process is required to support the basin planning processes. To allow for a collective consultation at the sub-basin level; it is proposed that a 'sub-basin level consultative group' is formed, the group representatives would be nominated by the various Panchayat Raj within the sub-basin with representation from the various stakeholders and civil society. The consultative group would also have a role to advise and inform the Water Regulatory Authority on water issues in the sub basin. Stakeholder Consultative Groups would operate at the district level, linkages would however be formed to enable lower level consultations at Panchayat level. For the sub basin level mechanisms would be established of a sub basin forum, comprising of representatives of the various consultative groups at district level.

(iv). **Independent Water Regulatory Authority (WRA)** will be very relevant to climate change adaptation and provide an institutional mechanism to regulate the allocation, management and utilization of limited water resources through a participatory approach. The 13th Finance Commission report of 2009 has recommended the establishment of state water regulators to address major problems associated with the management of water resources. Among these are: injudicious inter-sectoral and intra-sectoral distribution of water amongst various categories of water users, low water use efficiency, fragmented approach to water resources planning and development, low water user charges and meagre cost recovery. The Water Regulatory Authority in each state would include the functions to: (i) establish and regulate the water tariff system and charges for surface and sub-surface water used for domestic, agriculture, industrial and other purposes; (ii) determine and regulate the distribution of entitlement for various categories of uses as well as within each category of use including environmental requirements; (iii) periodically review and monitor the water sector costs and revenues; and (iv) water audits.

The regulator would be an autonomous, professional, inter-disciplinary body, with managerial, professional, mediatory and adjudicatory capabilities built in. The regulator must not be one more government department. It must be truly consultative and participatory in its composition and functioning, with representatives of civil society associated with it at all levels. The establishment of an effective and independent Water Regulatory Authority is a complex process and requires consultation and support. Understanding of the benefits, and support to establish a WRA at the state level is critical. An incentive grant of Rs 5,000 crore (about $1.1 billion) to the states have also been proposed for setting up the regulatory authorities.

(v). **IWRM at District Level:** Planning and implementation of water programmes would be through the state and districts. IWRM at the district level is mainly established with close liaison between sectors and the Deputy Commissioners. Water programmes within the districts would be mainstreamed through District Planning Committees (DPCs). Implementation of programmes and works, with the exception of major projects would

be through districts. Block development officers (BDOs) would take on a more major role in coordinating programmes and ensuring effective participation.

(vi). **Water Users Association (WUA):** WUA structure varies from area to area and is linked primarily to the surface water systems. In strong ground water areas it is apparent there is total absence or very limited establishment of WUA and in such cases other institutional arrangements need to be explored. However, the requirement for location specific studies to assess the appropriate WUA is important. It is important that the rationale for promoting community managed water institutions like WUA is based on a significant increase of empowerment and higher level bottom up approaches to establishment and development.

(vii). **Village cooperatives are** designed to help farming communities access to a package of basic support services. The village cooperative societies either at village level or for cluster of villages are able to provide information, guidance, and training, marketing support, support for self-help groups and banking structures for agricultural credit support, sale of agricultural inputs and rental of agricultural equipment. Village cooperatives can play an important role in supporting improved water use efficiencies and support for diversification and marketing. In areas where there is no WUA (groundwater predominant areas) the village cooperative can potentially play a key role in supporting the implementation of water resources conservation.

(viii). **Other Formal and Informal Organisations** at the village level are important and should be incorporated into the water planning and management processes. Deepening democracy through village level organisation allows for long-term sustainable change in human capacities and capabilities to plan and govern and in the long term ensures cost effectiveness in service delivery and sustainability. The constitution recognises the need for strong village governance to achieve development which then becomes the means to build the individual and community capabilities of the most vulnerable communities.

O. Focal Area 10: Strengthening of Central Water Commission and Other Attached Organisations of MoWR.

1. Introduction

227. A wide range of institutional responses have evolved over the years to use and manage the ever-increasing demand for irrigation water in India. Although the functions of CWC have evolved over a period of time, the needs and challenges of water resources and climate change are now moving very fast and it is important that CWC keeps ahead and on top of the complexities of addressing these issues, of key importance is climate change adaptation. To meet the future needs requires more effective partnerships between the sectors as well as central and state government. The National Water Mission identifies the need for internalising climate change within the existing institutions; it also recommends the adoption of IWRM and the needs for the water institutions to adjust to the changing functional needs. Restructuring/ strengthening of the CWC and the MoWR subsidiary organisations is not a new topic and is being discussed for some time. To meet the very heavy demands current issues as well as requirements for climate change adaptation increases the urgency of reform and restructuring. The changing requirements of water resources requires some major rethink in how water resources are managed and the most appropriate structures for management at the State, Central and Basin Level. The MoWR and CWC must take a key role in terms of driving forward new ideas and initiatives.

228. The Indian Constitution empowers the states to govern the water resources. However, the regulation and development of interstate rivers is entrusted with the federal government. The effectiveness of the various acts are clouded by lack of clarity in terms of institutional objectives, fragmentation of basins by state boundaries, lack of cooperation among states, and intense political lobbying by states.

229. The several attached and subsidiary organisations of the MoWR play and will continue to play a key role to support the Ministry of Water Resources. The key organisations relating to climate change adaptation are: (i) the Central Water Commission; (ii) the Central Groundwater Board; (iii) the National Institute of Hydrology; and (iv) the Central Water and Power Research Station.

2. ASCI 2007 Study[38]

230. A restructuring proposal for the Central Water Commission was commissioned by the Ministry of Water Resources and assigned to the India Administrative Staff College Hyderabad (ASCI), the final report was presented in July 2007. This assessment of CWC was prompted by the fact that future allocation of water will need to address competing uses as inevitable and the need to work towards a lower demand scenario of water requirements and also the need to address questions of equity in the distribution of water resources within and between river basins, among different sections of the population and the end users. Central and State water resources departments have to date been preoccupied with the expansion of irrigation and there is a fundamental need for MoWR to move away from its irrigation orientation toward a more integrated, holistic and inter-disciplinary approach to water resource management. Adaptation to climate change reinforces this requirement.

231. ASCI identified that the present advisory role of the CWC leaves the centre unable to enact effective laws regarding inter-state rivers, even when it has the powers and legal mandate; effective interstate management has not been implemented. Water is such a politically sensitive issue that the centre has refrained from being pro-active even during the decades of an increasing central presence in many other sectors.

232. **Strategic Options:** The ASCI study finds that despite being the major player, restructuring of CWC is considered necessary to create an enabling environment to allow implementation of the national water policy. The study recommends that the restructuring needs to involve CWC as well as other organisations under the administrative control of MoWR. After considering various models two options were presented by ASCI;

- **Corporatisation option:** parts of CWC could be converted into commercial units with potential to perform the existing activities on purely commercial lines. Other activities would not lend themselves to such corporatisation including the hydrological studies, flood management and river basin management.

- **Constitutional option:** The ASCI report's second and preferred option was to consider the possibility of converting the CWC into an autonomous constitutional body[39]. Reopening of the constitutional debate was considered very

[38]Source: Extraction from the Final Report -Restructuring the Central Water Commission : Commissioned by the Ministry of Water Resources, Government of India/ Administrative Staff College of India Hyderabad (ASCI)- July 2007
[39]This would be similar to the functionaries like the Comptroller and Auditor General of India (C &AG) or the Election Commission (EC)

seriously by the ASCI study but the widening gulf of issues of the interstate water resource management was considered so complex that radical empowerment of CWC was required. The ASCI proposal was to establish an Interstate River Basin Commission (IRBC) under which all water related subjects under the purview of MoWR and other ministries can be placed. The IRBC would form the umbrella organisation for River Basin Organisations RBOs to cover all major river basins in the country.

3. Proposed Strategy for CWC and other Attached Organisations of MoWR

233. The key functions of the Central Water Commission are to support implementation of water resources planning and policy and provide linkages and liaisons with other central government ministries, and state governments. It is essential that CWC moves towards IWRM and as such should incorporate all water resources including surface and groundwater, coastal, snow and glacier systems as well as coordination of demands from irrigation, water supplies, industry and environmental needs. Climate change is now a critical area and CWC will need to take on a lead role for water resources adaptation.

234. The ASCI's study provides a basis for direction and strategy for CWC as well as the other MoWR attached agencies.[40] The ASCI proposals were however not accepted for implementation despite agreements on some parts of the plan. There remains now increased need for strengthening and reform to address the very changing needs of water resources including incorporation of new emerging areas.

235. To cope with the new challenges in the water resource environment, the Central Water Commission (CWC) needs to make a conscious effort to develop new technical, managerial and behavioural competencies, while deepening the existing capacities in the organization. These new competencies would enable CWC to address the emerging areas that call for an enhanced role for CWC. Key emerging areas identified include; (i) strengthening of ongoing initiatives for the development of basin planning and enabled river basin organizations; (ii) promoting best practices in integrated water resource management; (iii) addressing climate change adaptation and (iv) water regulation and safeguards. The present organisational structure of the CWC is not appropriate to meet these new requirements and strengthening and adjustment of the CWC and other attached organisations of MoWR is proposed.

236. The **Legal Mandate** is an issue raised frequently during discussions; the present advisory role of CWC leaves a large gap in capacities to implement river management functions, this lack of empowerment will also likely be an inherent weakness of the RBOs unless stronger legal authority can be obtained. ASCI proposed a constitutional role for CWC; however more easily achievable approaches are required, at least for the interim period. The legal framework (River Board Act 1956) allows GOI to set up boards for interstate rivers and a few river boards have already been setup (Betwa River Board etc.) but they are not empowered RBOs but organisations only for the purpose of construction of particular projects on interstate rivers and managing the project operation. Even if a River Board has been set up it cannot be said that the riparian states have waived their rights under the Inter-States Water Disputes Act.

237. There is view that GOI can use the River Board act also for setting up of enabled and empowered RBOs but despite the legal provisions this has never been attempted so far; no state government has made a request to establish an empowered River Basin Organisation. In such circumstances, the co-existence of a River Board and a Water Tribunal seems questionable. Under the Inter-State Disputes Act the Central Government is bound to constitute a Water Tribunal when there is a complaint even by any one of the riparian states, whereas in the case of the River Boards Act there should be a collective request for the constitution of an inter-State River Board. Therefore, the element of dispute seems to be the primary reason for the government to act and not the regulation and development of the river. Addressing the legal mandate is a key requirement towards ensuring the long term strengthening of the CWC and empowerment of the RBOs

238. **Partnerships:** The CWC functions will be partnerships between states, specialist institutes and the strengthened regional offices as well as empowered RBO. Specialist requirements would be outsourced to institutes and consultants. Many functions should be devolved to the states and gradually the RBO. CWC can provide support to RBOs including data, studies, analysis etc. CWC officers could be members of the RBO on secondment. or might chair the RBO.

239. These changes will affect the size and actual organisational structure of the various functional units. Further studies are required to define the final institutional structure.

240. **Separation of Roles:** A modern, successful water management organization must reflect the concepts of good IWRM but cannot be all things rolled into one. The roles of regulator, standard setter, resource manager and operator should ideally be separated. In the Indian situation it is not easy to completely separate these functions. CWC currently holds

[40]The main relevant MoWR attached organisations are National Institute of Hydrology (NIH), Central Water and Power Research Station (CWPRS)

roles of 'resource manager' as well as provider of support for 'operations and development'. To achieve this requires CWC to gradually reduce and separate its project development functions and strengthen its role in resource management including regulation, safeguards and compliance functions.

241. **Functional Roles:** Seven key functional roles are identified. How these roles are incorporated into the CWC organisation require to be further studied and discussed.

- o Water Resources
- o Basin Planning and Management
- o IWRM/Climate Change/ Specialist Support
- o Projects
- o Safeguard and Regulation
- o Human Resources and Capacity Building
- o Planning and Policy

242. **Water Resources:** It is proposed that all aspects of water resources including precipitation, hydrology, groundwater, water quality, reservoir management, river morphology, climate, coastal water systems and glaciers are managed within one unit. The unit would also be responsible for water quality information. The water resources unit would be directed at creating a 'one stop shop for water resources information and analyses'. The water resources unit would in cooperation with IMD and states prepare trend assessments. The preparation of flood and other water forecasts would be a key responsibility of the unit. The water resources unit would play a key role in supporting the River Basin Planning and Management through provision of water resources data and analysis. The water resources unit would work closely with State Government to compile and integrate the central and state water resources data. Management of the collecting and compiling hydrologic data would be the responsibility of the states, regional offices and the CWC water resources unit. The water resources unit would have five sub units:

(i) **Surface Water:** All aspects of surface water systems including precipitation, water demands, glaciers, coastal;
(ii) **Groundwater:** Compilation of groundwater data and preparation of assessment reports. Data collection and compilation would be devolved largely to the regional offices and strengthened state groundwater departments. To be through CGWB but with close liaison with CWC;
(iii) **Other Water Systems:** snow. glacier, coastal systems, reservoirs ;
(iv) **Water Quality:** Working closely with state and regional offices to compile and analyse water quality information. Maintaining linkages and liaison with other parallel water quality initiatives including MoEF;
(v) **Flood and Drought Forecasting:** Precipitation, river level and flow data would be analysed and compiled to prepare flood and drought forecasting information.

243. **Basin Planning and Management:** All planning and management functions should operate under the basin planning and management umbrella. Planning would be a partnership between the state and centre. Plans would be integrated including groundwater, hydrology, catchment and flood and coastal management. The work would be implemented by outsourcing of specialist activities together with state responsibilities to prepare the plans and ensure stakeholder approvals. Initially plans would be sub basin plans but these would be merged into basin plans. Institutionally planning would be developed through the regional offices, the state IWRM units and gradually with the RBOs. The Basin Planning would incorporate aspects of interstate and international rivers as well as incorporating water demands for all sectors. The basin planning would incorporate:

(i) **Surface Water Planning and Management:** Addressing management issues of surface water including water resources modeling of resources and demands;
(ii) **Groundwater Planning and Management:** Proactive groundwater management with special support for critical areas;
(iii) **Demand Management:** Assessing multi sector water demands and how to balance demands, options for demand management;
(iv) **Flood Management:** The extensive flood management progammes need to be incorporated into the basin planning processes;
(v) **Coastal planning and Management** including coastal processes, shoreline management planning, coastal protection;
(vi) **Water Governance:** would support the development of effective institutions and management systems at state and river basin level together with support for appropriate water regulation and support systems.The step by step establishment of the RBO would be the responsibility of the water governance sub unit. Institutional changes would form an important part of the basin planning and management outputs.

244. **IWRM/Climate Change and Specialist Support:** The need to manage water resources based on integrated approaches as well addressing the issues of climate change is an emerging area for CWC. Water resources must move from the present irrigation focused development approaches to an integrated and holistic management of water resources with resilience to climate change. The IWRM and climate change unit will play a key role to liaise with the different ministries of central government and ensure exchange of data and support awareness of climate change and other water issues. It is proposed that IWRM, Climate Change and other specialist design support are merged to ensure maximum integration and provision of a cohesive approach to climate change adaptation and specialist support for planning and design. Two sub units are proposed:

(i) **Data Management and Coordination:** Data and information sharing is a critical requirement to meeting the needs of climate change adaptation. Establishing open IWRM information systems and data management and sharing partnerships with state and central government and specialist institutes are critical to the effective management of water resources and mainstreaming of climate change assessments. Data must incorporate the multi sectoral aspects of water resources including climate change projections. Establishment and maintenance of web based information portals building on the WRIS are key objective of the Data Management Unit. The unit would also support coordination and liaison with other sector ministries and departments at the State and Centre to ensure maximum sharing and exchange of data.

(ii) **Specialist Design and Research Support Sub Unit** would support the design and research relating to water resources including incorporation of the needs to building climate change resilience into the design. The sub unit shall be responsible for maintaining design standards and updating of standards to incorporate climate change including dam safety, water efficiencies, coordination of research to meet real needs of water resources planning and management. Mainstreaming of climate change impacts into planning and design will be a core requirement over the coming years. The design and research sub unit would work closely with the NIH and CWPRS and other central and state government research institutes and consultancy organisations to develop state of the art approaches to planning and design including the needs of IWRM and climate change. Outputs of the sub unit would be input into the basin planning and management processes.

245. **The Projects Unit:** A separate projects unit is proposed to reduce potential conflicts of interest between the operational/development functions and the resource management and safeguards responsibilities of CWC. The projects unit would be responsible for all project orientated work. The projects unit would provide continued support for design and investment support for water resources as well as coordination of investment by state and central government. The project unit would provide coordination of programmes by donors and investment banks etc. at state and central level. Specialist requirements would be outsourced to private sector or institutes. Investment support would be directed to support the outputs of the basin planning processes. Project support should not be limited to investment initiatives but should also include not structural support for planning, data management etc. Project preparation, and design of projects would be managed by the projects unit designers.

246. **Safeguards, Compliance and Regulation:** All the requirements for safeguards, compliance and regulation would be within one unit. The unit would work with state regulatory authorities, state level technical committees, panel of experts and state and central and state environment agencies to ensure compliance and safeguards for balancing water demand, environment water quality, environmental flows, technical and financial approvals of major projects. Compliance approvals would be provided by the centre for medium and major projects. Outsourcing of compliance assessments where appropriate might be given to specialist consultancy companies, institutes or panel of experts to ensure access to necessary specialist skills and to separate the roles of designer and checker/approver. The safeguards unit would provide guidance to ensure environmental compliance of water resources projects. Sub basin and basin planning would also be assessed by the safeguards/compliance unit; adequate levels of stakeholder consultations would be a key area of assessment. The safeguards unit would also be responsible for provision of design approvals; ensuring climate change resilience will be an important factor. The separation of ‘design approvals’ and ‘project support’ (under the projects unit) is an important requirement.

247. **Training, capacity development and awareness:** Capacity building is a fundamental requirement to meet long term effective management of water resources. Training and capacity building is required at all levels. MoWR needs to play a key role to support the overall direction of training as well as provision of financial support. Training needs to be a partnership of central and state governments. It is proposed that CWC and its National Water Academy would together take a key role to identify training needs and coordinate training.

248. The very large training needs for water resources across the various water sectors requires the development of partnerships and networking. It is proposed that the National Water Academy (NWA) in Pune working with the CWC Human Resources Department would form the Central Training Hub.

249. The central training unit hub would network with other training centres including the Department of Water Resources Development and Management IIT Roorkee and the state level training institutes including the WALMIs and State Irrigation Management Training Institutes (IMTI) and the various IITs. In addition to in house trainers, there would be a need to allow for external trainers to be recruited on a part time basis including specialists from the various MoWR and state research institutes and other national and international experts. Government funding for training could be supplemented by running training courses for private sector and other non government organisations. Independent monitoring and evaluation of training will be a key requirement. Routine updating of training materials and training of trainers based on monitoring and evaluation results will be required. The frequent transfer of staff is major constraint to capacity building especially at the state level.

250. **Planning and Policy:** a separate high level unit is proposed to support research and coordination of policy at central and state levels for water resources as well as international treaties, disputes and cooperation. The unit would include a strong highly respected independent policy panel to advise government at central as well at state levels. The policy unit will be required to keep up to date with planning and policy issues and would advise government on the wide spectrum of IWRM activities including technical, social and economic issues. The policy group would review and guide the various parts of CWC and the direction of the programmes. The planning and policy unit would maintain linkages with the basin and sub basin stakeholder consultation groups consisting of representatives of stakeholders and civil society. The planning and policy unit would work with the river basin planning unit, the regional offices and the proposed RBOs to support water disputes, technical arbitration and conflict resolution.

251. **CWC Regional Offices** are already working at the basin level. CWC is currently proposing to upgrade the regional CWC offices to a higher level and headed by a Director General/ Additional Secretary Level. This would support the move towards a more basin orientated management. The regional CWC offices would work very closely and support the State IWRM units to prepare the sub basin and basin plans as well as support the development of enabled and empowered River Basin Organisations. It is likely and there would be many advantages if the RBOs could gradually be developed through secondment and transfer of the CWCs experienced and CWES[41] cadre personnel. In this way the RBO can obtain leverage from this larger and experienced knowledge pool. The preparation of SWAT and water demand assessments at basin level would require specialist support from institutes or consultants which would be coordinated through the RBOs and CWC. There are presently thirteen regional offices. Further study is required to better define the roles, organisational structures, number and location of the regional offices. Closer working linkages with the CWC and CWGB regional offices is required.

4. Changes in Operations

252. There are ongoing operational changes that need to be accommodated within the operational arrangements of CWC.

(i) The capacities of the states is gradually improving and strategy must be to build up and strengthen state government capacities on all areas
(ii) It is not possible for CWC to hold expertise in all aspects of water resources and more outsourcing of work to institutes and private sector may be considered. The CWC needs to develop stronger partnerships with state governments, and stakeholders including agriculture, urban local bodies (ULBs), industrial users, and wider civil society groups. State capacities for planning and design require to be strengthened.
(iii) The CWC needs to work very closely and through proactive partnerships with the states. The integration of surface and ground water resources management is essential and the CGWB activities must be more closely integrated with the core surface water development and management responsibilities of CWC.
(iv) The strengthening and expansion of the regional offices needs to factored into the operational role of the central CWC functions.

5. Water Resources Studies and Research

253. Close coordination is required between MoWR, CWC and the research institutes. CWC is required to ensure the value and applicability of research. The aims would be to establish world class state of the art institutes for surface,

[41]CWC officers come from All India Services by competitive examinations by Union Public Service Commission (UPSC) and hold the position of CWES (Central Water Engineering Services)

groundwater and hydraulic modelling to support basin planning and design and as well as long term research. Core in-house expertise should be complemented by outsourcing to national and international experts. How to achieve levels of excellence within the constraints of the government systems is an issue; the lack of resources and the limitations on recruitment are areas of concern. One approach is allow more flexibilities for government institutes to do commercial or semi commercial work which can stimulate capacities and allow additional revenues which can be used to support non/ low revenue activities

254. The advancement of computer technologies means that there are now commonalities of the hydrology studies of the NIH and the hydraulic studies of CWPRS. Closer integration of the two research institutes is proposed. Similarly the research operations of CGWB need to be more closely integrated with the surface water research; conjunctive surface and ground water management is a key requirement for most basins and the research organisations need to be more closely aligned to meet this requirement.

255. Development of stronger linkages with the central and state institutes is proposed to ensure continuity and strengthening of capacities of the state institutes. It is proposed that the central research institutes could form a consortium with state water institutions to strengthen capacities in multi disciplinary research for water resources.

P. Strategic Framework Plan for the India Water Systems

1. Analysis of Problems and Opportunities

256. Climate assessments will have limited value unless the water resources organisations at the different levels have the capacities and skills to absorb and apply the information. To achieve this requires a major institutional development and capacity building programmes and systematic water resources planning. There are major issues of sustainabilities of many of the water systems under current conditions even without consideration of climate change; achieving sustainabilities and meeting the needs of development is a key prerequisite to climate change adaptation.

257. Opportunities exist to improve the productivities and sustainabilities of the water systems by integrated planning and management. Well managed water systems with early proactive responses to climate change will have higher capacities adjust and incorporate the climate impacts; poorly managed systems will be more vulnerable and run higher risks of human and economic loss Globally cost benefit analysis has shown the financial benefits of implementing early adaptation measures.[42]

258. The studies in the three sub basins have identified the issues and presented strategies to meet current issues and climate adaptation. Implementation of the identified adaptation measures in these basins in themselves presents a huge challenge; upscaling to the wider all India Water Systems presents will require a programme of change on an unprecedented scale.

259. The programme would be a partnership of the state and central governments initially working in the three pilot sub basins but gradually up-scaling to other sub-basins and basins. The programme would include climate change analysis for water resources, sub-basin and basin framework planning, detailed planning, sub-project design, institutional reforms, capacity building and awareness and multi-sector water investments.

260. At the central and state level support would be provided to upgrade the capacities and facilities for climate change assessments, data management, water resources planning included integrated water balance modelling, conjunctive use modelling and development of decision making tools. Support would be provided for a significant upgrade in training and capacity resources and facilities to improve the understanding of traditional and new initiatives in water resources planning and management. Strengthening and restructuring of the Central Water Commission is proposed.

2. Strategies for Climate Change

261. The approach for climate adaptation is primarily directed at the development of systematic planning with workable mechanisms to mainstream plans and ensure timely and effective implementation.

[42]Economics of Climate Change Stern 2006

262. Assessing climate impacts requires a strong partnership between IITM and MoWR/CWC to ensure the highest possible climate projections can be mainstreamed into water resources planning and management. MoWR and CWC and the State Water Resources Departments will play the key role to assess the implications of climate projections and incorporate necessary measures into the water resources planning and management processes.

3. Plan Objectives

263. The strategy for the all India Water Systems is to build up the planning and management mechanisms to develop highly efficient and sustainable water systems to address current issues and with adequate resilience the impacts of climate change, The framework plan objectives include:

(i) Strengthening of the capacities and resources to prepare accurate downscaled climate projections, analysis of climate and hydrological trends and water resources modelling to assess the hydrological responses.

(ii) Developing capacities, mechanisms and implementation of integrated strategic planning at the sub basin and basin level with mechanisms to mainstream the plans into actions on the ground. Plans will be directed at addressing existing issues as well as meeting the needs of climate resilience.

(iii) Strengthen states capacities for detailed feasibility level planning and design of sub projects and development of decision support systems. Incorporation of resilience to climate change planning and design.

(iv) Development of workable systems of water resources data management at the centre and the states to support planning and management of water resources as well as decision support systems. The data management will be an integrated system including climate information with open access and data sharing and use of web portals.

(v) Develop capacity building and awareness to support new ideas and initiatives for IWRM and climate change, as well as strengthening of the capacities in the use of modern technologies.

(vi) Strengthening of the institutions and mechanisms for strong water governance at the centre, states and communities. Implementation of reforms will include adjustments to existing institutions, restructuring of institutions and new institutions, including the establishment of empowered and enabled River Basin Organisations.

4. Framework Plan Proposals

264. A eight component strategic framework plan is proposed. The plan will be implemented as a partnership between CWC, the states and specialist institutes. The framework plan is based on eight components which are largely derived from the ten focal areas described above. The components have been packaged in a form designed to facilitate implementation. Implementation of the components will need to be coordinated as their are critical linkages between one component and another.

Component 1: Specialist Climate and Hydrological Support

265. Climate change analysis for water resources requires a partnership of central government and specialist institutes and with the support of consultants. Analyses are currently organised on an ad hoc project basis and there is a need to develop a systematic programme based on sub-basins for all states. New and improved data and climate projections need to be fed into the planning process as and when they become available.

266. Component 1 will focus on the specialist aspects to be implemented by Central Government with the support of institutes and consultants. State Government would provide climate, hydrological and catchment data as necessary. Component 1 is described in Table 19.

Table 19: Specialist Climate and Hydrological Support

Overview	Development and implementation of a systematic approach to climate change analysis for water resources to be implemented by CWC and specialist institutes.
Rationale	Climate and hydrological analyses are currently done on a project and ad hoc basis. New climate models offer significantly more robust outputs and higher levels of accuracy; systematic and state of the art analyses need to implemented to meet the needs of adaptation planning. Climate change projections need to be made available to Government and stakeholders and mainstreamed into planning.
Description	Development of key climate and hydrological information to support sub basin and basin planning
Studies/ research	o High resolution state of the art climate projections to be prepared by IITM down to sub basin level o Comprehensive trend analyses for all sub basins by IMD o Hydrological response analysis to climate projections by water resource modelling o Coordination and strengthening of water resources and climate change research initiatives.
Outputs	o State of the art climate analysis with climate projections down to sub basin level o Comprehensive trend analysis implemented for all sub basins o Hydrological response analysis to climate change for each basin o Analysis to be made fully available to government and non government stakeholders o Updating of analyses when new data becomes available.
Implementing Agencies	o CWC to plan and coordinate the implementation o Indian Institute of Tropical Meteorology (IIT) o Indian Meteorological Department (IMD) o Specialist institutes and consultants to undertake modelling work. o State Government to provide data on river flows, cropping and other supporting requirements

Component 2: Sub Basin and Basin Strategic Planning

267. The core component for climate adaptation will be the preparation of strategic framework plans. The plans will incorporate a diagnosis of the current issues as well testing of vulnerabilities to climate change. Plans will be implemented at state level with specialist support from the CWC and institutes and consultants. Component 2 is described in Table 20

Table 20: Sub Basin and Basin Strategic Planning

Overview	Sub basin strategic planning for all sub basins, and later compilation of sub basin plans into basin plans. Plans to be prepared as a partnership of central and state governments with specialist support. Plans to be participative involving stakeholder, plans to be endorsed by the district planning committees.
Rationale	Climate assessments will have limited value unless the water resources agencies have the capacities and skills to absorb and apply the information to meet the needs of climate adaptation. Integrated water resources planning is designed to meet this requirement.
Description	Preparation of sub basin strategic plans to meet needs of current issues and climate change. Plans will be endorsed and mainstreamed through the state and districts including a high level of stakeholder participation. Once basic basin level institutions are in place sub basin plans would be integrated to form basin plans.
Studies/ research	o Preparation of sub basin profiles to assess current situation o Assessment of climate trends, preparation of climate projections and assessment of the hydrological response (all prepared under component 1) o Assessment of vulnerabilities to climate change and incorporate measures for climate resilience. o Water use efficiency assessments o Preparation of Strategic Frameworks for Climate Change Adaptation for sub basins and basins
Outputs	o Preparation of sub basin strategic framework plans o Compilation and integration of sub basin plans into basin plans. o Plans to be endorsed by stakeholder consultative groups and district planning committees and RBOs management board.
Implementing Agencies	o CWC to plan and coordinate o Implementation to be through the state IWRM units o Specialist institutes and consultants as required o Regional CWC offices working with River Basin Organisations

Component 3: Detailed Planning and Design of Sub Projects

268. Detailed planning will follow on from strategic planning. Detailed planning will address key issues identified in the strategic plans. To ensure planning and design are adequate to meet climate impacts, climate design allowances and sensitivity assessments which would be factored into the design processes. Component 3 is described in Table 21.

Table 21: Detailed Planning and Design of Sub Projects

Overview	Detailed plans will be prepared to further refine key strategies in the strategic plans. Pre-feasibility and feasibility assessments will be undertaken to assess the technical social and economic viability of the proposed programmes. Feasible projects will be designed as sub projects for implementation. Planning and design would incorporate climate design allowances and sensitivity assessments.
Rationale	Strategic plans identify the key issues and broad strategies and require to be followed up by detailed feasibility level studies and design of sub projects.. To move forward towards implementation requires further study including assessment of social and environmental issues
Description	Preparation of detailed plans and designs of sub projects. Preparation of environmental impact and other assessments as required. Endorsement and approval of the plans by stakeholders and district planning committees.
Studies/ research	o Preparation of feasibility studies for proposed programmes o Review and approval by state and district and consultative committee o Incorporation of climate change resilience into planning and design o Preparation of water demand and balance models as required o DSS studies as required' o Preparation of designs of selected sub projects.
Outputs	o Detailed plans to feasibility level. o Climate resilience assessments and adjustments to designs. o Design and bid documents for sub projects o Approvals of plans and designs
Implementing Agencies	o State sector agencies o Specialist institutes and consultants as required o Regional CWC offices

Component 4: Data Management for Water Resources

269. Water resources data need to be accessible between central and state Government departments, researchers, and to organisations working on behalf of central or state Governments, and to any organisation that needs the data for design or operational purposes. Open data sharing is critical to sub basin/basin planning. Component 4 is described in Table 22.

Table 22: Data Management for Water Resource

Overview	Implementation of a programme of data sharing and management including the development of web portals for data sharing at centre and state levels
Rationale	Without access to data the scope for planning and effective climate adaptation is limited
Description	Building and strengthening the present WRIS information systems including establishment of state information systems including gradual establishment of data sharing between sectors and between state and centre
Studies/ research	o Define data requirements o Define current data availabilities from different departments o Define annual targets for data acquisition and sharing
Outputs	o Detailed assessment of data needs o Detailed plan and target for data acquisition and data sharing to 2020 o Web portals established o Integrated and open data management system established
Implementing Agencies	o CWC central and regional offices o State sector agencies o Specialist institutes and consultants as required

Component 5: Capacity Building and Awareness

270. Institutional strengthening and capacity building needs to be anchored in the institutional policy objectives. Knowledge and human capacity are critical to implementing successful water resource development and management initiatives within the framework of Integrated Water Resources Management (IWRM) as well as Climate Change. New skills and capacities within water management institutions are critically important to meet the new challenges of systematic planning and management of water resources.

271. Proper understanding of issues and new initiatives requires awareness and understanding and stakeholder awareness must be strengthened at all levels. Component 5 is described in Table 23.

Table 23: Capacity Building and Awareness

Overview	Designing and implementation of a programme of capacity building and awareness to meet the needs of integrated planning and management of water resources and climate adaptation.
Rationale	Strengthened capacities will be required to support the implementation of IWRM and climate change adaptation. High level of awareness will be necessary to ensure understanding and support
Description	An intensive multi sector capacity building and awareness programme for IWRM and Climate Change. The programme would be directed at all levels including centre, states and districts as well as communities and non government stakeholders.
Studies/ research	o Training needs assessment for centre, states, communities and stakeholders o Assessment of needs for awareness o Assessment of training resources o Preparation of a comprehensive capacity building and plan
Outputs	o Detailed plan for capacity building and awareness based on needs assessment o Training of trainers o Pilot programmes in sub basins, o Upscaling to other basins based on lessons learnt in the pilot sub basins o Strengthened Training Organisations at centre and state o Integrated training and awareness programme for centre, states and communities o Training for WUA and Community Organisations o Monitoring and evaluation of capacity building, training and awareness
Implementing Agencies	o CWC central and regional offices o State sector agencies o Training institutes -National Water Academy Pune, WALMIS and other institutes o Independent trainers and training consultants

Component 6: Establishment of IWRM at State and District Level

272. Improved water governance for state governments is needed at all levels to meet the needs of climate change adaptation. The issues and recommended approaches, including sub-basin and basin planning, require the application of integrated water resources management. At the state level water resources remains very sector driven, with a lack of integration of various sectors; there is little coordinated management of surface and groundwater; the lower level organisations are more integrated but are not well incorporated into the planning and decision making processes.

273. There are a number of institutional options for water management organisations. The proposed organisational structure for IWRM at state and district is to build as far as possible on the existing institutional structures and keep IWRM very much within the mainstream of water planning and management processes.

274. It is proposed to strengthen IWRM at State and District levels through a IWRM unit within the state WRDs, a state level water resources steering committee and a new state water regulatory authority. District planning committees and stakeholder consultative groups are critical to endorse and support the implementation of sub basin and basin plans.

275. The programme would be designed to support the ongoing proposals by the planning commission for the establishment of state water regulatory authorities and the programme would provide complementary support for establishment and initial development stages. Component 6 is described in Table 24.

Table 24: Establishment of IWRM at State and District Level

Overview	Establishment of fully functional institutional organisations for IWRM at State, District and community levels
Rationale	In the context of increased pressure on water resources, lack of potentials for additional water resources and climate change, there is a need for improved and integrated water resources planning, management, governance and regulation at state and district levels.
Description	Establishment of IWRM at all States and Districts, largely building on existing structures; incorporates the establishment of State Water Regulatory Authorities
Studies/ research	o Detailed proposals for restructuring for IWRM in the three pilot sub basins o Strategy study to establish approaches for upscaling o Monitoring and evaluation studies
Outputs	o Development of state level IWRM in the three pilot basins o Upscaling of to other states o Focused awareness initiatives to support key aspects of climate change adaptation
Implementing Agencies	o State Governments o Specialist institutional and management consultants as required o CWC regional offices to support

Component 7: Establishment of Enabled and Empowered River Basin Organisations

276. The National Water Mission places emphasis on the creation of enabled river basin organisations. It is proposed that the focus and priority for should be for interstate RBOs. In most cases the functions of the RBOs within states can be adequately managed by the state WRDs supported by improved coordination of the line agencies. The establishment or enabling of existing RBOs should be bottom up, with a prerequisite to establish water planning systems at the sub basin level prior to moving towards basin level planning.

277. Most of the existing River Basin Organisations (RBO) in India have specific functions, including operation of major structures (dam and reservoir), overseeing the allocation of water according to the tribunal awards of the interstate agreement or development of water resources infrastructure. Functionally integrated river basin management (IRBM) functions are very much secondary and are largely restricted to overseeing or implementing the agreed interstate water allocation and accommodating the states water allocations according to their monthly requests.

278. There is limited support for basin level planning and management by the states; basin management is largely seen now in the context of tribunals as well as the legal processes to maximise the states share of the water; the states are understandably very defensive. Planning at the river basin level is extremely sensitive and it is proposed that the RBO and CWC have full access to an independent national and international panel of experts to support the basin planning processes. Adequate funding from central government should be made available to support the recruitment of highest possible levels of expertise as well as provision of investment support for follow basin level investments. Component 7 is described in Table 25

Table 25: Establishment of Enabled and Empowered River Basin Organisation

Overview	Establishment and development of enabled and empowered interstate River Basin Authorities to support basin level planning and management. The programme will include the strengthening and empowerment of the existing organisations and also to establish new authorities where considered necessary. The process can be in stages with the scale of the authority developed gradually according to the local situations. The authority must incorporate needs of the states and stakeholders. Non government basin consultative groups and forums will be established to support the formation and operation of the RBOs.
Rationale	Not all of the water resources planning and management requirements can be implemented within the sub basin and there is a major need to develop integrated basin level planning towards realising the many potential opportunities for water resources development at the basin level. Sustainability, environment and climate change all require basin level approaches. It is essential to move forward from the present stalemate of the tribunals and develop enabled and empowered basin authorities to meet long term sustainability and climate adaptation.

Description	Development of empowered RBOs will be in stages, Empowerment of existing RBOS would be taken up on a pilot basis on two river basins. Lessons learnt and approaches would then be applied to other basins
Studies/ research	o Review of operational functions and alternative structures for RBOs o Central and State level consultations and agreements o Preparation of basin level strategic plans (defined in component 2) o Planning and design of basin level investment programmes.
Outputs	o Enabled and empowered RBOs established on two pilot basins o Basin level plans for two pilot basins o Basin level investments for selected pilot basins o Upscaling RBO establishment to other basins o Basin level investments in other basins
Implementing Agencies	o CWC central and regional offices o State sector agencies o Specialist institutes and consultants as required

Component 8: Strengthening of the Central Water Commission and Attached Organisations of MoWR

279. The MoWR and CWC must take a key role to drive forward new ideas and initiatives for IWRM and climate change. A wide range of institutional responses have evolved over the years to use and manage the ever-increasing demand for water resources in India. The effectiveness of the various acts are however clouded by lack of clarity in terms of institutional objectives, fragmentation of basins by state boundaries, lack of cooperation and intense political lobbying by states.

280. To cope with the new challenges in the water resource environment, the Central Water Commission (CWC) and other attached organisations of MoWR need to develop new technical, managerial and behavioural competencies. These new competencies would enable CWC to address the emerging key result areas that call for a enhanced role for CWC in facilitating the development of river basin planning and management organizations, support and partnerships with the states and promoting best practices in integrated water resource management. The present organisational structure of the CWC and other attached organisations of the MoWR is assessed to be inappropriate to meet these new requirements and strengthening and restructuring is proposed. Component 8 is summarised in Table 26.

Table 26: Strengthening of the Central Water Commission

Overview	CWC needs to change its structure to increase efficiencies and move forward as a highly efficient and modern organisation. Greater devolvement of activities to regional offices, the states and RBOs is required to ensure the highest level of technical competencies. Greater outsourcing of work to institutes and private sector is required to ensure access to highest levels of expertise. Basin planning has to address surface and groundwater and increased collaboration of CWC and CGWB is proposed together with establishment of empowered RBOs. Development of strengthened centres for water resources research and training.
Rationale	The present structure of CWC and the subsidiary organisations of MoWR are insufficiently effective and appropriate to the very changing requirements for IWRM, climate change and integrated basin planning
Description	Strengthening and restructuring of CWC and the attached organisations of MoWR
Studies/ research	o Detailed institutional analysis by management consultants including extensive consultation o Consultation and approvals o Planning and support for the implementation of strengthening and restructuring.
Outputs	o Detailed plan for restructuring o Government approvals and finance in place o Restructured CWC and MoWR subsidiary organisations
Implementing Agencies	o MoWR and CWC, CGWB and other MoWR organisations o Specialist Institutional and Management Consultants o Consultation with other central government water ministries, MoEF, Planning Commission, Science and Technology and State Government

Q. Road Map

281. It is proposed to develop a programme for **'Climate Change Adaptation for the India Water Systems'.** The programme would build on the recommendations of the National Water Mission (NWM), and the ADB Support TA to the NWM at State as well as all India levels.

282. The programme is based on a eight year programme (2012-2020). The road map is designed as partnership between the Central and State Governments. The plan is focused on the proposals of the ten focal areas identified and eight components of the strategic plan. It is understood that these are only a part of the overall water resources issues and requirements, but it is considered important to develop firm approaches to these key focal areas; additional aspects can be incorporated later. The programme would be largely in line with the proposals of the National Water Mission.

283. **Implementation:** The implementation of the road map is a major task and requires strong coordination and management. The broad approaches have been developed in the three sub-basins under the present study. The proposals need to be further refined and workable methods developed for to meet the very large requirements for upscaling. The MoWR and CWC would be the lead agency to coordinate and support the programme but the implementation would be partnerships with the CWC and specialist central institutes (including IITM, IMD and NIH) and the states and state institutes (including the WALMI) and gradually enabled RBOs.

284. **Priority Basins:** Moving forward from the three pilot sub basins, it is proposed to initially focus on Priority 1 sub basins, which would be selected by the states based on complexity, issues, and vulnerabilities. The Priority 1 sub basins would be taken up for framework planning by specialist institutes and consultants including international specialists. Priority 2 sub basins would follow the methodologies for the Priority 1 basins. The teams of specialist consultants and institutes recruited for the priority 1 sub basins would provide support and training for the state governments as well as the institutes and consultants who would implement the priority 2 sub basins. It is proposed that specialist implementation consultants are recruited to support the five year programme.

285. **Funding** requirements will need to be assessed. Funding will need to be sourced for planning design as well as the follow on investments. Various estimates have been prepared under the NWM and other studies but these need to be reviewed. Mechanisms to effectively identify critical areas and timely allocation of funds is critical. Without professional quality investigations of present issues and assessment of climate impacts financing will be wasteful and inefficient. Adequate funding for operation and maintenance of irrigation and water supply infrastructure has to be assured for upkeep of the irrigation system and to assure quality of irrigation.

286. **Implementation Responsibilities:** Implementation of the programme will require the development of an implementation and financing as well as recruitment of project management support consultants. A summary of the key responsibilities are given in Table 27. The complexities and scale of the programme will require a very large component of outsourcing to institutes and consultants, both national and international. Government at Central, State and lower levels will play a key role to implement the programme and facilitate the various IWRM and Climate change studies/modeling and support data requirements as well as providing support for stakeholder and civil society participation. The Government and other stakeholders have a key role to assess and review the planning outputs. The proposed implementation schedule is shown in Figure 9.

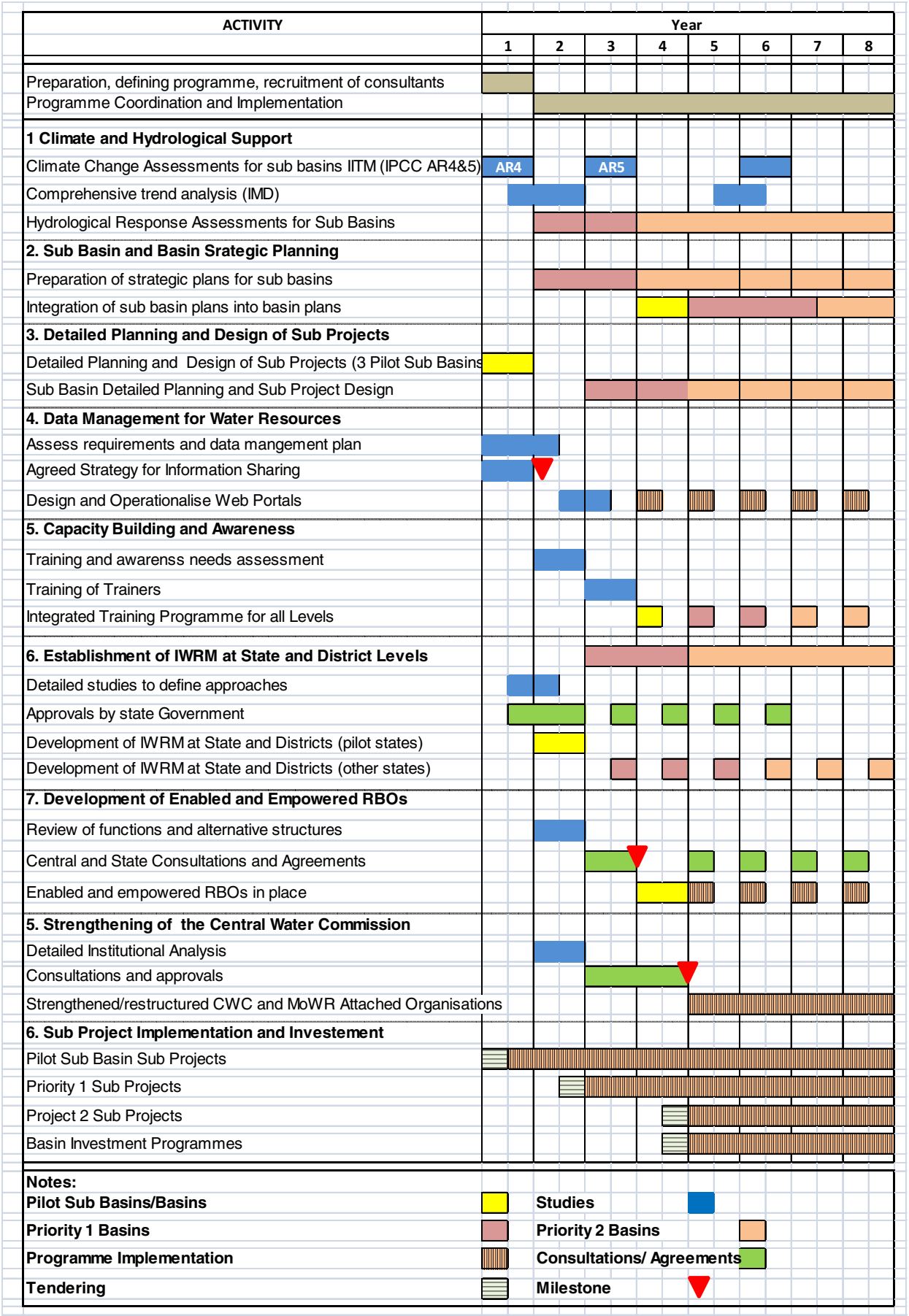
Table 27: Task Matrix

		Type of action	Central Govt Policy Makers	CWC	State Govt Policy Makers	States	Districts and lower levels	River Basin Organisations	Specialist Institutes	Specialist consultants
C1	**Climate and Hydrological Support**									
1	High resolution climate projections for sub basins (IITM)	S		X					X	
2	Comprehensive trend analysis (IMD)	S		X					X	
3	Hydrological response assessments for sub basins	S		X					X	X
C2	**Sub Basin and Basin Strategic Planning**									
1	Preparation of sub basin profiles	PS				X			X	X
2	Water use efficiency assessments	PS		X		X			X	X
3	Strategic Framework Plans for Sub Basins	PS			X	X			X	X
4	Integration of Sub Basin Plans to Basin plans	PS		X		X		X		X
5	Approvals by state district DPC and stakeholders	A			X					
C3	**Detailed Planning and Design of Sub Projects**									
1	Feasibility studies for proposed programmes & projects	PD			X	X	X		X	X
2	Assessment of climate design and sensitivity allowances	PD		X		X			X	X
3	Water balance & demand modelling and assessments	SM		X					X	
4	Other specialist studies as required	SM				X			X	X
5	Design and bid documents for sub projects	PD				X	X			
6	Approval by state district DPCs and stakeholder	A				X	X		X	X
7	Sub basin programmes and investments	PM				X	X			
C4	**Data Management for Water Resources**									
1	Define Data requirement and targets to 2020	S		X		X		X	X	X
2	Staged data sharing agreements put in place	A	X		X				X	X
3	Integrated and open data management system in place	PM							X	X
C5	**Capacity Building and Awareness**									
1	Assessments of capacity building and awareness needs	PS	X	X	X	X	X	X	X	X
2	Assessment of training resources	PS		X		X			X	X
3	Training of trainers and upgrading of training facilities	TA							X	X
4	Integrated training & awareness programme for all levels	TA							X	X
5	Training and awareness for WUA & community groups	TA							X	X
C6	**Establishment of IWRM at State and District Levels**									
1	Detailed studies to define approaches	PS	X	X	X	X			X	X
2	Approvals by state government	A			X	X				
3	Development of state IWRM in 3 pilot basins	I				X	X		X	X
4	Up scaling to other states	I		X	X	X			X	X
C7	**Establishment of Enabled and Empowered River Basin Organisations**									
1	Review operational functions and alternative structures	PS	X	X	X					
2	Central and state level consultations and agreements	I	X	X	X	X				
3	Preparation of basin level strategic plans	PS							X	X
4	Enabled and empowered RBOs in place	I	X	X	X	X				
5	Basin programmes and investments	PM		X	X	X				X
C8	**Strengthening of the Central Water Commission**									
1	Detailed institutional analysis	PS	X	X					X	X
2	Consultations and approvals	A	X	X						X
3	Restructured CWC and MoWR subsidiary organisations	I	X	X					X	

Notes:
Central Government Policy Makers: MoWR, Planning Commission and also senior level policy makers
State Government Policy Makers: Senior State Government Officials, Chief Secretary, Secretaries
State: State level departments with IWRM units taking a lead role.
State and District and Lower Levels: would include state and district departments, district planning committees, panchayat, stakeholders civil society and village level institutions. DPC-District Planning Committees

Key: S-study, PS Participatory Studies, M Modelling, SM Studies and Modelling, PD Planning & Design, I Institutions/policy PM-project/programme management TA Training and awareness A Approvals

Figure 9: India Water Systems Programme Schedule



Lower Sutlej Sub Basin, Punjab

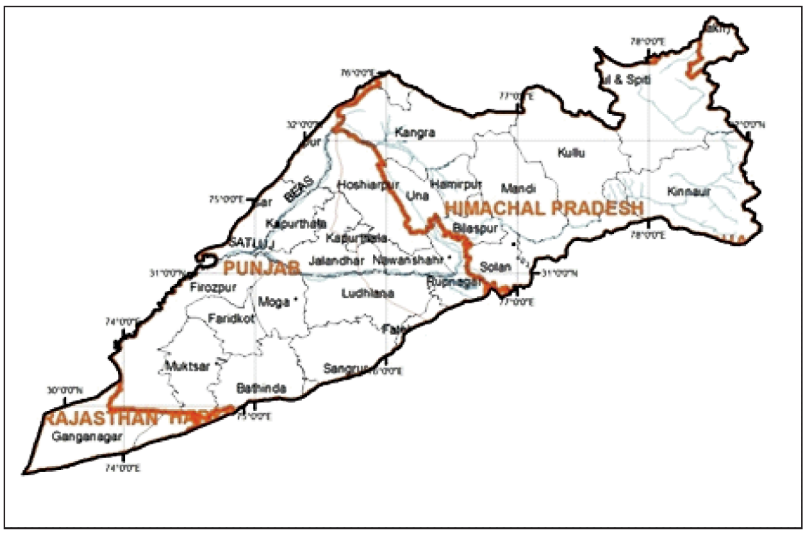
III. LOWER SUTLEJ SUB BASIN, PUNJAB

A. Sub Basin Profile

1. Surface Water Resources

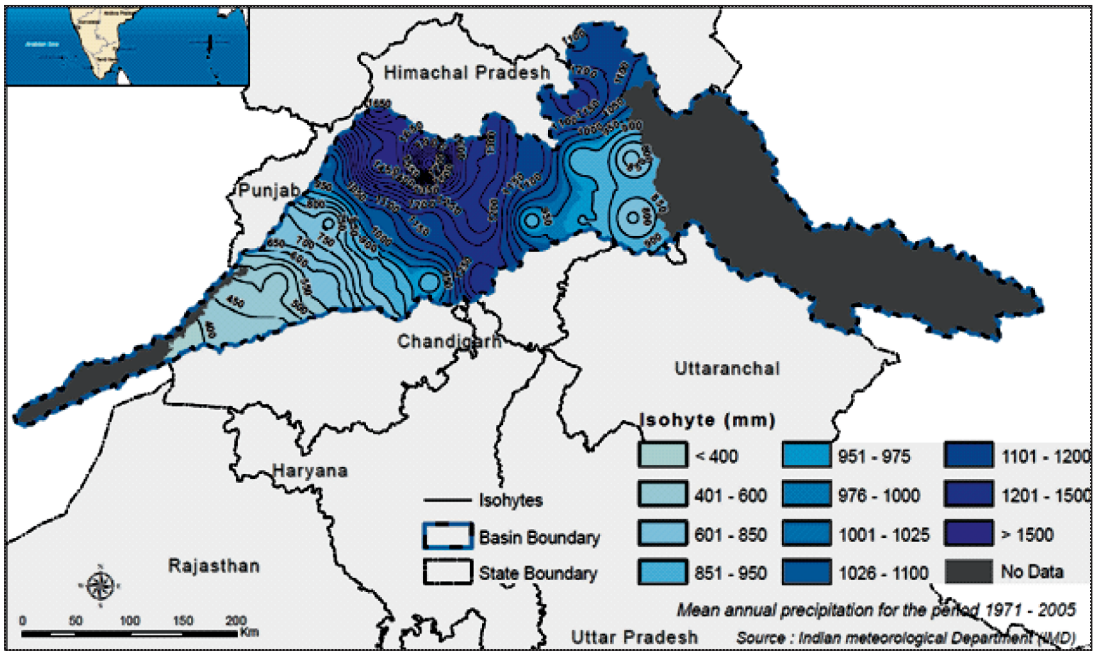
287. Location: The overall catchment above Bhakra is about 56,000km² of which the Indian part is about 20,275 km², about 36%, the basin covers outer, middle and greater Himalayan ranges. A map of the Indian part of the basin is shown in Figure 10 below.

Figure 10 Punjab Area Map



288. The average annual rainfall ranges from 580mm in the plains to 960mm in sub-mountain regions, and decreases from North to South. The temperature ranges from minus 2° to 40° C (min/max) in Punjab, but can reach 47°C (117°F) in summer and minus 5°C in winter. Climatically, Punjab has three major seasons: (i) hot weather (April to June); (ii) rainy season (July to September); and (iii) cold weather (October to March). The mean annual rainfall is shown is shown in Figure 11.

Figure 11 Mean Annual Precipitation

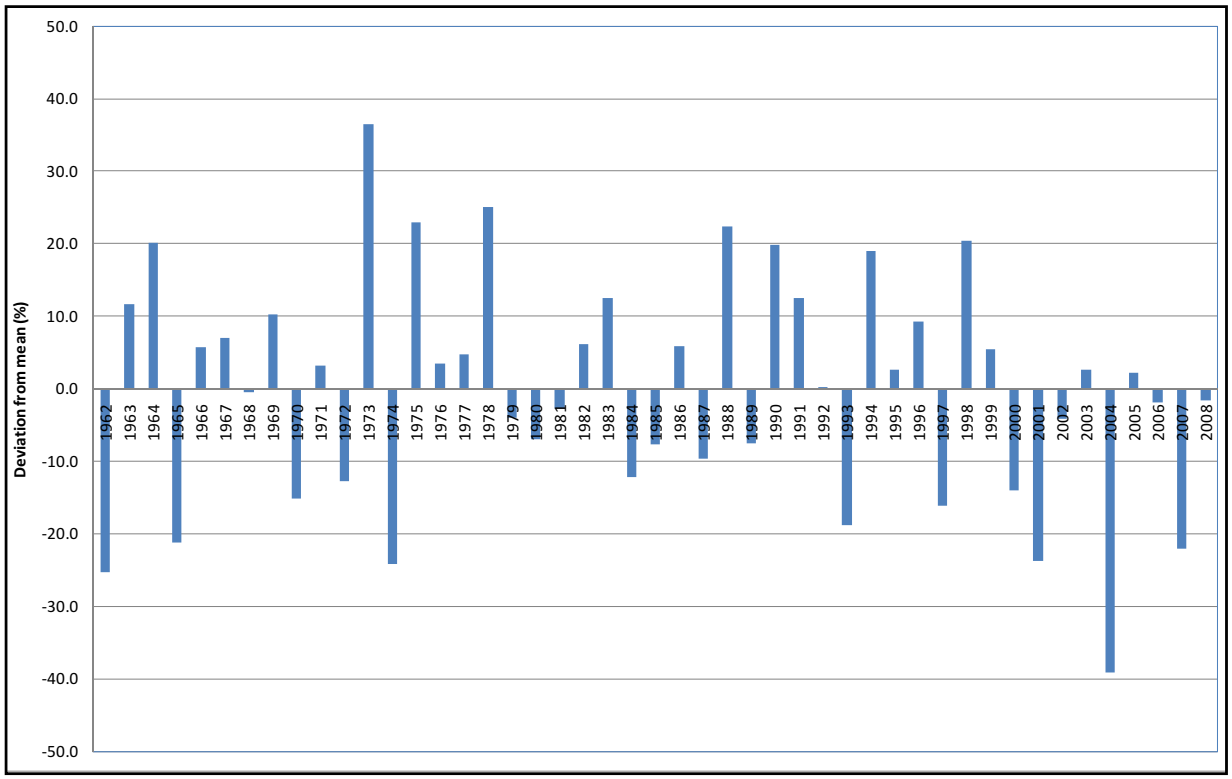


289. The catchment rises in PRC and with large differences in the relief, the basin is characterized by diversified climatic patterns. Winter westerly weather disturbances produce most of the precipitation during winter in the middle and upper parts of the upper basin. The monsoon rainfall affects the lower part of the catchment. It is estimated that about 60% of the inflow to Bhakra is derived from snow and glacier melt. Surveys of glaciers in the Himalayas are showing retreats in

the range of 10m and 35m per year. The glacier area in the Indian part of the Sutlej is estimated to be around 1200km², with an indicative ice reserve of around 60 to 90km³.

290. **Surface Water Resources Assessments:** The surface water resource of the Sutlej basin is effectively that of the basin upstream of Bhakra reservoir. The mean annual inflow from the Sutlej River in the period April 1962 to March 2009 was 14,450 Mm³. The mean annual inflow from the Bhakra Sutlej Link in the period April 1978 to March 2009 was 4345 Mm³. Figure 12 shows a plot of annual deviations from the mean of annual inflows to Bhakra from the Sutlej River. It is apparent that in the last decade, annual inflows have been below average, corresponding with below average precipitation. An analyis of the data shows the trend is random, and that there is no significant evidence of persistence or trend in the data. Outflow and inflow data for Bhakra reservoir were available for the period 1980 to 2009. During this period, the mean annual inflow from the Sutlej River and the Bhakra Sutlej Link was 18,608 Mm³, and the mean annual outflow 18,608 Mm3. It would appear therefore that reservoir precipitation and evaporation, and seepage losses are neutral. There are small differences year on year between inflows and outflows, but these are not significant

Figure 12 Deviations of the Mean Annual Inflow to Bhakra Reservoir

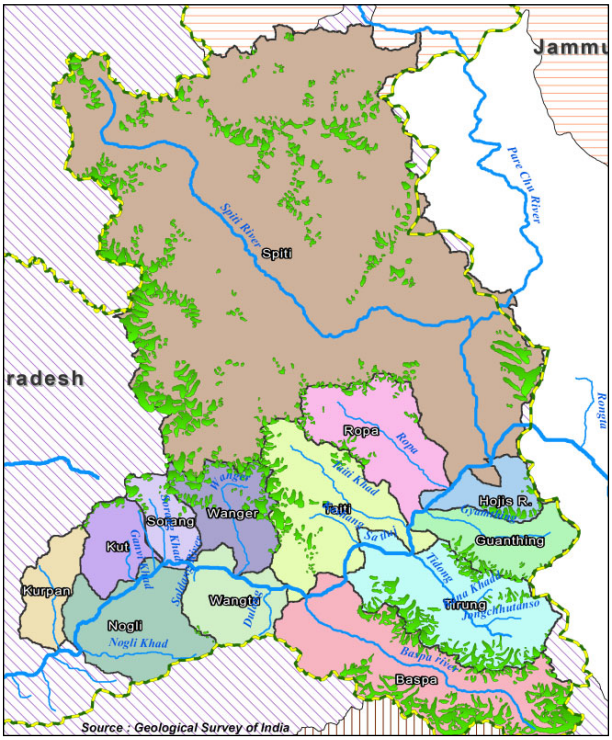


291. **Storage:** The Bhakra reservoir is able to provide a major buffer to the variability in river flow. At construction, Bhakra reservoir had a total storage of 9,800 MCM of which live storage was 7,400 MCM and dead storage was 2,400 MCM.[43] Recent surveys (end 2007) show an overall reservoir capacity loss of 18% of which live and dead storage loss are 12% and 38% respectively. The Kol dam and reservoir presently under construction upstream of Bhakra will catch most of the sediment over the next 30 years and only quite minor loss of storage in Bhakra is likely by mid century. The new Kol dam is primarily dead storage to catch sediment and will have a storage of 575MCM; it has been estimated that the Kol dam could extend the life of Bhakra by 14 years[44]

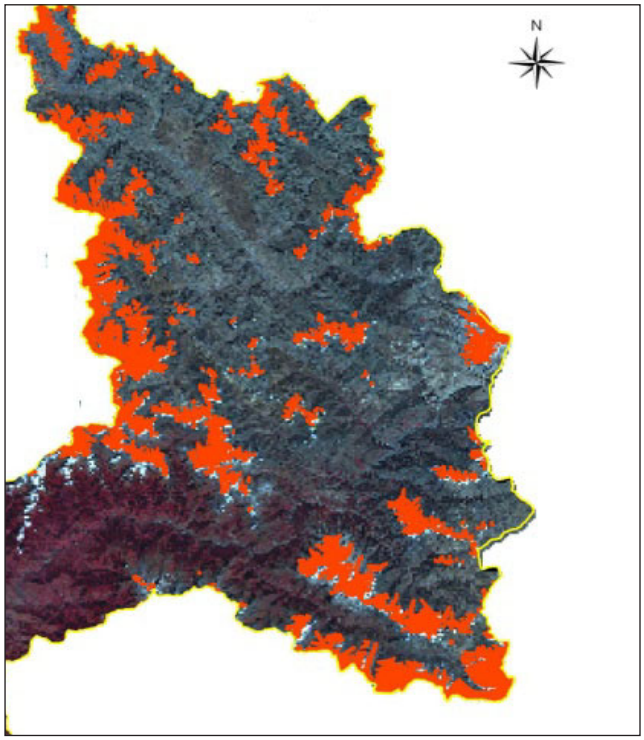
292. **Glaciers:** Two different inventories of glaciers have been sourced; each giving different assessments of the areas and estimated volumes; these are the Geological Survey of India and Himachal Palampur University. In both studies surface areas are derived from aerial photographs and satellite imagery. In the absence of factual information on the depth both studies have used information on the alpine and Himalayan glaciers in Nepal and China. Eighty percent of the Indian Sutlej river catchment in Himachal was observed to be snow fed at some stage during the year. The area of glaciers is shown in Figure 13.

[43] *Dead* storage refers to water in a reservoir that cannot be drained by gravity through a dam's outlet works, spillway or power plant intake. *Live* storage is the portion of the reservoir that can be utilized for flood control, power production, navigation and downstream releases.
[44] Cumulative Impact Assessment of the Sutlej DHI 2006

Figure 13 Glaciers in Upper Sutlej Catchment



Mapping by the Institute of Geological Sciences



Satellite Mapping by Himachal Palampur University

293. The number of glaciers and surface areas from both studies are quite consistent but with some differences in the ice volume shown in Table 28 below. The elevation of the glaciers has a significant effect on the rate of melt, lower glaciers are much more vulnerable; 56% of the glacier volume is above 5000m.asl, with 46% below 5000m.asl[45].

Table 28 Surface Area and Estimated Volumes

Source	Number of glaciers	Area (km2)	Estimated ice volume BCM for Indian Sutlej
Geological Survey of India	926	1251	61
Palampur University	945	1217	94
Average	935	1234	77

2. Groundwater

294. In the Lower Sutlej basin, ground water occurs in a multi-layered alluvial aquifer system which mainly comprises of unconsolidated permeable sand, silt and gravel layers. A moderate thickness of aquifer exists up to 300m. The shallow ground water occurs under unconfined and deeper under semi-confined conditions. Groundwater plays a crucial role towards food and agricultural production in Punjab, providing water for irrigation, drinking and industrial needs. The shallow ground water levels of less than 5 m below ground level occur in south western part of the Basin. In the north-central part, the ground water levels are in the range of 10 to 15 m. Deeper levels of 20 to 40 m below land surface, occur in the districts of Mogha, Ludhiana and Patiala. The northern and eastern part of the Basin has ground water level depth ranging from 5 to 10 m. Depth to ground water level is lowest (1.1 m) in Muktsar and highest (33.5 m) in Ludhiana.

295. The declining trend in water table due to groundwater over abstraction is depicted for observation well hydrographs (maintained by CGWB). Similarly due to excessive irrigation is south western district of the state a rising trend is occurring leading to a waterlogged situation has been created.

[45]bid

296. Groundwater is abundant in quaternary alluvial aquifer along river and in canal irrigated areas where infiltration of surface water, canal seepage and return seepage from applied irrigation is high. The CGWB have estimated the replenishable groundwater resource of the state at 24 BCM and net groundwater availability after allowing for natural discharge during monsoon, at 21 BCM. The estimated annual groundwater draft is 31 BCM (from irrigation alone is estimated at 30 BCM). Presently the annual ground water over extraction is about 10 BCM or 145% of the sustainable draft. Out of the 137 blocks in the state, 103 blocks are over-exploited 9 blocks are in the critical and semi-critical stage and only 24 blocks are in the safe category.

297. **Water Quality:** The most common groundwater quality problems in the lower Sutlej sub basin are largely caused by natural constituents but exacerbated by human activity. These are high salinity, high levels of fluoride, and high levels of chloride and nitrate in shallow unconfined groundwater of the basin. The salinity levels in groundwater increase from north to east and south to west in the basin. Groundwater in south-western districts have moderate to high levels of salinity in ground water. The central parts of the state have moderate salinity levels and north-east zone have low salinity in ground water.

298. A summary of the groundwater situation is given in Table 29.

Table 29 Summary of Groundwater

Annual Groundwater availability	21.4 BCM
Groundwater abstraction	31.2 BCM
Average level of groundwater development	145%
Over-exploited blocks (no)	103 out of 137
Critical blocks	5
Groundwater over-exploited blocks in 1984	64 nos.
Groundwater over-exploited blocks in 2006-07	103 nos.
Annual decline groundwater	varies from zero to 1.3m/year
Water logged area	200,000ha
Salinity affected area	1,000,000ha

3. Agriculture

299. Food grain production in Punjab has increased from 3 million tons in 1960-61 to 26 million tons in 2004-2005[46], agriculture growth has been significantly higher than in other states. The provision of the Minimum Support Price for wheat and paddy, combined with the procurement system of the Union Government has meant that crop production is greatly supported. The Green Revolution has been backbone of Punjab's development; the agricultural systems in Punjab have however become unsustainable and gradually less profitable. The gains resulting from the success of ever-increasing food production over the last four decades have had significant environmental and social costs; over intensification of agriculture has led to water depletion, reduced soil fertility and micronutrient deficiency and non-judicious use of farm chemicals and problems of pesticide residue.

300. The overall area of shorter, low water consuming crops has declined significantly, including crops such as maize (50%), groundnut, and millet (bajra, 80%). This reduction has been a result of the tremendous increase in area under rice (11 times), and wheat (2.5 times).

301. The increasing cost of production and diminishing economic returns in farming are adversely affecting the socio-economic conditions of farmers in Punjab. The cost of the inputs has increased significantly whereas the sale price of the crops has increased at a lower rate. The stagnation in the agricultural economy has resulted in heavy debt. The debt of the farmers, which was Rs 5,700 crore ($1250million) in 1997, has jumped to Rs 30,394 crore ($6700million) in 2008; subsidies to agriculture has become ever more critical. Increased agricultural production followed in Punjab was based on putting large cultivated areas under wheat and rice; use of high yielding seed varieties, water and fertilizers; and efforts to improve input-use efficiency to reduce the cost of production. Central government has encouraged the strategy, to enhance food grain production, particularly of wheat and rice, for meeting the emergent food situation and security requirements for the country. This has, however over the years resulted in depletion of groundwater and macro nutrients and damage to the physical characteristics of the soil. Heavy use of fertilisers and pesticides has resulted in pollution. Punjab, with just 2.5% area of total agriculture land in India, uses nearly 18% of pesticides of the country as a whole. The Malwa cotton

[46]Department of Agriculture

belt represents less then 0.5 % of the geographical area of country but uses almost 10 % of the pesticide allocations of the country. It is widely acknowledged that mono culture crops are more vulnerable to pest and diseases.

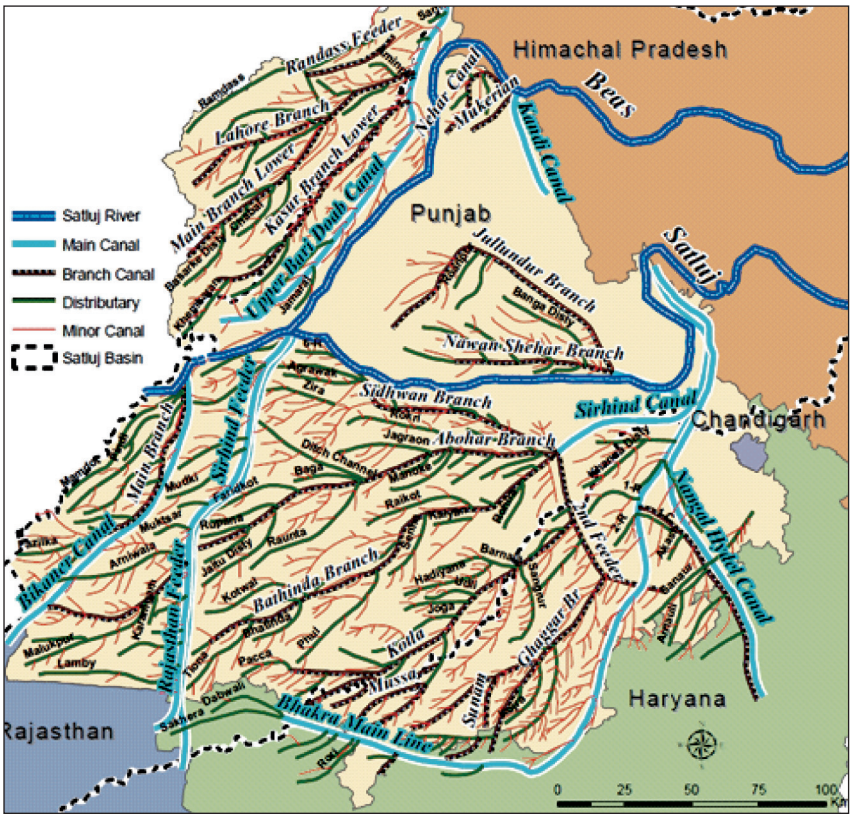
302. Punjab agriculture is no longer sustainable; neither financially nor in terms of water consumption. Stagnation of the wheat and rice yields and the lack of alternatives for diversification has resulted in rising capital costs and shrinking profit margins in agricultural production. The rice and wheat crops are only viable due to the wide ranging subsidies for inputs and price support for the produce. The free power keeps the farming system viable at the cost of long term water resource sustainability. IWMI[47] has recently commenced a study to assess the direct delivery of power subsidy for agriculture and present options for management.

4. Irrigation and Drainage

303. The state of Punjab has a well developed canal systems. The major systems are: Upper Bari Doab, Sirhind, Bikaner, Rajasthan, Bist, Doab, and Bhakra. Only the Upper Bari Doab canal is taking off from the river Ravi, with the other five canal system from the river Sutlej. The Sirhind Canal System is largest system, offtaking from the at the Ropar Head work which was constructed in the year1874-82 and was remodelled in 1952-54.

304. State Water Resource Department have indicated that as against the current water requirement of 44 BCM; the surface water canals provided about 14 BCM, with the shortfall of about 30 BCM met through ground water, and rainfall. Shortfall in monsoon rainfall causes further over-exploitation of ground water. Cultivation of high water demand crops is reported as the main reason for sharp decline in the water table in the command areas and elsewhere. The state surface water resources systems are fully utilized through the extensive canal irrigation. The combined surface and groundwater is supporting the intensive (paddy and wheat) agriculture production system. It is reported however that there has been gradual reduction in the canal irrigation and the area irrigated by tubewells has been increasing. As per 2005 estimate, there are 1.2 million tubewells in the state and the ground water is being over seriously exploited to meet the increasing demand of water for irrigation. However in the southern-western parts of the state (in the Sirhind canal system) ground water extraction for irrigation propose is very low due to the brackish and saline quality; water logging in much of the command area has occurred. The Punjab canal network is shown in Figure 14.

Figure 14 Punjab Canal Network



[47]"Direct Delivery of Power Subsidy to Rural Consumers" International Water Management Institute ESMAP International Water Management Institute

305. **The Sirhind Canal** system is supplied from the Ropar headworks constructed in 1874-82 to divert waters for irrigation supply through the Sirhind canal system. The Sirhind main canal has a capacity of 12624 cusecs (357 m^3/s), and commands a cultivable area of 1,359,000 ha (equivalent to a duty 0.26l/s/ha). Based on the period 1990 - 2010, the mean annual discharge of the Sirhind canal during this period was 196 m^3/s, which equates to an annual gross irrigation supply of 450 mm over the cultivable command area. Assuming an overall irrigation efficiency of 50%, net annual surface water irrigation supplies are unlikely to exceed 225 mm. Flows are regulated by the Bhakra Reservoir, and dry season flows are thus maintained as releases are made for hydropower production.

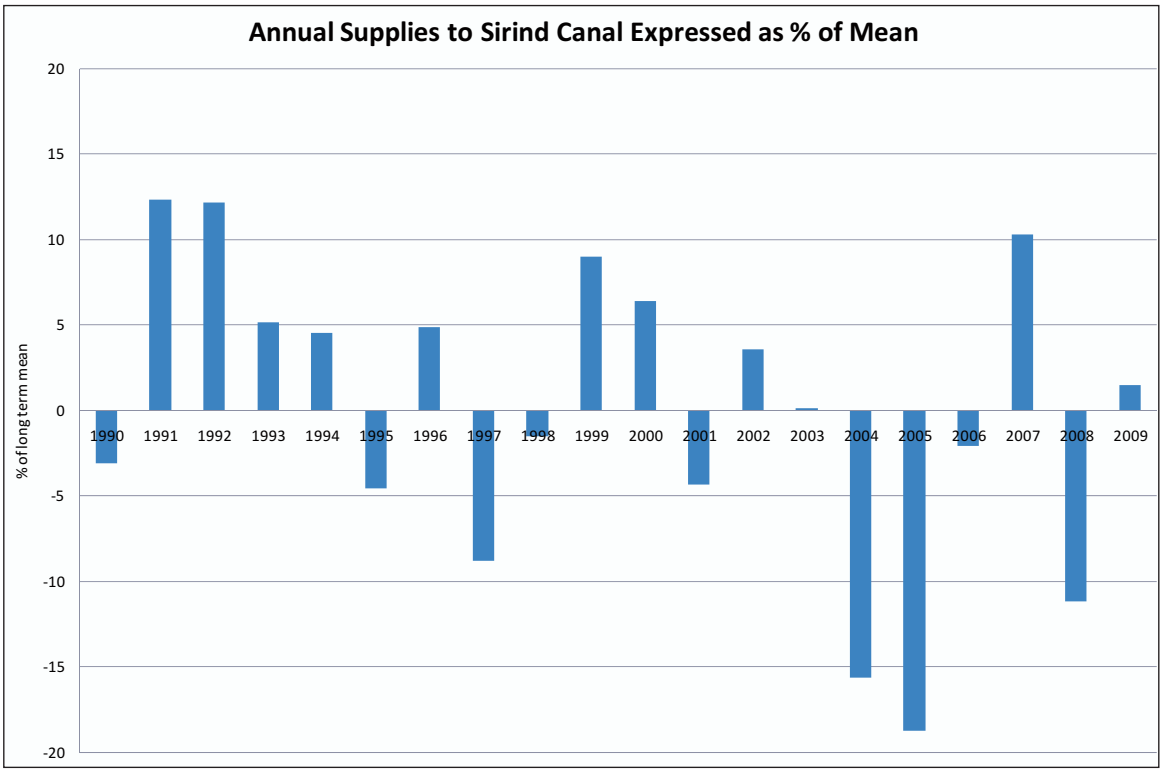
306. Irrigation diversions increase significantly in May and are maintained at a high level through to the beginning of September, and harvest of the Kharif crop. Field outlets from the irrigation system typically have a capacity of 3.5 cusecs per 1,000 acres, which is equivalent to 0.245 l/s/ha or 2.1 mm/day. The irrigation duties in the Sirhind system vary quite significantly across the command area, and the spatial variability in the system has to be considered in developing the framework plan.

307. **Water Allocations** are based on the Warabandi rotational supply system; water is allocated based on area and not on the actual crop water demands. The rotations and allocations are managed by the Irrigation Department; farmers do not have any formal role in the management or decision making in the supply system. Assessments of the Warabandi shows quite large variations between the design and actual allocations: this variation is more pronounced at the tail end of the system. Warabandi allocations are based on the original irrigation system design and do not incorporate groundwater availability. Rotation is practiced at field outlets on the basis of 10 minutes full supply per acre. This results in 14.7 mm delivery on a 7 day rotation (a gross application of 2.1 mm/day). The system was thus clearly designed for supplemental irrigation during the Kharif season and for irrigation of a reduced area during the Rabi season. During the Kharif in the period June to September, average annual gross irrigation at filed level from surface water is of the order of 190 mm, while in the Rabi season between October and February it is of the order of 150 mm.

308. Inter-annual variation in surface water irrigation supplies are shown in Figure 15. The twenty years of record available to the study are not sufficient to permit any conclusions to be drawn with respect to trends in water supply, although the supplies in the last decade have been lower than in the preceding one. The annual irrigation supply at 20% non-exceedance probability is about 185 m^3/s, which is only about 5% below the mean.

309. In the Sirhind, during the Kharif season about 90% of the area is planted with paddy rice; during the Rabi season wheat occupies about 94% of the area. Cropped areas are very similar in the Kharif and Rabi seasons.

Figure 15 Variation in Annual Irrigation Supplies to the Sirhind Command



310. There is clearly a significant variation in irrigation demands across the Sirhind system, with the highest demands at the tail ends where delivery is likely to be poorest. In the north of the Sirhind command, annual precipitation is of the order of 730 mm, and annual potential evapotranspiration of the order of 1400 mm. Given a gross irrigation diversion equating to 450 mm, the figures calculated for field delivery tie up reasonably well. Net surface water supplies will be of the order of 200 - 250 mm. The annual crop water requirement at Ludhiana is of the order of 850 mm and the annual input to the water balance of the order of 1200 mm. At Ganganagar, the annual crop water requirement is of the order of 1075 mm, and the annual input to the water balance is of the order of 680 mm (assuming surface irrigation to be equally distributed across the system). The Water Resources Department of Punjab estimate that groundwater abstractions exceed recharge by about 50% and the situation is clearly unsustainable.

311. **Water Resources Development:** There is no scope to expand the water resources beyond the fully utilized Bhakra multipurpose dam project. Improving the efficiency of water management is the only option for enhancing and sustaining the agriculture productivity The State Government is presently undertaking the modernization of the canal systems. Lining of some of the canal system has been taken up in phases under World Bank aided phase-I and phase-II lining project, when the length of 5554 km and 1092 km of channels respectively were lined. Lining has been limited to side lining to ensure some continued infiltration to groundwater.

312. The **Command Area and Water Management (CADA)** programme is providing a Rs700 crore ($155million) assistance to line minor water courses.(field channels). The programme which is funded 60% from central government, 40% state government and 10% farmers ins providing brick lining of the channels. Of the 120,000km of water courses, 45,000km have already been lined, 12,000m are ongoing and 30,000 will be taken up in the near future. The cost of the lining is is Rs700 to Rs 1100/m equivalent to Rs15000/ha of which Rs7500/ha is paid for by central government. The rate is apparently too low and realistically should be Rs25,000-30,000/ha. Quality is reported as a problem

313. **Drainage:** The lower part of the Sirhind Command area suffers from problems of drainage and salinity. The problems arise due to the flat terrain and inadequacy of natural drainage, even though the annual low levels of annual rainfall. Irrigation in the last few decades has led to a steady rise of the watertable to counteract this, an extensive programme was started to minimize groundwater, recharge by improving surface drainage, lining canals and distributaries, and more recently, tertiary canals and watercourses. In contrast the northern parts of Punjab the groundwater is fresh. In these areas, the increased abstraction from wells has kept the water table. under control. The Punjab government has announced a Rs14.41 billion ($320 million) project for re-lining of the Rajasthan and Sirhind feeder canals. The project, expected to be executed within four years, and should reduce canal seepage and some of the salinity issues.

314. **Flood:** The massive retention of the Bhakra absorbs the flood flows; the reservoir has only filled a few times since construction. In 2010 it filled to its design level, flood was avoided by careful management of releases. A DSS is being set up to assess the obtain early information on the risk of flood and develop appropriate reservoir operation routines. Flash floods occur in the minor tributaries which have no storage. Although localised flooding during periods of heavy rain is an issue major river flooding is not reported. Large releases from Bhakra are reported to be affecting flooding in Pakistan.

315. **Stakeholders Perceptions:** farmers have indicated that the surface water flowing through the canal system can only meet 10 to 30% of irrigation demand in paddy cultivation, and 20 to 30% of demand for wheat cultivation. The dependence on uncontrolled/open access groundwater resources is as high as 70 to 90%. Stakeholders are very much aware of the sustainability issues but lack both theoretical knowledge and practical experience in water management. The communities feel compelled to continue extracting groundwater at high rates to ensure their livelihood security through rice and wheat cropping which provide reasonable returns with low risk.

316. **Groundwater Management:** there is quite limited information on the operational mechanisms and efficiencies of the tube well systems. Similar to the surface irrigation, it is very much supply driven, with water availability defined by the capacity of the pump installed and the availabilities of power. There is a very low fixed charge of Rs 50/hp/month for power which is largely not collected. With no volumetric charging, farmers use their groundwater pumps whenever power is available, irrespective of the crop's physiological needs for water. Typically, farmers receive electricity for about 4 to 5 hours per day but farmers say lack of dependable power is an issue. Some farmers use diesel pumps to provide supplementary water; the dependability of the diesel pump against the irregular power for the electric pumps apparently compensates for the high running costs.

317. **Conjunctive Water Use:** There was little evidence of formal management systems for conjunctive water use; the expansion of groundwater has developed in response to the low surface water availabilities and good groundwater aquifers. Within the farmer water courses, it is understood that some negotiations of the *Warabandi* allocations takes

place. Farmers also sell groundwater to small holders who have no tube wells. The *Warabandi* allocations do not consider the availabilities of groundwater; there are no methodologies to optimise the supply. The southwest part does receive a higher irrigation duty, but this is to compensate for the lower rainfall and not specifically for the lack of groundwater. There is a number of on-going studies under Central and State Governments to increase irrigation efficiencies, primarily through lining, a side effect of this will be a reduction the groundwater recharge.

318. **Water Supplies:** Drinking and industrial water is from both surface water canals and groundwater. Parts of the area have water quality issues with pollution from agriculture and industry; in the southwest, the groundwater is saline, in these areas surface water is the key source. Growing industrialisation has increased significantly the demand for water. The National River Conservation Plan is presently undertaking rehabilitation and upgrading of 45 of the 141 municipal centres. The project cost is Rs2200 crore ($500 million) and will be implemented over three years. There are some operational problems of managing surface water supplies during canal closure periods and small flows are required to be maintained in the canals for potable and industrial water use.

5. Institutions

319. Although Punjab has a clear water policy, problems continue within the water sector. There is no agency dedicated to water resources management providing properly functioning regulatory services to equitably share resources and to protect the common property, environmental and social uses. Institutional problems include: (i) water management is based around the surface water systems, and there is no organizational system to look at the combined resources and conjunctive water management and water uses; and (ii) the "centralized" *warabandi* water management is designed for equitable allocation of the water, but does not incorporate consideration of crop water needs nor any form of integrated management of the surface and groundwater resources. The combined surface and groundwater does however fill this gap with groundwater able to provide water on demand; power availabilities are however an issue.

320. The introduction of regulation is very sensitive, and although some soft regulatory actions are being taken up, other more radical measures are not considered appropriate by Government of Punjab. The CGWB on behalf of Government of India has circulated a Model Bill to all the States and UTs. To date, the bill has not been taken up. The Government has recently however, issued an advisory on the earliest planting date of paddy to help reduce over-exploitation of groundwater, which is being followed. The state has however successfully implemented the Sub Soil Water Act which restricts early planting of rice crop to reduce evapotranspiration losses.

321. There is very limited development of community water associations, the *Warabandi* allocation system is based around a routine and fixed allocation system and is managed without any Water User Association. Tubewell irrigation is almost entirely on an individual farm basis, although some selling of water does take place.

322. What has become important in the change context in that water agencies also need to consider non-water issues, such as environment, equity and social factors. Water governance is needed to implement public policies for sustainable water investments and management with support and involvement of people from all levels of society.

323. **The Bhakra Beas Management Board** (BBMB) is engaged in regulation of the supply of water and power from Bhakra Nangal and Beas Projects to the states of Punjab, Haryana, Rajasthan and Himachal Pradesh, and the union territories of Delhi and Chandigarh. The board also operates the dam and the hydropower plants-operation is based on fixed operational rules. The board is presently in cooperation with the HP2 project, upgrading the rain and snow monitoring systems and preparing a decision support system to improve reservoir management during the monsoon.

B. Strategic Framework to Address Current Issues

1. Introduction

324. Water management has always been a challenge. It is evident that the current management and use of water in Punjab is unsustainable. The major existing water issues in the lower Sutlej Basin are: (i) over-exploitation of groundwater and the falling groundwater table; (ii) water logging and salinity in the south west; and (iii) groundwater quality issues. The dynamic groundwater regime in the basin is under significant stress and abstraction continues despite the incremental costs of abstraction from greater depths than in the previous years. Groundwater abstraction is estimated to be about 46% above the sustainable volume; about 31 BCM is abstracted annually against a sustainable annual groundwater availability of 21 BCM. For comparison the live storage capacity of the Bhakra reservoir is 7.4 BCM.

325. In the longer term, the key issue for the Sutlej is the coupled depletion of storage of groundwater of about 10 BCM per year with the gradual depletion of glacier and snow storage due to increased temperatures.

2. Farmer Perceptions

326. From the consultations and the Participatory Rural Appraisal exercise conducted it was found that farmers are well aware of the water and environmental problems and were generally enthusiastic about various water saving management practices as long as these did not impact on their crop returns and the market security of their produce. Farmers are aware of the issues of drawdown of groundwater and are highly concerned about the effects on long term sustainability; they have, however, limited knowledge of the possible actions to conserve the water. The rice-wheat cropping system gives them the best secured returns and they would be responsive to change if equal or better alternatives can be introduced. Farmers in general appeared very positive about possible innovative solutions for conservation and conjunctive use of water so long as it ensures their crop specific water demand. Farmers wanted the minimum support price to be extended to other crops. A summary of some of the farmer responses from the field interviews[48] is shown in Table 30 below.

Table 30: Farmer Response to Possible Conservation Initiatives

Aspect	Response; % in favour		
	Bathinda	**Sangrur**	**Ludhiana**
Introducing charging for electricity	60	50	91
Charging for surface water	50	50	50
Use of sprinkler and drip	50	50	limited awareness
Expand lining	78	100	100
Expand laser levelling	93	100	100
High value lower consumptive crops to replace rice	89	100	100
Shorter duration rice varieties	89	100	91
Artificial recharge through community incentives	89	100	100

327. Farmers are fully aware that the high water demanding rice-wheat cropping system is threatening the sustainability of groundwater resources; increased depths to groundwater are adding significantly to the cost of pumps which typically only last a few years; this escalating cost of pumping water from deeper ground water aquifers using submersible pumps is resulting in financial difficulties for many farmers.

328. Farmers are of the opinion that there is no single solution to the present issues and that a portfolio of actions is required. Many farmers are of the view that diversification from rice-wheat cultivation can be possible if cost effective options can be found and there is technical support. Farmers were interested in controlling the number of boreholes; they felt that political decision making was short sited. Some farmers in the southwest felt that their water user associations are weak and should be strengthened.

329. A recurring them in most discussions was the Minimum Support Price (MSP). Farmers would like the minimum support price to be extended to other crops. Farmers were not satisfied with the subsidy system; they reported that the free power was factored into the MSP so, in fact, they were actually paying for the power. Farmers commented that the present system of a flat rate on the motor size of pumps is unsatisfactory, and corruption in the collection of fees is said to exist. Farmers were interested in capacity building, including training and support for awareness programs, so that they could better understand the issues involved. Farmers agreed metering would reduce groundwater use but considered metering not such an acceptable option due to the possible cost implications and the difficulties of effective administration.

330. All farmers questioned felt that the climate is changing and is already impacting on agriculture; the duration of cold weather is said to be getting shorter - it is perceived that the cold period was previously 4-5 months and is now reduced to 1-2 months with adverse effect on winter wheat, with a 25% reduction of yield. All those questioned felt there was a reduction in rainfall with more erratic rainfall patterns. The occurrence of unseasonal rainfall - especially showers - during the harvest in November has affected the yield at maturity and decolourised crops. Other impacts reported included occurrence of hail stones. These used to occur in March, but have now occurred in November or December. In 2010, hail caused major damage to crops (~ 25 - 40% loss). Farmers also noted a delay in the start of the monsoon which appeared to be delaying by 15-20 days. It was however pointed out that 2010/11 wheat crop had very good yield.

[48] The PRA was based on field interviews of 80 farmers in three parts of the Sirhind Command area.

3. Agriculture

331. Nearly all farmers follow a rice-wheat pattern, except in the south west where cotton is the predominant crop. This currently provides the best combination to sustain farmer incomes with minimum risks due to the 'minimum support price' (MSP) fixed by the government. The MSP is not available for other cereals or oil seeds. There is also stability in rice and wheat yield that cannot be matched with other crops such as vegetables and sugar cane, etc. Punjab has modern commercialized and mechanised farms that are geared towards maximization of profits. Labour shortage is an emerging issue, and wheat and rice cultivation offer opportunities for almost complete mechanisation which is a key reason in favour of this cropping system. Farmers are concerned about the heavy risk in diversification due to non-availability of assured markets, yield variability and labour concerns.

332. Central Government policy to meet the needs of food security has for many years promoted the production of rice and wheat in Punjab which now provides a significant part of the countries food needs. The provision of stable prices, simple government systems for buying of grain and the available surface and groundwater resources have all led to a boom in the rice wheat production systems. The Government provides a minimum support price and guaranteed market for rice and wheat.

333. The Punjab government is working on a number of initiatives to reduce groundwater use, including the "Punjab Preservation of Sub Soil Act", which regulates the earliest dates for sowing and transplanting rice. This is estimated by researchers to save about 14 - 90mm of the water applied and would allow savings of 7% of the annual GW draft for the state[49]. Alternative cultivation techniques are being researched and supported including; direct seeded rice, raised beds, SRI, zero tillage. Uptake of these has been mixed; increased labour requirements for SRI are seen as an issue, and as there is no financial incentive to save water farmers are reluctant to invest in additional labour

334. **Private sector** support to agriculture offers potential scope to increase the efficiency of the food production and distribution systems. Options to strengthen and open new market areas should be developed for high value crops and potentially private sector can play a part in this. It is important to identify niche markets that can increase the income of the farmers; one potential area is a move to production of hybrid and non hybrid seeds. The state government is keen to attract domestic and foreign investment to help promote industrial and agricultural growth. Three core areas have been identified; diversification of the agriculture base and promote value addition, promotion of industrial clusters to strengthen their competitive position, and restructuring and empowerment of the public sector units to maximise their potential value. Private sector involvement has had a mixed success.

335. For Punjab the development of PPP is not so much about finding an "absolutely private" partner as it is about finding a viable "third party" between farmers and government, to support agricultural productivity, marketing, investment support and some element of risk sharing. This third party may be public (e.g. a reformed or financially autonomous government agency, or cooperative) or private (e.g. a private service provider like a contracting firm, or a WUA turned into a private corporation).[50] There are some examples where larger farmers are setting up small agricultural support enterprises.

336. Focusing on high value and value addition of agricultural commodities is important. The development of agribusiness to support production and marketing systems is ongoing but take up could be increased if the agribusiness contract models were adapted to promote more active involvement of farmers in the decision making process and there was a move towards a real partnership model. The role of private sector is to assure remunerative prices to the farmers along the value chain including identification of favourable markets and provision of timely market information. The Agricultural cooperatives can provide agri-services (inputs) and needed financial services, liaise between corporate and farmers in the negotiation process for remunerative prices and favourable market conditions. The role of Government institutions is to provide extension services, improved technologies, exposure to demonstration plots, irrigation services and *environmental services* and provision of regulation and support. A suggested model for farmer involvement in agribusiness is shown in Figure 16.

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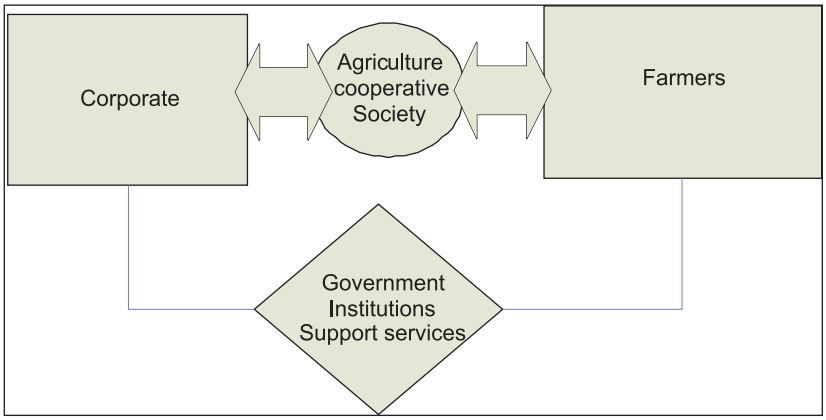
[49]National action plan on climate change. Available from: http://pmindia.nic.in/Pg01-52.pdf [last assessed on January 25 2011]
[49]IWMI Research Brief Series V
[50]Irrigation reforms in Asia: A review of 108 cases of irrigation management transfer Aditi Mukherji, Blanka Fuleki, Tushaar Shah, Diana Suhardiman, Mark Giordano and Parakrama Weligamage Revitalising Asia's Irrigation: Options for the Future Final Report Submitted to the Asian Development Bank by IWMI

Figure 16 : Farmer Involvement in Agribusiness



337. More investment in research on the ecological and economic viability of Resource Conservation Technologies (RCTs) is required. Punjab farmers need to move away from common rice and wheat varieties and focus on high value crops facilitating the promotion of agribusiness ventures but meeting the needs of conservation. The potential role of contract farming model with the agricultural cooperatives playing a greater interface between farmers and the corporate needs to be explored

338. It is important that the present role played by the Food Corporation of India be revisited with regard to it playing more a supportive role to farmers for selling their food grains and look for alternative marketing outlets. The agriculture price policy needs to be made much more farmers friendly so that it offers incentives to continue agriculture as an enterprise in a sustainable manner.

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4. Surface Water Irrigation

339. **Surface water irrigation** is estimated to directly provide about 25 to 30% of the irrigation water demand but also provides indirectly a significant proportion of the groundwater recharge. Ongoing initiatives to conserve water are to provide lining to the main, distributory canals and water courses. Water allocations under the *Warabandi* system are supply led, based on the land holding areas and do not address crop water requirements. The surface water duties are very low and spreading scarce water over large areas which results in high evaporative losses. Field outlets from the irrigation system typically have a capacity at the turnout (locally termed mogha) of 3.5 cusecs per 1,000 acres, equivalent to 0.245 l/s/ha or 2.1 mm/day. The allocated time in a seven day cycle is very low at only 10 minutes per acre. Field allocations, especially at the tail end are significantly lower than the prescribed duties at the canal outlets.

340. Allocations to branch canals are made according to a standard proportion of the supply. Flow measurement and allocation is by measuring water levels and gate opening. More accurate allocations to the branch canals can improve the overall scheme efficiencies. Use of crump or broad crested weirs or measuring flumes can significantly improve the accuracy of measurement and allocation.

341. Adjusting the irrigation to a semi demand based system may have some advantages in terms of efficiency. Canal capacities are based on equal allocation per area and remodelling the irrigation canals would be a major undertaking. Irrigation managers do make some allowance for demand through reductions and closures during the lean season; but is understood that canals do run during periods of low demand. During these low demand periods there maybe potentials to use surface water for groundwater recharge. Outlets are presently ungated and there is no mechanism to reduce or close individual offtakes.

342. The Bhakra Beas Management board is currently undertaking real time forecasting for flood flows and releases, and it would be potentially useful to apply a similar approach and development of a decision support system for dry season flow and irrigation and agricultural management.

343. **Period of Supply:** The irrigation system in parts is presently supplying water for the whole year, primarily to meet the needs of surface water for drinking water and industry. To meet the demands on double cropping a supply of about 240 to 280 days might be sufficient. At the reservoir there is demand for water for hydropower production, and demands in April and May are at their highest, which is the lean season for irrigation demands. A study of how off season reservoir releases might be used to best advantage in the irrigated areas is required, the study would incorporate the requirements

for potable and industrial water and hydropower. There could for example be potential for allowing some early planting of surface only irrigated rice, or water spreading to help augment groundwater recharge; these could be focused on critical overexploited blocks. Demands for irrigation in the south west part are different; the main crop is cotton, the area has poor quality groundwater, surface water is the main water source; some mixing of surface and groundwater is practiced.

5. Groundwater Irrigation

344. Groundwater is almost entirely managed by the farmers although some small government tubewell programmes are being implemented

345. The heavy over exploitation of groundwater raises the issue of regulation: Punjab Government is not in favour of groundwater regulation as it is felt that regulation will create hardships for farmers. Groundwater regulations suggested by CGWB and other reform measures have never been taken up. Charging for power is an issue that been discussed for a long time, but the Punjab government has never accepted the proposal. There is preference to minimise over-abstraction by promotion of less sensitive methods including large scale artificial recharge. Recent regulation under the Punjab Subsoil Regulation Act to make mandatory that rice planting is delayed until June is gradually being adopted without any significant loss of production or higher cost to farmers demonstrates the potentials and acceptability of softer regulations.

346. Punjab in 2010 banned the sinking of tubewells in 300 villages. The state has however not accepted proposals to meter power supplies or to increase the power tariffs as a means to reduce groundwater extraction. With a reported 1 million tubewells in the state, it is extremely difficult for the Government to control and regulate such a massive number of units. The political and social sensitivity of the issues make it difficult to contemplate how major regulative initiatives would work without major provision of compensations.

347. **Electrical Power Management** offers an indirect method to try and control the extraction of groundwater. The present flat fee for power is Rs 50/hp/season; (requirements for payment have, however, recently been suspended). Farmers say more dependable supplies are important to ensure crop water needs are met; many pumps are permanently switched on to maximise the opportunity of water when power is provided. There are good arguments that, improved or more regular power supplies could support reduced groundwater use with pumping targeted towards crop water needs rather than pumping whenever the power is available. Power management strategies require to be developed that removes the current inbuilt inefficiencies and yet provides farmers with assurance that they will be better off. The approach and mechanisms need to be researched, but the basic premise is to the provide an incentive of improved and guaranteed power in return to accept some level of control measure to reduce power consumption and wastage. The Jyotirgram scheme in Gujarat has developed this approach with reported apparent success. The need for an alternative subsidy model for power for groundwater is currently being studies by IWMI[51]; the outputs of this study will be very relevant to Punjab. The study will propose alternative power subsidy delivery models; options and parameters under consideration include:

- Provide better quality of electricity supply to farmers. Better quality could mean more number of hours and at timings convenient to farmers, less voltage fluctuations translating into lower motor burn-outs and repair and maintenance costs, better alignment of power supply with critical periods of crop growth – all or some of the above. Farmers' definition of "better" power supply will vary depending on the local conditions
- Provide incentives (monetary like cash back or non-monetary like energy efficient pumps at discounted rate) to farmers to use electricity more efficiently, either through lesser number of hours of usage (while irrigating same amount of land), or through same hours of usage, but by irrigating larger amount of land. The outcome measure of efficient use of electricity is Kwh consumed per acre of land irrigated year. The lower this value, higher the efficiency of electricity use for pumping groundwater. Efficient use of electricity may or may not translate to efficient use of groundwater. Conditions under which efficient use of electricity leads to efficient groundwater use (measured as groundwater applied/acre of land) and when it does not, need to be defined.
- Lowering the burden of the state exchequer by ensuring that the subsidy support it gives to the electricity utility is only for the amount of electricity consumed by the farmers and not for hidden inefficiencies.
- Is the intervention politically acceptable? It may be politically acceptable if it can be shown that farmers will get "better" electricity supply and under some circumstance, may even be rewarded for "efficient" energy use against some soft interventions to restrict power consumption including low tariff metered supplies.
- Is the intervention easily implementable. Ease of implementation will be measured in terms of the transaction costs of metering and billing and monitoring millions of agricultural consumers spread across the state. The use of new technologies (Information and Communication technology ICT) can be considered if it makes a good business case; where cost of solution may be greater than current system, but potential water savings are proportionately greater to justify the investments. Another indicator of ease of implementation will be the technical and financial integrity of the model—namely, how easy or difficult is it to prevent illegal tapping, bypassing of meters, tampering with meters, if installed and prevent leakage of subsidy amount to non-beneficiaries.

[51]Direct Delivery of Power Subsidy to Rural Consumers" IWMI and Infosys Consulting funded by ESMAP

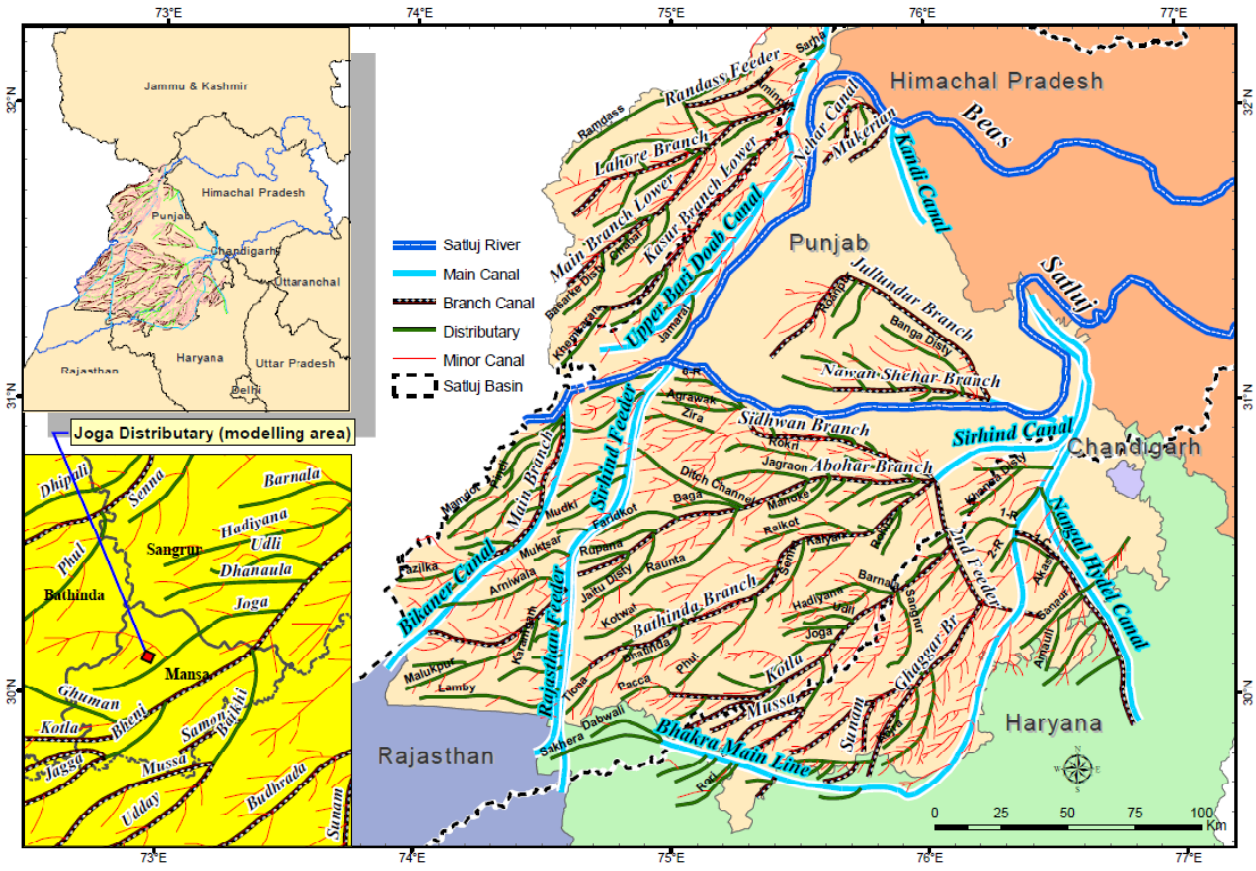
- o Creation of incentives for utility staff to help in effective implementation of such a solution. This could be done through creating an incentive structure whereby the lower level of field staff could be given monetary or non-monetary incentive if they could limit line losses to a certain pre-specified percentage.
- o Improves financial viability of the electricity utilities by making sure that whatever is consumed by the agricultural sector is actually billed and recovered (from the state government, not necessarily from the farmers) and that it builds up additional incentive to reduce technical and commercial losses.

6. Conjunctive Surface and Groundwater Use

348. **The surface and groundwater balance** is critical. Although there are high losses in the surface water system, the combined surface and groundwater system is quite efficient. A move to understand and apply the principles of conjunctive water use is essential to support the decision making process. By using a water balance model, different cropping and irrigation scenarios can be analysed; assessments could include the impacts on the water balance of different water saving initiatives such as changes to cropping, lining options, impacts of a change to drip or sprinkler system. Without fully understanding the complex water balance, it is not considered prudent to embark on any major water management programmes; some actions that may benefit the surface water systems may be of limited benefit to the integrated systems. The present practice of considering surface water efficiencies in isolation is considered inappropriate and a move to address conjunctive efficiencies and management of the surface and groundwater systems is proposed. The exception is for the parts with saline groundwater where investments in lining will be more cost effective.

349. **Conjunctive Water Use Modelling**-using the WEAP[52] model in a sample area near Ludhiana, shown in Figure 17 below, found that potentially significant reductions the groundwater draft could be achieved through changes in cropping. Four possible initiatives were assessed ; (i) planting of a short growing period variety of rice (existing 145 days reduced to 120); (ii) the use direct seeded 120 day rice introduced everywhere, dispensing with need for nursery and water application for puddling combined with delayed planting to early July; (iii) a reduction of groundwater losses from direct seeded rice reduced from 50% to 30%; field losses with wheat remain at 30%; and (iv) reducing the area planted with rice by 25% (and leaving the land fallow).

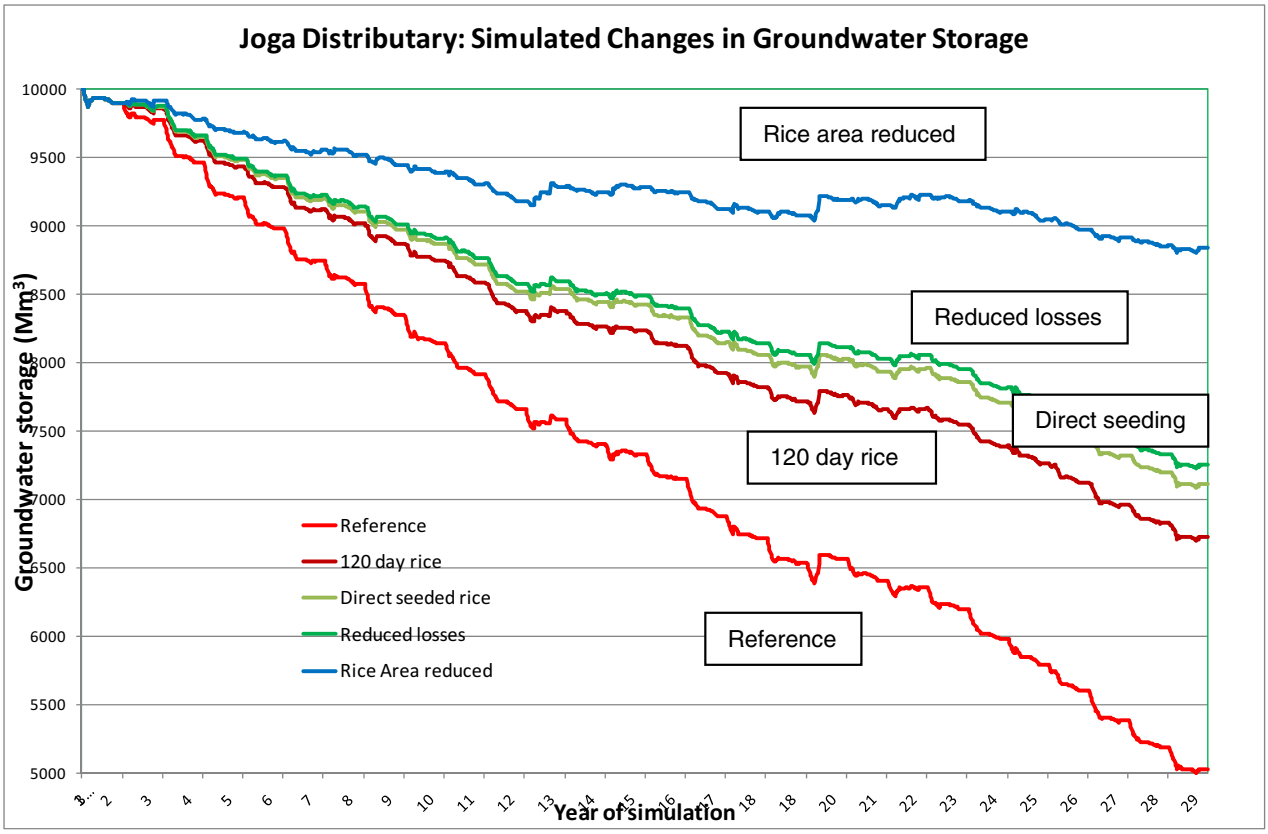
Figure 17: Sirhind Canal Network and Joga Distributory



[52]Water Evaluation and Planning System developed by the Stockholm Environment Institute

350. The effects of these are shown against a 'reference', where present practices continue. The findings are shown in Figure 18 below (each intervention is considered incremental). The reference scenario indicates that with 'no change', pumping costs could increase sevenfold over 30 years due to the increased pump lifts from increased depths to groundwater. The figure shows the big benefit of moving to a shorter duration crop, some benefit of direct seeding, but quite small benefit through reducing field losses. The top line which would bring in a near sustainable situation is to set aside about 25% of the rice area as fallow. The analysis gives an indication of the hydrological response of some selected conservation measures ; this type of assessment is considered an essential part of the decision making processes towards identifying and assessing the effectiveness of various water conservation initiatives.

Figure 18: Simulated Changes in Groundwater Storage



351. **Conjunctive Use Efficiency:** Most studies and conservation assessments are presently directed at addressing surface water use efficiency (SWE) or the savings in water applied, without consideration of the conjunctive efficiencies. Improving conjunctive efficiencies is more difficult and primarily achieved by reducing the evaporative losses through delayed planting, shorter duration crops, avoiding transplanting and reducing the planted area. There is a need to change the approach to consider the conjunctive water use efficiency (CWE) of surface and groundwater. Under CWE efficiencies are much higher as losses to groundwater infiltration are effectively reused. For the saline parts in the south west SWE is appropriate. In the non saline groundwater areas Resource Conservation Technologies (RCTs) require to be evaluated against the potential to improve the conjunctive efficiencies not surface water efficiencies.

352. **Substitution of rice** is widely seen as an essential requirement to reduce the water consumption. Substitution of rice for another crop in terms of CWE would have fairly minimal benefit over say a shorter duration direct seeded rice, unless the production period of the substitute crop was significantly shorter than rice. Growing shorter period crops may encourage farmers to grow a third crop, pulse crop or similar, which would largely negate any benefits of diversifying from rice. Cropping in the pre-kharif season has very high consumptive use due to extreme levels of evapotranspiration during this period. The importance of understanding the water balance implications and possible implications of different cropping strategies is critical. Market limitations is a important reason given why farmers are reluctant to diversify from rice.

7. Artificial Recharge

353. The government is placing significant emphasis on Artificial Recharge as a means to supplement the groundwater

deficit. While the study considers that Artificial Recharge (AR) is an important requirement, its viability and cost effectiveness must be determined. No comprehensive analysis of the costs and sustainabilities of artificial recharge has been made. Preliminary information suggests that the potential of AR has limitations and would only compensate a small fraction of the groundwater deficit. Further study is required to assess the cost effectiveness of various AR options. Lack of rainfall and lack of land are issues. The ongoing development of canal lining will be reducing the quantity of groundwater recharge; although some of the main canal lining is limited to side lining to allow for partial recharge.

8. Control and Support Measures

354. There are a number of potential areas to reduce the groundwater abstractions through RCTs. These include new technologies for agriculture management such as direct seeding rice, mulching, direct seeding of wheat, use of more efficient irrigation systems such as drip, reducing the area of wheat or rice to lower water consumptive crops, or even leaving some parts unplanted (set aside). Such initiatives would require to be taken up on a large scale to have any significant impact on the groundwater deficit. To meet the groundwater reduction targets within a reasonable time frame would require a major commitment by farmers and the government in tandem. Some element of regulation may be applied and if seen by farmers to not be threatening their income security, would likely be accepted; the recent notification to delay the monsoon planting is an example of simple regulatory control being accepted and implemented by the farmers. Other water saving initiatives would likely require to be implemented through financial support or subsidy in conjunction with some element of control or regulation. Most of the RCTs do not add any financial gain to the farmer, and with no incentive to save water their take up will be limited without control and/or support measures.

355. It is proposed that a mix of control and support measures will be required to address the groundwater over extraction. Support measures would likely be financial support or subsidy to encourage the take up of new water conservation measures.

356. **Control Measures:** Tough and stringent regulatory measures are difficult to enforce, and therefore where possible "soft" control measures as against the "hard" regulatory measures needs to be examined. Control measures could include; restrictions of the area of crop grown or the area of rice, reducing the area of rice grown but applying this on a rotational basis, increasing the power tariff and ensuring payments are made effectively. The need for combining control and support measures as well awareness programmes is stressed. Control measures need to be introduced gradually and parallel support to increase productivity and financial returns need to be introduced in parallel. There may be options to apply controls only to the larger land holdings whilst leaving smaller units unrestricted. Arguments against this are that with extended families it is relatively easy for larger landowners to split their land holdings into smaller units. Rotations of control measures is another strategy; farmers cropping would be restricted say once in every three years.

357. Reform or change measures are significantly more successful and sustainable when accompanied by a communication campaign aimed at the public and all levels of civil servants to build public confidence in government and address the specific concerns of both public and civil servants.

358. **Support Measures:** For Punjab, the application of **Payment for Environmental Services PES** is relevant; there is a need to reduce groundwater extraction and farmers need some form of compensation or incentive to do this. Farmers are legally entitled to abstract groundwater under the Easement Act; they have, however, indicated willingness to switch cropping systems and support groundwater conservation measures as long as their baseline incomes are not too seriously impacted. The price security and ease of marketing the rice and wheat is reported as a key reason for the reluctance to switch crops.

359. The compensation could be direct financial grants; for example 'for not planting rice'; or 'crop set aside'; or 'planting trees to reduce salinity'; or other incentives to reduce abstractions or address water quality. Other options would be support incentives for increasing the efficiency of the water and agricultural systems, including incentives for rice planting using new technologies, moving from rice to lower water-consumption crops, application of sprinkler/drip, increasing the efficiencies of the surface water systems, etc. In India, subsidies for irrigation and agriculture are very significant. To meet the needs of conservation, it is recommended that subsidies move from a blanket approach to a more targeted approach to meet the specific needs of water conservation and reduction of groundwater abstractions.

360. A possible model is the U.S. Conservation Reserve Program (CRP) that was implemented in the 1980 and onward to take erosion-prone land out of cultivation. Farmers bid on how much they would accept (per acre) to sign a contact constraining them to remove their land from cultivation, and the lowest bids were accepted first, thus minimizing the overall cost of a given acreage reduction (or maximizing the amount of land that could be placed in reserve for a given

amount of money). Those who made the lowest bids were in general those farmers whose land was the least profitable to cultivate, so that the best land was kept in cultivation. In the same way, Punjab farmers could in a similar way submit bids to be paid for ceasing to pump, and the lowest bids accepted, which would probably have the effect of reducing water use by the least efficient farmers (or those with the least productive land), which is the desired outcome.

361. **Water Conservation Plans** are proposed to address the various issues. The plans would be participative and developed jointly by the Government and the communities. The Government would explain the issues facing the community-based conjunctive use assessment of surface and groundwater, and the indicative climate change effects. The Government would set out targets to meet sustainability, including options to reduce groundwater abstraction and needs for crop diversification. These could include: reduction in the rice area; change to shorter period and lower consumptive use crops; improved more efficient irrigation systems; drip sprinkler; etc. Plans would be phased with simpler less controversial requirements brought in earlier, more controversial initiatives will require to be phased in slowly.

362. To meet possible financial losses, the Government would have to offer appropriate mitigation packages based on the lines of PES (payment for environmental services). These would include price support for a wider range of crops, incentives to take up new irrigation or planting systems, minimum price support or financial support for set aside (non planting). Incentives to implement artificial recharge or water harvesting would also be considered. Improved power supply in return for agreements to reduce pumping may also be appropriate.

C. Institutions

1. Present Institutions

363. In Punjab the main organisation for water resources is the Irrigation Department. The department, although called the irrigation department, undertakes many water resources functions. Within the irrigation department there is the Directorate of Water Resources and Environment which is a key organisation supporting integrated water resources management including the surface, ground water and watersheds. Other departments related to water resources include; the Water Resource Organization which is entrusted with research and development activities.

364. The other institutions linked to water resources are the Punjab State tube well corporation is engaged in sinking and installation of direct Irrigation and augmentation Tube wells, installation and construction of tubewells and other connected works on behalf of private individuals/bodies/Govt. Institutions, and companies, in carrying out all kinds of ground water exploration business to quantify the ground water resource in different areas. The department of water and soil conservation is involved in irrigation conservation including increasing water application efficiencies, ground water recharge, micro irrigation, brackishwater management and soil reclamation. The regional office of the Central Ground water board is engaged in macro level ground water management studies, exploratory drilling programme, monitoring of ground water levels and water quality through a network of ground water observation wells, implementation of demonstrative schemes for artificial recharge and rainwater harvesting for recharge augmentation, providing a scientific base for water resource planning by the stakeholders and advising the States and other user agencies on planning and management of ground water resources

365. There currently exists a three tier institutional arrangements for effective water resource management in the state

(i) **Tier-1: The Punjab State Water Resource Council (PSWRC)** headed by the stet Chief Minister and all the ministers of various ministry like Irrigation and Power, Agriculture , Local Bodies, Panchayat Raj and Rural Development etc as members of the council. The key functions among others include approving a) the state water policy for both surface and ground water b) draft legislations for regulation, development, planning and use of water resources on an integrated basis c) state water master plan with regard to assessment of quantum and quality of water resources in the state

(ii) **Tier-2: The Punjab State Water Resource Committee (WRC)** headed by the Chief Secretary and all the secretaries of the departments including the principal secretary to Government of Punjab and Finance commissioner are its members. The key functions among others include preparing draft; (i) the state water policy within the framework National Water Policy; (ii) draft legislations for regulation, development, planning and use of water resources for approval of the SWRC; (iii) to approve water allocation priorities for water use by various sectors with the provision drinking water being of highest priority, to approve schemes for maximizing hydro power generation within the constraints imposed by others users and to promote user participation in all aspects of water planning and management etc.

(iii) **Tier-3: State level Technical Advisory Committee (TAC)** is headed by the Chief Engineer, Water Resources and the chief engineers of water supply and sewerage board, Drainage and Irrigation works, Public Health, Irrigation Research, Regional Chief Engineer of CWC, Chairman of Pollution control board, etc are the members. Key functions among others include; (i) preparing a draft for state water policy; (ii) preparing a draft state water master plan; (iii) preparing draft legislation on use of water; (iv) to give technical approval of the schemes; and (v) to set up computerized data bank etc.

366. However, one could infer from the above institutional arrangements, though logically connected with each tier, that, the structure still lacks comprehensiveness to provide an operational basis to pursue the concept of IWRM with an approach to river basin management and therefore the current arrangement needs to be revisited .

2. Proposals

367. Governance changes are needed to move from surface water management to an integrated surface and groundwater managed approach. The different government water departments and communities need to work together to develop mechanisms for sustainability, combined with maximum productivity from irrigated agriculture as well as high levels of service delivery of potable water. Power for pumping is also a factor and viable strategies for supplying power have also to be incorporated into the planning process. The state departments have to integrate their efforts including the key water sector agencies; irrigation, potable water, agriculture, horticulture, groundwater and power (for pumping). Coordinating their activities to develop holistic planning and strategies is essential.

368. The current functions of the various water sector departments in their present form do not provide adequate operational basis for implementing IWRM. Groundwater use is almost entirely individual farmer led and appropriate management mechanisms need to be developed. The requirements for groundwater management are indirect, with a focus on supporting more water efficient cropping systems, micro irrigation, catchment management, artificial recharge, and the introduction of support mechanism and regulatory controls.

369. **IWRM under Existing Institutional Structure:** The proposed approach is to build IWRM as far as possible under the existing institutional structure. These proposals include the establishment of a State Steering Committee, an IWRM unit as a part of the Water Resources Department and empowerment of the district planning committees and the sector departments at district levels.

370. **Water Regulatory Authority:** The existing institutional set up is characterized by multiplicity of roles being performed by the state water departments and the water boards like CGWB. For all aspects of natural resources, strong community participation, a clear separation of the roles of; (i) regulator, standard setter and auditor; (ii) resource manager and (iii) operator and service provider to enable efficient management of water resources following IWRM principles is needed. Given the problems around water sector and based on the recommendation of the 13th Finance commission, a Water Regulatory Authority (WRA) is proposed which will provide an institutional mechanism to regulate the allocation, management and utilization limited water resources through a participatory approach.The WRA would include the following functions to: (i) establish and regulate the water tariff system and charges for surface and sub-surface water used for domestic, agriculture, industrial and other purposes; (ii) determine and regulate the distribution of entitlement for various categories of uses as well as within each category of use; and (iii) periodically review and monitor the water sector costs and revenues. The regulator would be an autonomous, inter-disciplinary body, with managerial, professional, mediatory and adjudicatory capabilities. The regulator would not be a government department and must be truly consultative and participatory in its composition and functioning, Representatives of civil society must be associated with it at all levels. The regulator would be able to support basin-level institutions and decision making. The water regulator must be truly consultative and participatory in its composition and functioning, and that representatives of civil society are associated with it at all levels. This authority would be a quasi judicial body headed by a retired High court Judge. The establishment of an independent and effective WRA is complex and requires understanding of the benefits, well planned institutional arrangements and state agreement.

371. **A State Water Resources Steering Committee** (WRSC) is proposed to support improved coordination of the sector agencies. The State level steering committee would be chaired by the Chief Secretary, with the convener being the Principal Secretary (Department of Water Resources). The other members of the steering committee would be the Principal Secretaries of the various sector departments including water resources, agriculture, rural development and panchayat, urban water supply, sanitation and forestry. The regional representative of the Central water Commission and Central Ground Water Board would also be members. The committee would be supported by experts in relevant fields who can be called on as required. The steering committee would be charged with overseeing fairly significant institutional

reforms to meet targets of efficiency, effective service delivery, participative management and financial sustainability through cost recovery for O&M costs. The committee would promote inter-sector coordination and would also advise the proposed water regulator on specific issues. The existing Punjab State Water Resources Committee would appear to meet many of the functions of the State Water Resources Steering Committee.

372. An **IWRM Unit** is proposed within the state Irrigation Department and would be headed by a Chief Engineer. Its main task would be coordinated planning for preparation of holistic and integrated planning for water resource management. Planning would be multi sector, participative and iterative. Planning would incorporate appropriate and relevant planning inputs from the key water sector departments. The regional representatives of the Central Water Commission and Central Ground Water Board would also work closely with the unit. The IWRM unit would communicate with the River Basin Organization concerning trans-boundary issues. Data management functions would be incorporated into the IWRM unit. The existing Water Resources and Environment Directorate under the Department of Irrigation already forms some of the functions of the IWRM unit and could form the nucleus for the unit.

373. The new 'IWRM unit' would play the key role in water resource planning, including providing guidance to the water regulator about water issues including advising on water licences and permits. The new IWRM management unit would encompass water resource aspects of climate change and would liaise with the Proposed Climate Change Centres being developed by DEST. Staff from the different sector departments would be seconded to work with the new unit. Hydrology and Data Management would be within the IWRM unit.

374. **River Basin Organisations:** There is a key need for a strong and effective and more enabled river basin organisation for the whole Sutlej river basin. It is estimated that holistic river basin management and optimisations of supply and demands could be beneficial to all the states in the basin. It is proposed that the BBMB takes on a more significant role in holistic river basin management, to support the efficient and effective management of the whole Sutlej river. The BBMB would work closely with the new IWRM units in the states of Himachal, Punjab, Haryana, Rajasthan and Delhi. The BBMB would help in coordination and data sharing and would support hydrological and other analysis as required. BBMB would work closely with state and national institutes to build and improve the understanding of the hydrology of the Sutlej basin including further study of the hydrological response to climate change.

375. **Empowerment of the Districts for Planning and Management of Water Resources:** It is proposed that the District level should take on an increased role in the integrated planning and management of water resources. This would include the strengthening of the District Planning Committees to oversee the integration of sector programmes as well as ensuring effective stakeholder participation.

376. **Sub Basin Consultative Group:** A lower level consultation process is required to support the basin planning processes these would include the Panchayt Raj institutions, community organizations. To allow for a collective consultation at the sub-basin level, it is proposed that a sub-basin level consultative group is formed, the group representatives would be nominated by the various Panchayat Raj within the sub-basin with representation from the various stakeholder groups. The consultative group can advise and inform the Water Regulatory Authority on water issues in the basin.

3. Community Management

377. Community water management is poorly developed in Punjab. The role of communities to address the issues of water management and groundwater overexploitation is a widely discussed option. These proposals are aimed at creating self governing groundwater user organisations that can be given responsibility for sustainable management of aquifers through collective monitoring of aquifers and behaviour of groundwater users.[53]

378. From a wide range of consultations, it is concluded that for Punjab, community water management through Water User Associations (WUA) would be difficult and probably a less viable management option. Farmers are in general reasonably happy with the Warabandi system which operates without a real need for a WUA. Historically farmers have developed very individual farming systems with minimal history of community based water management. Establishing effective WUAs without any real function beyond being a village regulatory body is not considered appropriate in the Punjab context. There is clearly a role for communities to participate in a support role for water management and conservation initiatives, it is considered, however, that the key direction must be targeted initiatives directly towards individual farmers; ensuring farm incomes are maintained or improved whilst introducing parallel water resource conservation measures. Strengthened WUAs may potentially be useful in the south western part where saline conditions result in high reliance on the surface water systems; From the participatory rural appraisal there would appear to be community support for strengthening WUA in the south west area.

[53]Deep Wells and Prudence Towards Pragmatic Action for Addressing Groundwater Overexploitation in India World Bank

4. Cooperatives

379. Despite some areas of poor performance, cooperatives are now playing an increasingly important role in Punjab agriculture. State government is supporting the cooperatives and with the Union government and the National Bank for Agriculture and Rural Development (NABARD), implementing the revival package for short-term cooperatives in the state and reviving the short term rural cooperative credit structure in Punjab. In 2010 autonomy has been given to over 20,000 village cooperative societies in Punjab. The Act would run "parallel" to the 1961 Punjab Cooperative Societies Act; village cooperative societies can shift their registration from under the old Act to the new Act. Under the new Act, the entire functioning of the cooperative society would be with the cooperative's elected head and not with the government. Under the new Act, cooperatives would be member driven and would be free to choose their own economic activities and manage their own funds and would be responsible for implementing their own audit. The cooperatives would appear to offer a sound institutional base for implementation of resource conservation initiatives.

380. **Rural Electricity Cooperatives** constitute a very small portion of India's overall rural electrification programme. The Government of India has indicated an interest in utilizing the cooperative model for increasing the reach of rural electrification. There would appear to be potential to resolve some of the entrenched dysfunctions in the existing electricity distribution and retail system for agriculture through electricity cooperatives.

381. Resolving India's rural electrification challenge, particularly overcoming entrenched dysfunctions in the existing electricity distribution and retail system, will entail simultaneously addressing a variety of deficiencies and issues, this is especially important for the electricity to be supplied to the agricultural sector. There is certainly clear scope for including some form of cooperative development for the purpose of engaging the consuming public as part of this effort. Studies have shown that electricity cooperatives linked to income generation have higher chance of success[54] than domestic supplies. The potential for electricity cooperatives to use a part of the revenue collected to support water conservation technologies would appear to offer many advantages in achieving acceptability and support.

5. Summary of Institutional Proposals

382. The current functions of the various water sector departments in their present form do not provide an adequate operational basis for effective IWRM. The institutions are fragmented with limited capacities to implement the type of integrated approach required to address the water issues. The institutional proposals are designed to maintain the sectoral functions but bring in levels of coordination and integrated decision making. The institutional proposals are summarised in Table 31.

Table 31: Summary of Institutional Proposals

1	Water Regulatory Authority	A Water Regulatory Authority (WRA) is proposed which will provide an institutional mechanism to regulate the allocation, management and utilization limited water resources through a participatory approach. The WRA would include the following functions to: (i) establish and regulate the water tariff system and charges for surface and sub-surface water used for domestic, agriculture, industrial and other purposes; (ii) determine and regulate the distribution of entitlement for various categories of uses as well as within each category of use; and (iii) periodically review and monitor the water sector costs and revenues. The regulatory authority would be an autonomous, inter-disciplinary body, with managerial, professional, mediatory and adjudicatory capabilities. The regulator would not be a government department and must be truly consultative and participatory in its composition and functioning, Representatives of civil society must be associated with it at all levels. The regulator would be able to support basin-level institutions and decision making
2	State Water Resources Steering Committee	A 'State Water Resources Steering Committee'(WRSC) is proposed to support improved coordination of the sector agencies. The WRSC would build on the present Punjab State Water Resources Committee. The committee would comprise of the Principal Secretaries of the departments of Water Resources, Agriculture, Forests, Environment, Panchayats, and Rural Development. The committee would be supported by experts in relevant fields who can be called on as required. The steering committee would be charged with overseeing fairly significant institutional reforms to meet targets of efficiency, effective service delivery, participative management and financial sustainability through cost recovery for O&M costs. The committee would promote inter-sector coordination and would also advise the proposed water regulator on specific issues.

[54]Experiences in Cooperative Rural Electrification and Implications for India NRECA International for ADB 2002

3.	Integrated Water Resources Management Unit (IWRM) within Department of Water Resources Development.	The present planning and hydrology sections within the WRDs would be combined, expanded and strengthened with a new mandate and skills to become an "IWRM Unit". The IWRM unit would build on the existing structure of the Irrigation Department but would incorporate all the sectoral water needs (power, water supplies, agriculture, groundwater, surface water, catchments etc). The operational functions of the WRD would be separated. The new 'water resources management unit' would include a role in water resource planning including providing guidance to the water regulator about water issues including advising on water licences and permits. The new IWRM management unit would encompass water resource aspects of climate change and would liaise with the Proposed Climate Change Centres being developed by DEST. Staff from the different sectors department would be seconded to work with and support the IWRM unit. The existing Water Resources and Environment Directorate would be expanded into the IWRM Unit.
4.	Empowerment of the Districts for Planning and Management of Water Resources	It is proposed that the District level should take on an increased role in the integrated planning and management of water resources. This would include to the strengthening of the District Planning Committee to oversee the integration of sector programmes as well as ensuring effective stakeholder participation.
5.	Stakeholder Consultative Group	There is a need for districts, panchayats, stakeholders including civil society to participate in the basin planning and management processes. It is proposed that the Panachayat Raj of each district would nominate representatives of stakeholders including civil society to review and endorse the strategic and detailed plans and support water resources management. The groups would work at district and lower levels. Representatives of the various groups within the sub basin would meet periodically to address sub basin issues.
6.	Formal and Informal Organisations at the Village Level	Village organisations are critical to implement change including improved surface and groundwater management and water conservation. In the Sutlej the most appropriate type of village organisation needs to be defined. WUA are poorly established and in the groundwater dominated irrigation the WUA are less appropriate or their functions need to be redefined. Consideration of alternative organisations is required; options might include the role of cooperatives including electricity cooperatives to take on a proactive role in promoting water conservation, agricultural productivity, marketing and power management. The exception would be the south west area where due to saline groundwater, surface water is the main water source. WUA should be established and strengthened in this area.
7.	River Basin Authority	It is proposed that the BBMB takes on a more significant role in holistic river management, to support the efficient and effective management of the whole Sutlej river The BBMB would work closely with the new IWRM units in the states of Himachal, Punjab Haryana, Rajasthan and Delhi. The BBMB would help coordination and data sharing and would support hydrological and other analysis as required. BBMB would work closely with state and national institutes to build and improve the understanding of the hydrology of the Sutlej basin including the hydrological response to climate change.

D. Climate Change Scenarios

383. For climate change projections in the Sutlej basin, the output from one member of the Hadley Centre HadCM3 QUMP[55] ensemble was downscaled using the PRECIS RCM by IITM Pune. Apart from the baseline (1961-1990) which represents the present, two future time slices were investigated: mid-century (2021-2050) and end-century (2071–2100). All three time slices use the SRES scenario A1B. In addition, data were available for the SRES A2 and B2 scenarios for the baseline and end-century and were used for comparison[56].

384. To meet the needs of climate change adaptation, it is necessary to: (i) assess how the strategies for 'current needs' meet the requirements for climate adaptation; and (ii) assess the gaps and what additional aspects have to be incorporated into the strategy to meet climate impacts.

385. Some climatic changes are already being observed with statistical significance, the main factor is temperature rise. There are also indications of other changes which are not statistically significant. When looking at smaller regions (e.g. state level or river sub-basins) it is often difficult to detect these changes with any confidence.

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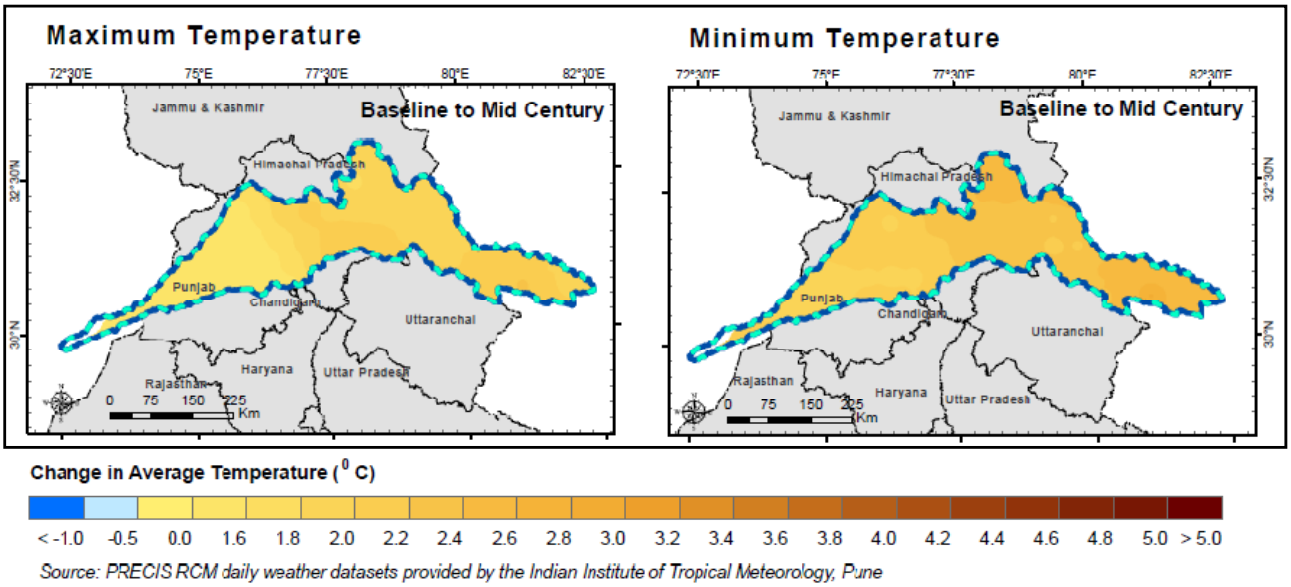
[55]Quantifying Uncertainty in Model Predictions is an approach which aims to provide probabilistic predictions of future climat

[56]**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.
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.

1. Temperature

386. Temperatures are estimated to rise with the average maximum and minimum temperature (with reference to the 19070s baseline) estimated rise by about 20C by mid-century. Temperature rise will directly impact on some crops. Farmers are already reporting temperature impacting on the yield of crops, there are reports of loss of yield of winter wheat and some other crops such as grams. It is proposed that a part of the adaptation plan is the inclusion of crop diversification to meet impacts of increased temperature and other changes (CO_2 and ozone) on crop viabilities. These impacts can be investigated further using a crop response model such as DSSAT (Decision Support System for Agricultural Technology). Projected temperatures are shown in Figure 19.

Figure 19: Projected Temperature Changes to Mid Century



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

387. The projected temperature range (maximum and minimum) for the basin are shown in Table 32. These are taken from simulations conducted by IITM Pune using the PRECIS model with HadCM3 boundary conditions and a member of the QUMP ensemble for the A1B emissions scenario.

Table 32: Temperature Projections, A1B Scenario

	JF	MAM	JJAS	OND	Annual
Mean daily maximum					
1970s baseline	5.3	19.7	25.0	11.0	15.3
2030s	7.0	21.8	26.6	12.3	16.9
2080s	9.8	24.4	29.3	15.5	19.8
Mean daily minimum					
1970s baseline	-9.6	5.6	11.9	-7.1	0.2
2030s	-2.9	12.0	13.8	-4.3	4.7
2080s	0.1	15.0	16.7	0.4	8.1

388. The PRECIS model has also been run by IITM Pune for the A2 and B2 emissions scenarios. A comparison of the changes in mean daily maximum and minimum temperatures projected with the A1B, A2 and B2 scenarios for the 2080s are shown in Table 33. Changes in maximum temperatures projected under the A1B and A2 scenarios are similar. The B2 scenario produces much lower temperature increases. The A1B scenario produces significantly higher changes in mean daily minimum temperature than does the A2 or B2 scenarios. It is interesting to note that under the A1B scenario the projected increase in minimum temperatures in the winter months is double that of the maximum temperatures. The changes in minimum temperatures projected under the A1B scenario would have a significant impact on snow accumulation and glacial melt in the upper Sutlej. The distribution of temperature changes under the A2 and B2 scenarios is very similar to that of A1B.

Table 33: Comparison of Projected Changes in Temperatures, A1B, A2 and B2 scenarios, 2080s

Mean daily maximum temperatures					
Scenario	JF	MAM	JJAS	OND	Annual
A1B	4.5	4.7	4.3	4.5	4.5
A2	5.0	4.1	4.1	5.2	4.6
B2	2.9	1.8	2.9	6.1	3.4
Mean daily minimum temperatures					
A1B	9.7	9.4	4.8	7.5	7.9
A2	5.5	5.1	4.0	5.6	5.0
B2	3.7	3.0	2.9	7.2	4.2

2. Potential Evapotranspiration

389. Potential evapotranspiration has been estimated from PRECIS simulated weather data for three locations in the Sirhind irrigation command in the lower Sutlej basin. These locations were chosen to be representative of the south western part of the command, the middle and the area close to the Ropar headworks. The computed annual potential evapotranspiration figures are given in Table 34 below. Little change in ETo is forecast by mid-century under the A1B scenario

Table 34: Changes in Annual Potential Evapotranspiration

	ETo (mm)		
Location	**Baseline**	**Mid-century**	**End-century**
Southwest	1890	1900	2080
Middle	1680	1660	1810
Ropar Headworks	1260	1290	1350

3. Historic Rainfall Trends

390. An analysis was made of historic annual and seasonal rainfall using IMD data for stations at Ferozepore, Jullandar and Ludhiana, to test for the existence of trend in the records. Approximately 30 years of data were available for each station. At Ferozepore there was an indication of a declining trend in annual and monsoon rainfall, but the significance level was greater than 10%, and this would not be considered conclusive. At Jullandar and Ludhiana there was an indication of an increasing trend in annual and monsoon rainfall. At Jullandar the significance level was greater than 10%, but at Ludhiana the upward trend in monsoon rainfall was significant at the 5% level. It has not been possible to investigate the reasons for different results at Ferozepore, but it was noted that there were more missing records at this location. At Ludhiana, a longer composite record was created using archived records from the GHCN[57] precipitation archive. This longer term record was used in analysis. The trend in annual precipitation amounts to an increase of 25% over a 99 year period. The projected future changes in precipitation under the PRECIS A1B scenario are in line with the trend observed historically at Jullandar and Ludhiana.

4. Projections for Precipitation

391. The river basin receives most of its rain during the monsoon season, which starts in June/July. The present average annual rainfall ranges between 960 mm sub-mountain region and 460 mm in the plains. The projected annual average precipitation across the Sutlej basin is shown in Table 35 and Figure 20. The whole basin is projected to receive increased precipitation with most of the increase located in the western parts of the basin. The least increase will be experienced in the very eastern upstream parts and a small tongue-like region in the southwest.

392. Precipitation in the decadal period to 2020 is likely to remain largely unchanged. The projected rainfall increase to mid century is plus 10 - 15%, with about plus 15% projected for the average monsoon precipitation. The trend is for an increase in precipitation. The net effect under the A1B scenario, with little change in evapotranspiration, would be reduced irrigation demand and some increase in more intense rainfall events.

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

Table 35: Projected Precipitation, A1B Scenario

	JF	MAM	JJAS	OND	Annual
1970s baseline	126	165	572	155	1018
2030s (A1B)	122	181	659	194	1156
2080s (A1B)	142	177	746	202	1267

393. A comparison of the seasonal changes in precipitation projected under the A1B, A2 and B2 emissions scenarios for the 2080s is given in Table 36 and Figure 21. The A1B scenario results in a significantly higher increase in precipitation that does either the A2 or B2 scenario. In all scenarios the greatest increase in precipitation is in the monsoon season. It is of interest to note that the seasonal pattern of increases is different between the A1B and A2 and B2 scenarios. The A2 and B2 scenarios produce higher increases in the MAM season and a reduction in precipitation in the OND season.

Table 36: Projected changes in seasonal precipitation under the A1B, A2 and B2 scenarios to 2080s (mm)

Scenario	JF	MAM	JJAS	OND	Annual
A1B	16	12	174	27	249
A2	6	25	79	-13	98
B2	20	51	77	-18	131

Figure 20 : Change in Annual Rainfall

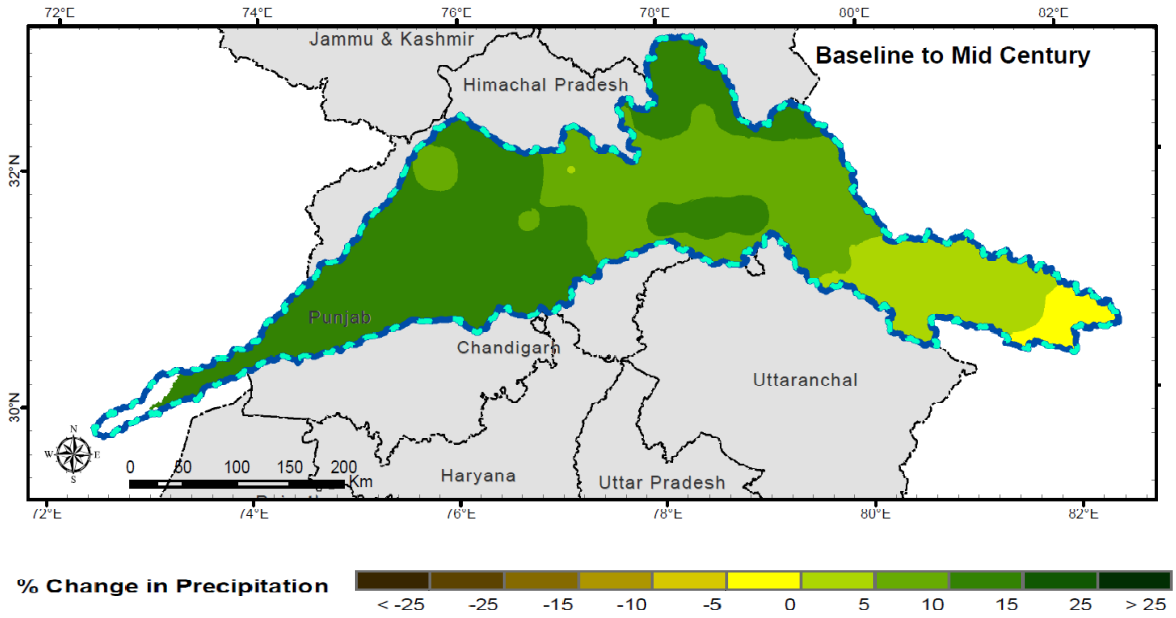
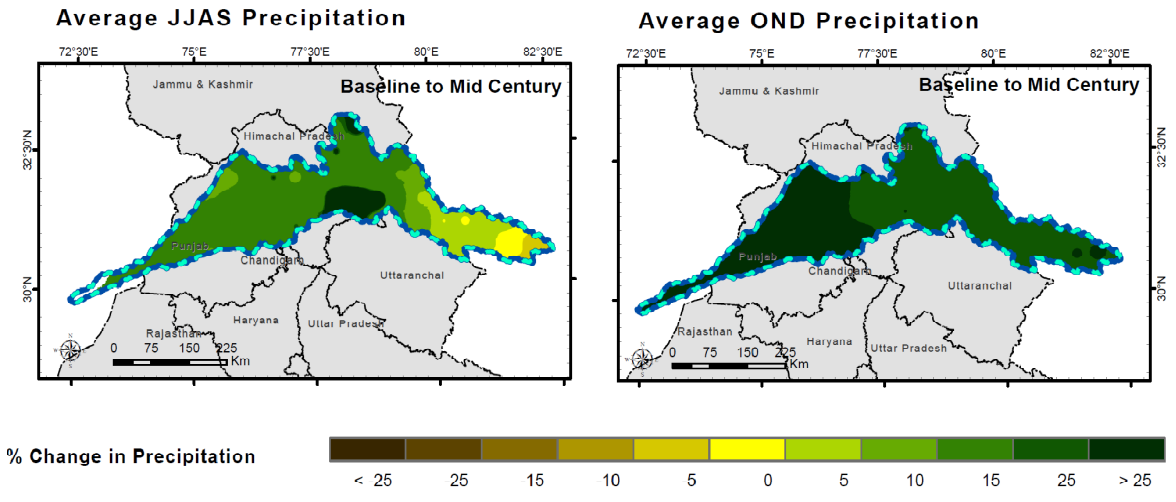


Figure 21: Change in Seasonal Precipitation



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

394. **Intense Rainfall Events:** Small increases in the number of rainfall events are projected to occur mainly in the northern part of the state.

5. Estimated Changes in Snow and Glaciers

395. **Snow and Glaciers:** Surface water resources at Bhakra are estimated to be 60% derived from snow and glacier melt. In the short to medium term reduced snow melt due to evaporation will be largely compensated by increased glacier melt. In the longer term, however, a gradual decline in the combined melt flows will occur. The time scale very much depends on elevation. In the lower level catchments some decline is already occurring and lower level tributaries will be most affected in the short to medium term. In addition to temperature, snow and glaciers will be affected by changes in evaporation and precipitation. Black carbon and the soot loading of the atmosphere (*"brown haze"*) also impacts on the temperature profile of the atmosphere and the precipitation patterns in the region. The quantity of rock and other debris falling on the glaciers is estimated to affect glacier melt rates[58]. The snow fall occurs almost entirely in the winter months as a result of the westerly disturbances in the higher parts. The projected change in the winter westerly disturbances is quite minimal. The PRECIS model does not, however, represent winter snow well. The summer monsoon, due to blockage by the high mid Himalaya mountains, very rarely enters into the northern parts of the basin.

396. **Snow** is only during the winter months; November to March and comes from the Westerly Disturbances which originate in the Mediterranean. The summer monsoon contributes insignificantly to snow, so changes in the monsoon precipitation will not affect the amount of snow. Increased evaporation will however reduce the volume of snow with increased temperatures resulting in earlier snow melt. Studies of the effect of warmer climates[59] on the rate of depletion of snow suggest accelerated effects. For a 2°C temperature increase scenario, the annual evaporation for the rain-fed basins increased by about 12%, whereas for the snow-fed basins it increased by about 24%. This high increase of the evaporation losses would reduce the runoff from snow. There is only limited research on the possible changes to the Westerly Disturbances, but based on the information available there is estimated to very small change predicted in the levels of winter snow fall[60].

397. **Glacial Loss** estimates are supported by with only limited information. From remote sensing studies[61] it is estimated that there are about 930 glaciers with a total surface area of 1200km^2 with an indicative ice volume of between about 60-90km^3 (about 45-70 BCM water equivalent) in the Himachal part of the Sutlej catchment. The glaciers located in Kinnaur and Spiti; there is no information on the glaciers in the PRC but it is considered to be relatively small. There is no survey data on the volume of glaciers and volumes are estimated based on simple empirical formula applied to the surface area. Analysis of various data sources for the Spiti valley show that there is an annual glacier loss of about 2.5%. Studies[62] have shown that melt rates will increase with increased temperature; a 2°C increase in temperature could increase melt by about 28%, a 3°C increase could increase melt rates by up to 45%. At present temperatures; the annual loss of 2.5% represents an indicative glacier loss of about 50% over 30 years. A 3°C temperature increase could result in a 60% glacier loss by 2050. In the initial stages the increased melt will result in increased stream flows, which might be up to 33% of the normal flows; however the gradually shrinking glaciers will reach a critical point when the melt will start to decline due to the reduced ice volume. There is no information as to when this critical point may occur.

398. **Glacier and Snow:** Estimates are that glacier melt may account for about 70% of the combined snow and glacial melt. It is found that increased temperatures will bring earlier snow melt and also reduce the annual snowmelt due to evaporation; a 2°C increase in temperature could reduce the annual snowmelt by about 18%. Conversely it was found for the same temperature the flow increased by 33% for glacier-fed basins[63]. Impacts of warmer climates on the melt from the snowfed and glacier-fed basins were found to be opposite to each other. The study suggests that out of three types of basins, snow-fed basins are more sensitive in terms of reduction in water availability largely due to the increase in evaporation. The decrease in melt from seasonal snow may be counterbalanced by increase in melt from glaciers. However, on a long-term basis, the areal extent and volume of glaciers will decrease to a critical level when the overall water availability from the basin will be reduced. Analysis of inflows to Bhakra show presently no significant statistical trend of increasing or decreasing flow which tends to confirm that there is balancing of reduced snow melt and increased glacier melts from the lower and higher parts of the catchment.

399. Based on an assessment of various research outputs an indicative summary of the broad implications of hydrological changes on the various water sources is summarised in Table 37.

[58]Scherler, Bookhagen and Streckler Spatially Variable Response to Himalayan Glaciers Affected by Debris Cover Natural Geoscience 2011
[59]Effect of Warmer Climate on the Depletion of the snow Covered Area in the Sutlej Basin Singh and Bengtsson (2003)
[60]INCCA Climate Change in India November 2010
[61]CSK Himachal Pradesh Agriculture University Centre for Geo-informatics Palampur and the Geological Survey of India 2009
[62]Singh and Bengtsson ibid
[63]Hydrological Change of a large Himalayan Basin to Climate Change Singh and Bengtsson (2004)

Table 37 Indicative Snow and Glacier Changes Himachal Pradesh Sutlej

Location	Short term Decadal	Medium 10 to 30 years	Long beyond 30 years
Lower Level Catchments	Reduced snowmelt due to evaporation. Earlier depletion of snow Lower level glaciers in decline.	Snow and glacier contributions will disappear in some catchments. Increased summer monsoon rain.	Snow and glacier contributions will severely reduce or disappear in most catchments. Summer monsoon rain may increase by up to 15%.
Higher Level Catchments	Reduced snowmelt due to evaporation. Earlier depletion of snow. Increased glacier melt from medium and high glaciers	Increasingly reduced and earlier snowmelt. Increased glacier melt from medium and high glaciers -melt rate could increase. potentially by up to 45%. Some medium altitude glaciers in already in decline.	Severely reduced and earlier snow melts. Melts will be in serious decline from many medium altitude glaciers. Higher altitude more robust glaciers likely to provide continued melt for a significant time period.
Combined basin scale impact on main stream flows	No significant trend is presently observed and this will likely continue for the next decade.	Loss of melt from snow and glaciers at lower levels will be compensated from increased melt from higher catchments. There is insufficient data to confirm the trend at this stage. Increased precipitation in lower catchment likely to contribute to increased runoff.	Overall gradual decline in glaciers and snow melts will reduce the inflows to Bhakra reservoir. Increased rain in the lower catchments.

400. **Sediment:** The increased melt rates, increased monsoon and increased number of intense rain events all point to increased soil erosion. The strengthened summer monsoon is also likely to increase the chance of incursion of monsoon rains into the desert areas of Spiti and PRC, which is likely to result in major increases in sediment load and risk of destabilisation including avalanche blockages as well as glacier lake floods.

6. Hydrological Simulations in the Upper Catchment

401. A SWAT model analysis was tried for the catchment upstream of the Bhakra reservoir as well as a reservoir operation model. The plan was to calibrate the SWAT model with available observed stream-flow records and with rainfall inputs from the IMD gridded 0.5° precipitation dataset for that part of the basin in India, and the Aphrodite dataset for that part in China. In parallel with the calibration process, the performance of the PRECIS model representing historic climate for the basin was also investigated.

402. Precipitation simulated by PRECIS in parts of the upper basin was found to be more than three times higher than the estimated observed precipitation, while potential evapotranspiration calculated from PRECIS simulated data was significantly lower. It was concluded that at this time, the PRECIS model is not capable of adequately simulating climatic conditions in the Himalayan region. The simulated baseline climate was so significantly different from that observed, that no meaningful bias adjustment of PRECIS results was possible. It was considered that the results are so different from observations, that there could be little confidence even in simulated changes in climate under future emissions scenarios. Assessment of possible climate change impacts on river flows in the upper Sutlej using PRECIS results to drive the SWAT model is not at this time possible.

403. This lack of accuracy in the model projections is a major information gap and priority must be given to further research to improve the reliability of the climate projections and be supported by improved modelling of the hydrological response. Improved estimation of the changes in snow and glaciers is essential. Although some estimates of glacier loss have been made there is no surveyed information on the actual glacier resources.

7. Hydrological Response in the Lower Catchment

404. Although PRECIS weather simulations in the upper basin were not considered to be suitable for hydrological modelling, the PRECIS simulation of baseline climatic conditions in the lower basin was considered to be satisfactory. The SWAT model was used in the lower basin to assess possible changes in surface runoff and evapotranspiration under the influence of climate change. The change from the baseline to mid century of the annual water balance is shown in Figure 22 and for JJAS in Figure 23. The PRECIS A1B scenario indicates an increase in JJAS precipitation in the lower Sutlej basin of about 30% by mid-century. The model results indicate that around 52% of this increase in precipitation will get converted to runoff and around 15% will go as groundwater aquifer recharge. The change in the base flow is negligible and evapotranspiration is predicted to increase by 8%. It can be seen that although 15% will go to ground water recharge, most of the increased precipitation results in increased runoff. 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[64], 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, current drainage design criteria to incorporate increased rainfall should be reviewed and adjusted.

[64]Some assumptions were made for running the scenarios using the hydrological model, no landuse changes and the use of current crop management practices in the future were assumed.

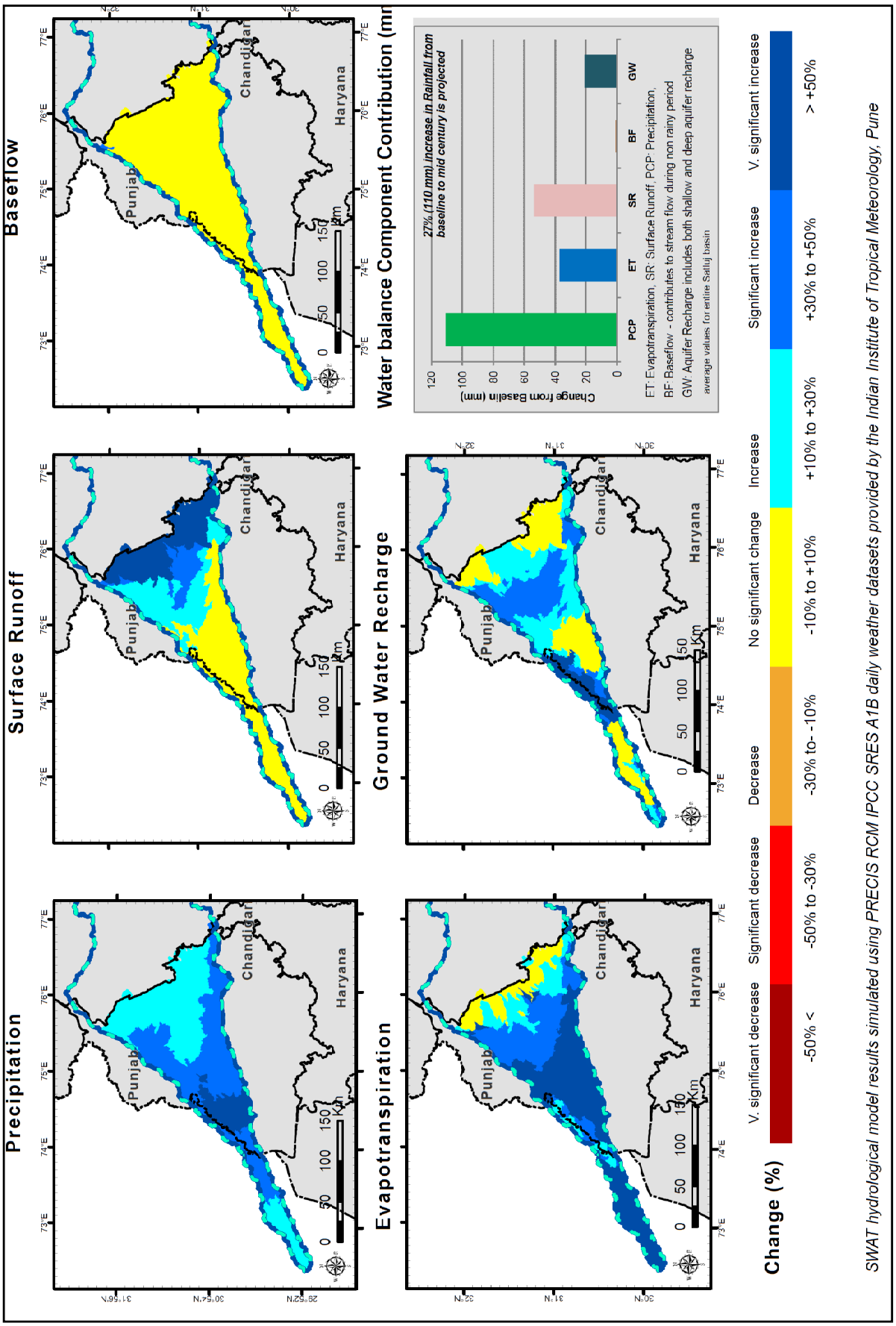


Figure 22 Change in the Annual Water Balance to Mid Century

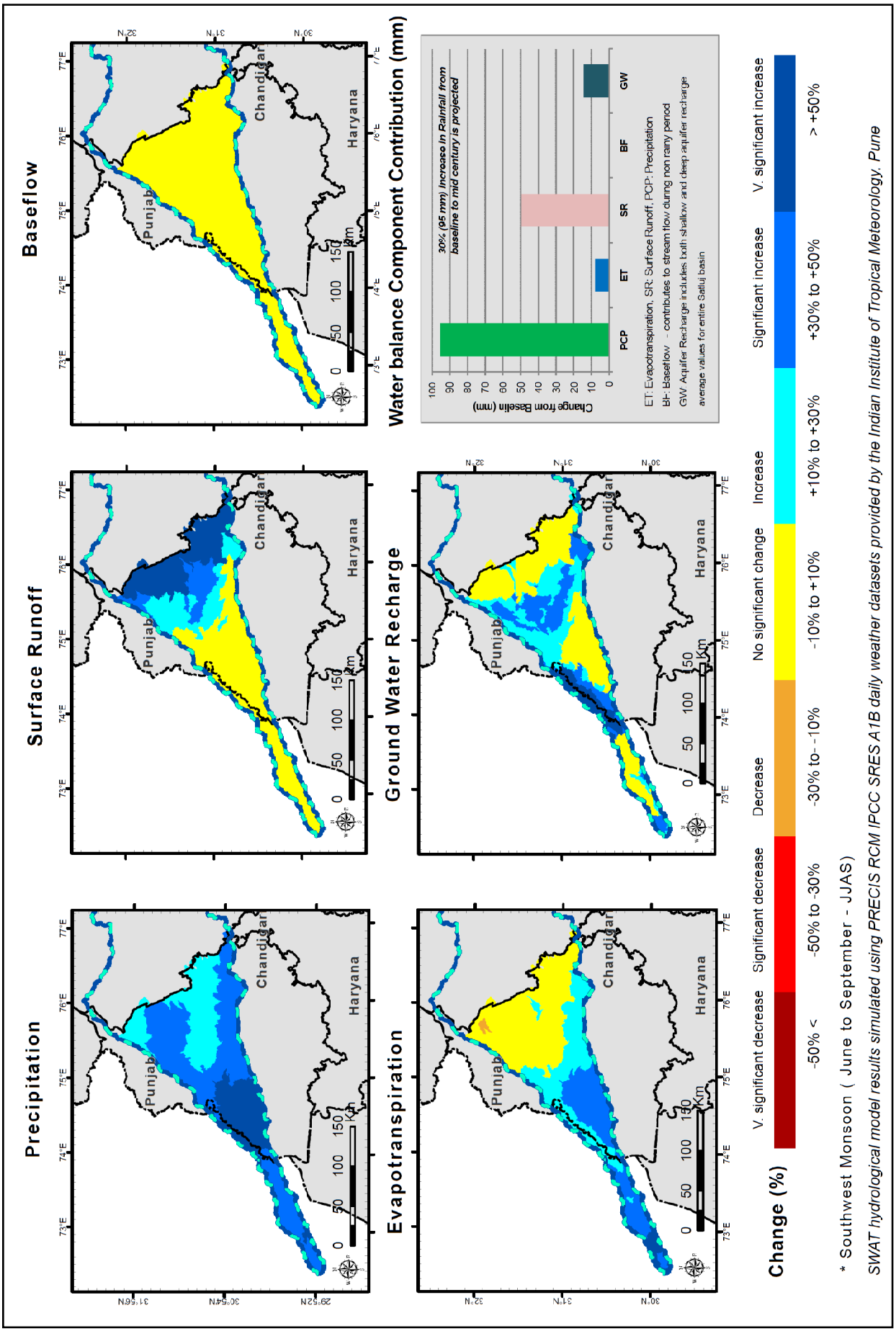


Figure 23 Change in the JJSAS Water Balance to Mid Century (A1B)

8. Other Factors

405. **Flood:** Increased rainfall intensities and increased snow and glacier melt rates may likely increase the flood flows, especially in the northern part of the State. Flood in the main Sutlej river will mainly be absorbed by Bhakra but the experience of floods in 2010 showed that the dam was very close to emergency releases. Flood, although not a very significant issue at present, may become more significant in the future. The on-going flood analysis and proposed management system for Bhakra being implemented by BBMB will be very useful. It is proposed that the DSS being developed is extended to factor in potential climate change impacts.

406. **Sediment:** Increased rainfalls and glacier melt will likely increase sediment inflows to Bhakra reservoir. Maximising the life of the Bhakra reservoir seasonal storage potential is important. In the medium term, any loss of storage will be compensated by increased glacier melt, but the long term prognosis is an overall decline both in glacier melt and storage capacity at Bhakra. There is no solution to the glacier melt issue, but early action to preserve the storage at Bhakra is considered important. Liaison with the Himachal Pradesh government to fast track the catchment management activities is an important part of the strategy. Catchment management in the upper catchment is probably of more value to Punjab than to Himachal Pradesh. Water conservation in the tributary rivers in the lower foothills of Himachal Pradesh may be of benefit to groundwater recharge in Punjab.

407. **Climate Uncertainty:** The models are designed to give the best possible estimates of climate projections within the present level of knowledge. Uncertainties in these projections remains and increased variability in the weather patterns remains likely even within the framework of the projections. Government has limited capacity to handle variations and creation of strengthened community institutions to promote self reliance at the community level is considered important. Markets and pricing systems are very rigid and a more flexible more open market systems to encourage diversification for farmers to better adjust to markets, conservation and climate variabilities is recommended.

408. The indicated trend from the A1B scenario is for some increase in water availabilities by 2050 mainly increased rainfall. This will be generally beneficial and should reduce the irrigation demand. The changes in glacier and snow melt contributions to the river flow are not well understood.

E. Vulnerabilities Against Impacts of Climate Change

409. Climate change will affect the water systems which will impact on present vulnerabilities. A summary of potential climate impacts and key areas of vulnerability is shown in Table 38.

Table 38 Specific Climate Change Vulnerabilities

	Parameter	Quantitive assessment	Confidence of estimates	Estimated climate change to mid century	Adaptation requirements
1.	Temperature	yes	High	+2°C avg. max and min temperature in the lower catchments	Research into crop response and access to temperature resistant varieties to be up-scaled
				+2.5 °C avg. max and min temperature in the upper catchments	Temperature increases are projected to be higher in the upper catchments. Increased evaporation and temperatures will reduce flows from snow melts. Flows from glacier melts will initially increase but in the medium tem will reduce. Inflows to Bhakra are estimated to remain stable in the short term, but in the medium to long term will reduce Loss of glacier and snow storage needs to be compensated through efficiencies in the Sutlej water resource systems including sustainable groundwater
2.	Precipitation annual	yes	Medium	+15%	Increased catchment management and support for recharge and reduce flood runoff.

	Parameter	Quantitive assessment	Confidence of estimates	Estimated climate change to mid century	Adaptation requirements
3.	Rainfall Intensities	Yes	Medium/ low	No significant change in the number of intense rainfall events projected	Adaptation must incorporate potential risk of increase rainfall intensities. Infrastructure design needs to factor in increased rainfall intensities.
5	Evaporation/ evapotranspiration	Yes	Medium	Little change to evapotranspiration Significant decrease in snow melt due to increased evaporation.	Present high levels of evapotranspiration to be addressed by crop management. Decreased snow melt contribution will reduce surface water inflows to Bhakra.
6.	Floods	no	Poor	Increased rainfall intensities and increased snow melts would likely increase flood risk .	Major flood increase largely buffered by Bhakra reservoir except in tributary rivers Adequacy of reservoir to absorb future floods needs to be assessed. On-going DSS by BBMB and HP2 project) should incorporate climate projections.
7.	Droughts	yes	low	Non quantified but rainfall variabilities may increase	Sustainable groundwater can buffer against precipitation variabilities
8	Other Extreme events	no	Medium	Non quantified events- hailstones, wind	Not easy to define-increased farmer awareness, crop insurance, strengthening of off farm incomes to buffer against agricultural uncertainties.
9..	Groundwater	no	Medium	Minor increase in groundwater recharge estimated	Ongoing depletion is a major issue affecting robustness to climate change. Conservation and groundwater management is key requirement.
10	Surface water inflows to Bhakra	no	low	No significant change in next decade. Insufficient data to predict change medium term change.	Detailed studies to better assess snow and ice melts and improved estimates of ice reserves. Improved projections of precipitation changes. Further refinements to calibrate the swat model. Further refinements to calibrate the swat model.

410. Storage can provide one of the best buffers against climate change and precipitation variabilities, and preservation of the groundwater is the key adaptation measure proposed. This is required both under the present and future climatic conditions. The projected climate impacts over the next decade are less significant and the present day requirements are still valid over the next 10-15 years.

411. For the medium term 2020 to 2040, increased water availability (precipitation and river flows) may increase the water availability for agriculture and groundwater recharge, and could reduce the groundwater over extraction. During this period increased glacier melt contribution will likely also increase the surface water availability.

412. Post 2040 the prognosis is for increased precipitation in the lower catchment but reduced snow and glacier melt contribution. The exact balance of the precipitation, snow and glacier melts is not quantifiable at this stage. The almost complete lack of surveyed information on the glacier ice volume makes it very difficult to estimate the tipping point for glacial melt.

413. In terms of strategy, it is proposed that policy should be to bring groundwater extractions into equilibrium within the next decade. Medium term changes in precipitation and surface water could possibly improve aquifer recharge but benefits would be small compared to the present levels of over abstraction.

414. The level of knowledge on the glacier melt projections and the time frame for change in the medium term is of serious concern. The long term prognosis is for depletion of glacier melts and decreased storage at Bhakra leaving the groundwater as a key resource to buffer climate irregularities. Achieving sustainable levels of groundwater abstraction is considered an essential part of the strategy.

415. **Conclusions:** The indicative impacts of climate change on the strategy are discussed above. In the upper catchment it was found that PRECIS poorly represented the present climate conditions and precipitation in particular. Hydrological

modelling with PRECIS inputs to assess future river flow response to climate change was not possible. The confidence levels in the projections especially relating to precipitation and snow and ice changes in the mountains and the impact on flow in the Sutlej river are not good enough to define potential medium to long term impacts. An analysis with the SWAT model in lower catchment (below Bhakra) showed that the increased rainfall would mainly go to runoff but about 15% of the increase or about 20mm would support groundwater recharge. This would still be significantly less than the level of over extraction.

416. Within the context of current uncertainties, key adaptation measures include:

(i) To upscale research and mainstreaming of crop varieties to meet impacts of increased temperature and changes in CO^2 and Ozone. This would be done using a crop response model such as DSSAT (Decision Support System for Agricultural Technology).
(ii) To maintain the targets of reduction in groundwater abstraction; this will be done on a step by step basis with a target to achieve equilibrium within by 2020. Continued monitoring of the groundwater is proposed and improved climate change assessment may allow some review of the target; it is estimated that improved climate projection information would be available within five years.
(iii) To include climate change effects into the ongoing flood management DSS being prepared by the BBMB.
(iv) To reduce increased risk of sedimentation in Bhakra through liaison/coordination with the Himachal Government to fast track catchment management in Himachal Pradesh.
(v) To improve capacities to address uncertainties including training and awareness of farmers and other vulnerable stakeholders.
(vi) To widen the market support systems to assist crop diversification, both for water conservation as well as the needs of agricultural adaptation to temperature and other climate impacts.

F. ADB Supported Studies in the Upper Sutlej in Himachal Pradesh

417. The Asian Development bank has recently completed a scoping study for the Upper Sutlej sub basin in Himachal Pradesh. The study[65] developed a strategic framework plan which identified seven key strategy areas to address present issues as well as directions towards adaptation for the impacts of climate change adaptation. Of special relevance to the lower basin in Punjab are the recommendations for improved river and catchment restoration and management including soil and water conservation of the catchments and treatments to protect against flood risk from avalanche, land slips and glacier lake bursts. The study also recommends improved information systems on trends and impacts of glacier and snow melts and the hydrological impacts; improved information on the water systems in PRC and specialist assessment of climate impacts that can be brought into mainstream planning.

G. Framework Plan for Climate Adaptation and Sustainable Water Resource Management

1. Analysis of Problems and Opportunities

418. The Sirhind irrigation system dates from 1874; cropping has moved from single crop subsistence farming to a highly intensive agricultural production system. The area is supported by good soils, water resources and skilled farming communities. Water resources are served by surface water irrigation from the Sutlej river supported by very large reservoir storage in Bhakra, as well as storages of groundwater, and snow and glaciers. The water resources are presently facing major problems of sustainability; groundwater extraction levels are significantly higher than the recharge and surface water resources are only able to directly provide a quarter of the irrigation demand, although provide a significant portion of the groundwater recharge. Although climate change may provide some increase in precipitation, the long term prognosis is for a loss of surface water flows due to a gradual loss of the snow and glacier storages. Temperatures are projected to rise which will affect yields of certain crops. Pressure on water resources are ever increasing from agriculture as well as for water supplies and industry. Water quality is a major issue; saline groundwater in the southwest of the state is affecting productivity in that area.

419. The increasing cost of production and diminishing economic returns in farming are adversely affecting the socio-economic conditions of farmers in Punjab. The cost of inputs has increased significantly whereas the sale prices have increased at lower rates. Agriculture is however very heavily subsidised and power for pumping remains without charge. This situation results in major questions about the financial sustainability and the capacities or willingness of the farmers

[65] ADB Climate Change Adaptation-Focused Water Resources Strategy for Himachal Pradesh 2011

to take on climate change adaptation especially where the adaptation and necessary conservation measures will not provide any improvement in financial returns.

420. Agriculture in Punjab is moving fast towards modern mechanised systems, however by international norms yields remain quite low. Farmers prefer the security of rice-wheat systems which provide secure returns but have high water requirements. The agricultural economy is also deteriorating. Increased costs have not been effectively balanced by increases in crop prices; agriculture is very heavily dependent on access without costs to surface and groundwater. The approach to climate change adaptation and sustainability requires achieving significantly higher efficiencies and returns in the agricultural systems in tandem with conservation and water management to bring the water resources balance into equilibrium. Parallel programmes to address water quality issues are also required.

2. Strategy for Climate Change

421. The projections for climate change indicate a robust estimate of an increase in temperature of about 2 °C by mid century. Projections of precipitation from the A1B scenario are less robust but indicate a precipitation increase of plus 10-15%; The projections indicate no significant change in evapotranspiration but a small increase in the number of the rainfall events in the northern part of Punjab is estimated. Temperature increases in the upper catchment in Himachal Pradesh indicate higher temperature rises of about 2.5 °C.

422. No quantitive assessment of the change is surface water resources has been possible; the indications are that there would be no significant change in the next decade; the prognosis for the longer term is not clear with a number of different effects interacting which make definitive assessments of change and time scales of change not possible at this stage.

423. The level of confidence of the projections of temperature are estimated to be robust; farmers are already reporting some production loss in winter wheat and the development and mainstreaming of temperature resistant crops including wheat are seen as critical.

424. The need to conserve groundwater is critical both for current as well as the likely future conditions. The medium term depletion of glacier and snow storages further reinforces the need for ensuring the sustainability of the groundwater.

3. Plan Objectives

425. The framework plan is an outline and draft proposal towards sustainable water resources management. The framework plan sets out broad proposals to meet the needs of sustainability, development, and meeting the needs of climate impacts. The plan focuses on the development of sustainable and efficient surface and groundwater systems. Five key objectives have been identified;

(i) Reduce net groundwater abstractions to below the maximum sustainable yield, requiring an annual reduction of around 10 BCM or about 55% of the present levels of abstraction

(ii) Develop mechanisms to improve water quality including reduction of salinity levels in the south western area though drainage and other initiatives. Reduction of pollution levels from pesticides and fertilisers;

(iii) Develop improved and viable catchment management and artificial recharge to help replete groundwater.

(iv) Develop strengthened agriculture productivity and marketing systems to support financial sustainability, meet climate impacts, and help mitigate against impacts of necessary water conservation measures.

(v) Develop and mainstream new seed varieties and other measures improving crop tolerance to increased temperatures.

426. There is no single solution towards meeting the needs of groundwater conservation and a portfolio of different initiatives will be required. The broad requirements are to develop improved agricultural production and marketing systems within a framework of resource conservation. To meet the objectives, four key focal areas are identified:

(i) **Improved Agricultural Production and Marketing Systems:** Agricultural sustainability requires financially viable production systems to improve farmers' incomes as well as help support additional costs of resource conservation. Financial sustainability of the agricultural systems will be an essential requirement to effectively address conservation measures as well as provide robustness to climate impacts.

(ii) **Upscaling of Resource Conservation Technologies (RCTs)** to reduce agricultural water demands. The RCTs need to be evaluated in terms of impact on water use, farmer and market acceptability and readiness for upscaling. Fully researched and viable RCTs should be taken forward to full implementation; other RCTs can be up-scaled as pilots. Increased resources are required to support intensive research to bring forward new RCTs as well as the development of resilient crop varieties to meet impacts of climate change. RCTs include cropping systems, micro irrigation land levelling, power management etc.

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(iii) **Water Resources and Catchment Management** will focus on water supply management. Key areas include: water management to address salinity and water quality, improved surface water allocation systems, catchment management, rainwater harvesting, artificial recharge, sustainable urban water management, rehabilitation of wetlands and village ponds.

(iv) **Institutional, Regulatory and Support Measures:** Implementation of programmes to address productivity and marketing; resource conservation and water resource conservation and management require to be supported by the establishment of IWRM, a regulatory authority and improved government support systems.

4. Framework Plan Proposals

A four component strategic framework plan is proposed. The components and objectives are described below.

Component 1: Improved Agricultural Productivity and Marketing Systems

427. The component objective is to support development of more efficient production and marketing systems through; (i) strengthening and coordination of government extension and support programmes; (ii) support for farmer/cooperative orientated private sector partnerships and agribusiness; (iii) special support for productivity and marketing initiatives that support water resource conservation; and (iv) support for adaptive research and pilot up-scaling of new productivity and efficiency initiatives.

428. Improving farmer productivity and competitiveness are important elements of the Punjab State development plan. The state strategy is to develop agriculture within a business perspective involving greater commercialisation of production systems including agribusiness and contract farming and diversification to higher return cropping. Support for local enterprises and ensuring participation and security of the small and lower income farmers are key focal areas.

429. Experiences in agribusiness and contract farming have been mixed; the lack of farmer involvement and local partnerships are seen as major limitations. Emphasis should be directed towards small local enterprise including strengthening of the local cooperatives and farmer groups and improving access to mechanisation. Small seed production enterprises growing improved hybrid and non hybrid seed for use in Punjab and elsewhere would be one area which could offer good potential returns and wider benefit to agriculture.

430. The focus will be to find appropriate and viable “third parties ” between farmers and government. These third parties may be public (e.g. a reformed or financially autonomous government agency) or private (e.g. a private service provider like a contracting firm, or a village organisation turned into a private corporation).[66] There are some good examples where larger farmers are setting up small agricultural support enterprises.

431. Appropriate mechanisms to support the introduction of resource conservation technologies (Component 2) will operate in parallel with improved productivity and marketing. Demonstration of water resource conservation would form an important factor in the evaluation process of potential subprojects, funding priority would be given to projects that demonstrate elements of resource conservation or supporting the upscaling of new technologies for resource conservation.

432. The issues and potentials to adapt the government market support system to better meet the needs of farmers as well as resource conservation will be addressed in parallel under Component 4. The objective will be to develop a better harmonisation of government support subsidies towards meeting the objectives of water resource conservation and crop diversification. Component 1 is summarised in Table 39.

[66]Irrigation reforms in Asia: A review of 108 cases of irrigation management transfer Aditi Mukherji, Blanka Fuleki, Tushaar Shah, Diana Suhardiman, Mark Giordano and Parakrama Weligamage Revitalising Asia’s Irrigation: Options for the Future Final Report Submitted to the Asian Development Bank by IWMI

Table 39: Improved Agriculture Productivity and Marketing Systems

Overview	Improved agricultural productivity and Marketing linked to water conservation and water efficiencies.
Rationale	Agricultural sustainability requires financially viable production systems that can improve farmers' incomes as well as help support additional costs of water resources conservation. Financial sustainability of the agricultural systems is essential to support conservation measures as well meet the needs of robustness to climate impacts.
Description	o Intensification and diversification of production through strengthening of the extension system, promotion of private sector extension efforts, training and support for new market opportunities. o Support for new agricultural production innovations, including cropping, mechanisation etc; priorities would be given to areas where water conservation can be demonstrated. o Support for mainstreaming agricultural research to make research outputs more available to farmers. o Expansion of infrastructure facilities including processing, marketing, transport including the upgrading of market yards, storage and cold storage. Support would be directed to strengthen and empower the cooperatives. o Improvement in market information systems including promotion of e-trading, strengthening of the market chain including backward links between the markets and the producers. o Strengthening of the private sector and private sector partnerships to support the opening of domestic and international market opportunities.
Studies/ research	o Research into marketing systems and opportunities o Review of MSPs and discussions with state and central government to develop mechanisms to better support crop diversification and water savings through the MSPs (in coordination with component 4)
Outputs	o Improved infrastructure to support crop processing, storage and markets. o Improved farmer access to markets and opening of new market opportunities. o Increased involvement of private sector partnerships in agriculture and marketing. o Increased yields, production and financial returns.
Implementing Agencies	o Department of Agriculture . o Department of Cooperatives o Private sector

Component 2: Upscaling of Resource Conservation Technologies (RCTs)

433. This component is directed at achieving a significant upscaling of resource conservation technologies. This would be carried out in stages with fully researched and accepted technologies taken up quickly and the less developed less accepted taken up initially on a pilot basis. Upscaling of research into new RCTs as well as climate robust crop types and cropping systems would also be supported. The objective of the component is to directly impact on the level of over abstraction of groundwater, supporting the mainstreaming of new ideas and initiatives and research efforts.

434. Clear mechanisms to upscale RCTs have to be established; some of the RCTs remain presently unviable due to market constraints (such as short duration hybrid rice varieties which are not accepted for MSP) or low acceptability by farmers (direct seeding, power management).

435. The upscaling of RCTs would incorporate five focal areas; (i) full upscaling of proven and acceptable RCTs including; precision laser levelling of all farms, delayed planting of 100% of the rice area, reduced and zero till wheat, mulching etc; (ii) upscaling of high investment RCTs including micro irrigation; (iii) pilot upscaling of new RCTs to support mainstreaming including direct seeded rice, upscaling of 120 day short duration rice etc; and (iv) upscaling of adaptive research and pilots for RCTs; and (v) adaptive research and upscaling of temperature tolerant crop varieties.

436. Resource conservation technologies (RCTs) are now quite well researched and there is sufficient basis to implement a full upscaling of tried and proven RCTs together with pilot upscaling and more intensive trials of RCTs not fully endorsed. Mechanisms to enlist farmer support for RCTs will be required to be identified, most of the RCTs although reducing water demand have fairly limited financial benefit to the farmer. Linkages have to developed where support for new cropping and marketing systems are made with some conditionalities to ensure some parallel uptake of resource conservation. Pilot RCTs can be initially subsidised to bring them into the mainstream. These could requried as conditionalities for Government support or by regulation or a mixture of both. Evaluations of the RCTs is required to assess the impacts on the conjunctive water balance, farmer acceptability including assessment of farmer returns, risk etc.

437. Micro Irrigation offers good potentials to improve conjunctive use efficiency, improve yields, financial returns and reduce the quantities of inputs. Micro irrigation also offers potential ways forward to support the diversification from rice. The advantages and farmer preferences of sprinklers and drip need to be assessed but the higher water efficiencies, yield potentials and lower energy requirements of drip would appear to make drip more attractive than sprinkler. Other

pipe systems such as gated pipe and furrow irrigation should also be tried. There are constraints in the take up of micro irrigation due to the high costs. Subsidies from central government are available and are topped up by state government; however the subsidies for micro irrigation are lower in Punjab than other states. There would appear to scope for private sector partnerships for suppliers of micro irrigation to do more to source credit and provide extension support.

438. Power management is an important way towards conserving both water and power. Well researched power management can support groundwater conservation and also free up government funds that can be better applied in other areas. Supporting the use of more efficient pumps should be explored. Minimising power consumption is a parallel requirement to be a part of the planning process, stabilising the groundwater level probably offers significant potentials for power conservation. Component 2 is summarised in Table 40.

Table 40: Upscaling of Resource Conservation Technologies

Overview	Upscaling of resource conservation technologies focusing on agriculture technologies and micro irrigation. Proven technologies would be upscaled to reduce water consumption as well as mainstreaming of new ideas and research initiatives.
Rationale	There is a portfolio of possible measures to conserve water resources. Farmer adoption of these technologies will require a major support programme. Further research into new technologies as well as crop research to develop varieties resistant to increased temperature and other climate change impacts is required.
Description	o Full upscaling of fully researched and accepted RCTs to reduce water resource losses. o Upscaling of micro irrigation and other high investment RCTs. o Support for mainstreaming of new RCTs and other research outputs. o Adaptive research for existing and potentially viable technologies.
Studies/ research	o Review of RCTs and assessment of viabilities. o Continued research into RCTs and mechanisms for upscaling. o Research into impacts on climate change on crops including development of crop varieties resistant to increased temperatures and CO_2 levels.
Outputs	o High take up of fully researched and accepted RCTs. o Medium upscaling of high investment RCTs including micro irrigation. o Mainstreaming of selected partially accepted RCTS. o New viable and researched new RCTs ready for upscaling. o New seed varieties with increased resistance to temperature increases and other climate impacts.
Implementing Agencies	o Department of Agriculture . o Punjab Agriculture University o Private sector

Component 3: Water Resources and Catchment Management

438. Water resources and catchment management will focus on supply and water quality management and will include the following; (i) saline water management in the southwest zone; (ii) water quality management to reduce pollution levels in surface and groundwater; (iii) integrated catchment management together with development of artificial recharge to support groundwater recharge; (iv) rehabilitation of village ponds, wetlands and other water bodies to support recharge; (v) improved irrigation management to improve efficiencies and levels of service delivery; and (vi) urban water conservation and management including sustainable drainage, water harvesting, leakage control and water reuse.

440. Saline and water logged areas in the south west of Sirhind would be brought under salinity water management. Options include; (i) use of multiple well points; (ii) conjunctive use of canal water and poor quality groundwater; (iii) bio-drainage to lower ground water levels through planting of highly transpiring and salt tolerant Eucalyptus species; (iv) sub surface drainage; and (v) brackishwater fish farming. Other water quality issues will be addressed by effluent management and treatment including agricultural, industrial and domestic effluents.

441. Catchment management and artificial recharge offer scope to support recharge of the groundwater. The lack of unutilised water resources limits the scope for Artificial Recharge(AR) and would likely only compensate a fraction of the groundwater deficit. Technical and financial viabilities need to be better assessed to select the most cost effective measures. Rehabilitation of village ponds and wetlands offers scope to increase the scale of Artificial Recharge. Improved coordination and support for catchment management of the upper catchment in Himachal Pradesh is required to reduce the flood flows in the tributary rivers as well as to reduce the sedimentation of the Bhakra reservoir.

442. Efficiencies in the management of the surface water irrigation could be achieved through review of the irrigation and water supply scheduling to better meet the needs of crops at different stages of development and reducing the allocation

during the lean crop periods. Excess water during the lean period could potentially be used for groundwater recharge in spreading basins. Improved measurement and more accurate water allocation could be achieved by the use of fixed measurement weirs at canal headworks and ensuring design water levels are maintained in the canals to allow more accurate surface water allocations.

443. Urban water conservation and management offers potential to reduce runoff and increase infiltration. New urban water reuse technologies need to be piloted including the increasing use of effluent soakaways (sceptic tanks) to support groundwater recharge.

444. Surface water conservation in the pre kharif Season (March to end May) needs to be assessed; during this period crop demands are less but evapotranspiration is at its highest. There are some needs to meet operational demands of hydropower, drinking water and land preparation for cotton. Indications are that there maybe some excess surface water during this lean period that could be used to promote recharge. Increased retention of water in the Bhakra reservoir to allow for increased allocation to the Kharif crop may be an option if the needs of hydropower can be met.

445. A summary of component 3 is given in Table 41 below.

Table 41: Water Resources and Catchment Management

Overview	Implementation and strengthening of integrated management of water resources and the catchments to support sustainability and conservation of the scarce water resources and address issues of water quality.
Rationale	There is no scope to develop new water sources and additional water availability must be through water resources and catchment management. Water quality issues require to be addressed in parallel.
Description	o Design and implementation of saline water management programmes. o Implementation of water quality projects including water treatment and enforcement of water quality regulation. o Integrated catchment management and artificial recharge investments including rehabilitation of ponds and wetlands through devolved community approaches. o Investments in surface water irrigation to increase efficiencies focusing on measurement and improving water allocations. o Urban water conservation projects (rainwater harvesting, leakage control, water reuse etc)
Studies/ research	o Modelling of the surface and groundwater systems to assess scenarios to meet the needs of sustainable water resources. o Assessment of conjunctive water use efficiencies and potential to improve the management and service delivery of the surface water supplies for irrigation, industry and potable water supplies to better meet needs of crops and development. o In depth studies of the snow and glacier systems to better assess long term hydrological trends in the Sutlej river. o Implementing an integrated water systems analysis of the surface, groundwater, snow and ice and reservoir systems and economic assessments of different scenarios. o Technical, economic and environmental studies to assess viabilities of various catchment and artificial recharge options, including rehabilitation of village ponds and wetlands. o Studies and design of saline and other water quality management interventions. o Assessment and development of improved surface water management for irrigation, water supply and industrial needs. o Planning and design of subprojects.
Outputs	o Improved surface water availability from optimisation and efficiency measures. o Improved agricultural production in the saline areas through integrated drainage. o Reduced surface and groundwater pollution. o Reduced runoff and increased recharge through catchment management and artificial recharge. o Rehabilitated water bodies, and village ponds to support recharge. o Improved control and management of surface water irrigation to improve efficiencies. o Reduced runoff and water demand from urban areas though sustainable drainage, water harvesting and water reuse.
Implementing Agencies	o Department of Water Resources o Department of Agriculture o Urban Local Bodies

Component 4: Institutional, Regulatory and Support Measures

446. The effective implementation of the other components requires to be supported by a series of initiatives relating to water governance. The present institutional, financial and legal frameworks are not adequately directed to meet the needs of water resources and catchment management. Under this component six key activities are proposed; (i) establishment of IWRM; (ii) agreed support and financing arrangements to meet targets of water conservation and climate adaptation; (iii) agreed power management strategy for agriculture; (iv) agreed regulatory framework; (v) water resources data management; and (vi) intensive training support for awareness of stakeholders at all levels.

447. **Establishment of IWRM:** The requirements have to be fully defined; but institutionally this would include the establishment of; a water regulatory authority, a state water resources committee, an IWRM unit to be established within the Water Resources Department and operationalising of the District Planning Committee and the District Sector Departments implementation programmes. Water resources planning would be based on the sub-basin plans. The institutional proposals are elaborated in the India Water Systems report. Also included will be strengthening and empowerment of the Bhakra Beas Management Board to improve river basin management.

448. **Agreed Support and Financing Arrangement:** The implementation of water conservation and climate adaptation require a portfolio of investments and programme support measures. To implement these requires an agreed approach to financing and support. There is a need to address wider areas of agricultural subsidies to move from blanket subsidies and price support to more focused subsidies to meet conservation targets. A review the MSPs is proposed and will require to be coordinated with central Government. The potential role of soft PPP to support some of the conservation and productivity programmes needs to be explored. Appropriate public-private sector or community-private sector partnerships offer new opportunities which would not be fully feasible by the government alone.

449. **Agreed Power Management Strategy** is critical to reduce groundwater wastage, reduce the financial costs of subsidised pumping together with requirements to reduce energy wastage. The need to bring in some form of charging system is seen as critical to the conservation strategy. Charging linked to the actual power consumed would have the greatest impact on conservation; prepaid meters are a possible option. The agreed approach and enforcement would be a part of the remit of the water regulatory authority. Farmer support is required and consideration should be given to establishing agricultural power cooperatives with part of revenues earned directly used to target improved conservation and productivity programmes. Upgrading of power supplies and improved power availability is seen by farmers to be an important requirement; experience in Gujarat has shown that pumping wastage can be reduced by improved and more reliable power supplies. Improving power supplies in return for farmer agreement to accept power management initiatives would appear to be a logical approach. The value to farmers of adequate water available exactly at the correct time is significant with significant potentials to improve yields. The use of tensiometers is being promoted by PAU and supported by the Columbia University Research Institute, have demonstrated the potential water savings and yield benefit from correct and timely applications of water. However, without any financial incentive for the farmer to conserve and erratic water supplies water the application of tensiometers may be limited. The increasing number of diesel pumps indicates the value to farmers of having water available when required. Farmers report significant reduction of pump life due to voltage fluctuations. The potential for power cooperatives linked to the agricultural cooperatives may offer a potential way towards power management.

450. **Agreed Regulatory Framework:** A stronger regulatory framework is required to work in parallel with the various support initiatives. New ideas and pilot projects can be supported by subsidies. However, at some stage there is a requirement to bring in regulation to reduce wastage and ensure the long term sustainability of the water resources. Regulation will have to come in slowly and will have to be balanced by support measures and improved productivity to offset any loss of farmer income.

451. **Water Resources Data and Management Systems** are required to support the planning and management of water resources. The development of a GIS based integrated water resources information system with access to information on surface, groundwater, snow and glacier resources, catchments, forestry, and environment is required. Information on development, including hydropower, irrigation, water supply, agriculture, industry etc., and flood risk, is also required. Data on finance and project benchmark monitoring and evaluation is a further requirement. The development of information and management systems should build on ongoing information and studies being developed by the different sectors including the Punjab Remote Sensing Centre.

452. **Training and Awareness:** the programme requires to be supported by an intensive programme of training and awareness. Areas to be addressed include understanding of importance of sustainability of surface and groundwater

resources, the potential impacts of climate change and identification of areas of vulnerability. Communities have to be made aware of climate change impacts as well and their capacity for self help to adaptation increased and dependency on government reduced.

453. Component 4 is summarised in Table 42 below.

Table 42: Institutional, Regulatory and Support Measures

Overview	Establishment of institutional reforms together with regulatory and support initiatives will be required to effectively implement the programmes of productivity, resource conservation and water management.
Rationale	The present institutional and management systems are not adequately focused towards the needs of integrated water resources management, conservation and productivity. Large scale take up of necessary conservation measures will require to be subsidised or regulated or a mixture of both.
Description	o Establishment of IWRM through improved coordination of sector departments through a water resources steering committee, an IWRM unit, a water regulatory authority and empowerment of the districts. o Agreed financing strategy to better support targeted initiatives for conservation and productivity. Promotion of appropriate PPPs to support productivity, marketing and conservation initiatives. o Agreement and pilot introduction of a power management strategy. o Agreed regulatory framework and support for phased introduction in parallel with support measures. o Establishment of an integrated water resources information system. o Training and provision of awareness material to support awareness of water resources sustainability and adaptation to climate change. o Strengthening and empowerment of the Bhakra Beas Management Board to manage the whole Sutlej River Basin.
Studies/ research	o Participative studies and consultations to support the development of IWRM o Consultation and studies to support financing strategy. o Review and consultation to support power management strategy.
Outputs	o Functional IWRM strategy in place. o Agreed and targeted financial management of investments and programmes. o Agreed power management strategy in place. o Phased regulatory programme in place.
Implementing Agencies	o All water resources and water resources related sectors, Senior State Government

H. Road Map

1. Lower Sutlej Sustainability Programme

454. It is proposed to establish a 'Lower Sutlej Sustainability Programme ' to address ongoing development, environmental and potential climate issues of the Sutlej River Basin in Punjab. The programme would put into place wide ranging initiatives, programmes and investments to meet the needs of highly effective agricultural productivity and marketing systems, resource conservation, water resources and catchment management and institutional reforms, support and regulation.

455. The programme will be based on an IWRM approach; with a focus to address the sustainable development of water resources whilst addressing the issues of agricultural production, marketing and resource conservation. The sector departments presently lack the flexibilities, capacities and level of integration required to meet the project objectives and an IWRM institutional framework would be established, including the formation of a state water resources committee, an IWRM unit, a regulatory authority, and empowerment of the district planning committee and district level sector agencies. The programme focus would be in two parts; (i) investment and support programmes in the Sirhind Command Area which

is the largest area supplied from the Sutlej river and (ii) institutional, regulatory and support measures directed at the whole state.

456. An eight year programme is proposed and would be implemented through an IWRM framework. The programme would be integrated, involving and working closely with the key water sector agencies, the district administrations and private sector partners. The programme would work under the direction of the Water Resources Steering Committees but working closely in coordination with the sector departments at State and District level, District Administrations and Panchayats. The programme is designed as an integrated programme and each component requires cross cutting support from the other components so it is critical the programme incorporates all four components.

457. The programme will implement field level support programmes within all the districts of the Sirhind command area. In parallel the programme will address institutional and reform measures over the water sector departments over the whole of Punjab state. The establishment of IWRM and institutional reforms is critical towards the long term sustainability of water resources in the State. Institutional reforms would be implemented in stages and would include the establishment of an independent water regulator.

2. Programme Organisation

458. It is proposed that the programme work closely with the Government Departments but should be semi autonomous with it own operating and investment budget. As a multi sector integrated project there is a need to coordinate planning and policy decision through a 'Water Resources Steering Committee ' made up of the principal secretaries of the key water sector agencies (Water Resources, Agriculture, Rural Development, Horticulture, Cooperatives, ULBs and Environment).

459. Coordination and optimum use of the different funds would be important. These would include Mahatma Ghandi National Rural Employment Guarantee Act (MNREGA) funds, and Central Government funds.

3. Requirements for External Support

460. The programme would require external specialist support to complement the existing skills of the government and government corporation staff. One key objective of the programme is to bring in the development of new ideas and technologies that might be applied to support the development and sustainability of the Sutlej river. It is estimated that specialist support would be required for all four components.

4. Programme Scope

461. The programme would involve a mixture of studies and consultation, planning, sub project design, community liaison and participation, institutional development, and reforms. The focus of investment would be the Sirhind Command Area however wider institutional strengthening and reform would be taken up to the whole state.

5. Investment and Support Programmes

462. Possible areas of investment and support are summarised in Table 43. The programme implementation would require supplementary investment support as well as ensuring coordination of the direction for other ongoing programmes, such as MNREGA. Financial support would be required for investment as well as specialist inputs for research, planning, design and training.

Table 43: Possible Areas for Investment and Support

IMPROVED AGRICULTURAL PRODUCTION AND MARKETING SYSTEMS	
1.	Improved infrastructure for crop marketing including crop processing, marketing, access roads.
2.	Establishment of market information systems, training in marketing.
3	Funding support for soft PPP initiatives to improve production and marketing.
4.	Support packages for mechanisation, diversification and other production initiatives.
UPSCALING OF RESOURCE CONSERVATION TECHNOLOGIES	
5.	Financial support packages to upscale and mainstream viable RCTs.
6.	Support for private sector support partnerships to implement RCTs.
7.	Financial support for upscaling of micro-irrigation.
8.	Investment in improved electricity supply for agriculture (improved voltage stability and supply and introduction of mechanism for cost recovery).
WATER RESOURCES CONSERVATION AND MANAGEMENT	
9.	Support for saline water management projects in the south west.
10.	Investment in pollution control including water treatment.
11.	Investment in decentralised catchment management and artificial recharge.
12.	Rehabilitation of water bodies including village ponds and wetlands.
13.	Investment in surface water management systems; focusing on improved water measurement and allocation systems.
14.	Investment for urban water management including leakage control, rainwater harvesting, sustainable drainage and water reuse

6. Follow on Studies and Operational Research

463. Subject to agreement and endorsement of the report, it would be necessary to implement a programme of follow-on studies and design of selected pilot projects. These would be feasibility studies to verify the technical and financial viabilities of the proposals including extensive consultation and participation at all levels to ensure acceptability. Visits to other parallel projects would be important to discern the lessons learnt. Based on the outputs of the studies, it is proposed to implement some pilot projects to validate the proposals and make adjustments before embarking on up-scaling. Regular review of the strategy is proposed based on monitoring, studies and improved climate projections.

464. The implementation of the plan will require well coordinated activities including studies, participative planning and policy decisions, and implementation of programmes. At this stage, the plan is preliminary and would require careful review by the Government of Punjab. More work is required to technically assess and define all the options, before moving onto detailed programme design, subproject design and implementation. At present there are major gaps in the understanding in the current water systems as well impacts of climate change, to fill this gap it is proposed to improve decision making through advanced analytical techniques.

465. **Proposal for Operational Studies and Research for the Sutlej Water Systems;** there are major gaps in the understanding of the Sutlej water systems including: (i) poor information on the hydrological response to snow and glacier melts; and (ii) limited understanding on the conjunctive surface and ground water systems and how water management and conservation can be applied to develop sustainable water systems. It is proposed to develop an operational research study to:

(i) improve the assessment of the medium and long term hydrological response to changes in glacier and snow melt. The study would focus on the upper catchment in Himachal Pradesh and would provide improved assessment; of glacier mass and mass balance changes using remote sensing supported by ground truthing, use of ice penetrating radar to measure glacier thickness and improved modelling of glacier and snow melt;

(ii) implement conjunctive water use studies in the Sirhind Irrigation System including; surface and groundwater modelling, agriculture studies and community consultations to assess alternative cropping and other water saving initiatives to conserve water. Socio economic and institutional studies would be implemented to assess the viabilities and appropriate mechanisms for meeting water sustainabilities; and

(iii) implement a integrated water systems analysis for the Sutlej River using a water model such as WEAP to represent the evolution of surface water and groundwater supplies based on simulated hydrological processes, incorporating the glacier/snow and conjunctive use studies. The model would simulate the evolution of demand based different management scenarios for agriculture, irrigation, water supplies and hydropower and economic assessments of different scenarios. Supply management would include optimisation of the Bhakra reservoir as well as studies to assess the potentials for artificial recharge. Proposals for improved surface and groundwater management would be developed from the analysis.

466. The outputs of the operational research will be tailored to be directly applied to the detailed design of the programme and the design of the various component and sub projects. The study would build on parallel studies by the HP2 project for flood operation of the Bhakra reservoir as well as studies by Punjab Agricultural University and IWMI. An eighteen month programme is proposed. It is proposed that the operational studies are taken up as soon as possible to allow the outputs to be incorporated into the planning and implementation of the main programme.

7. Selection and Design of Sub Projects

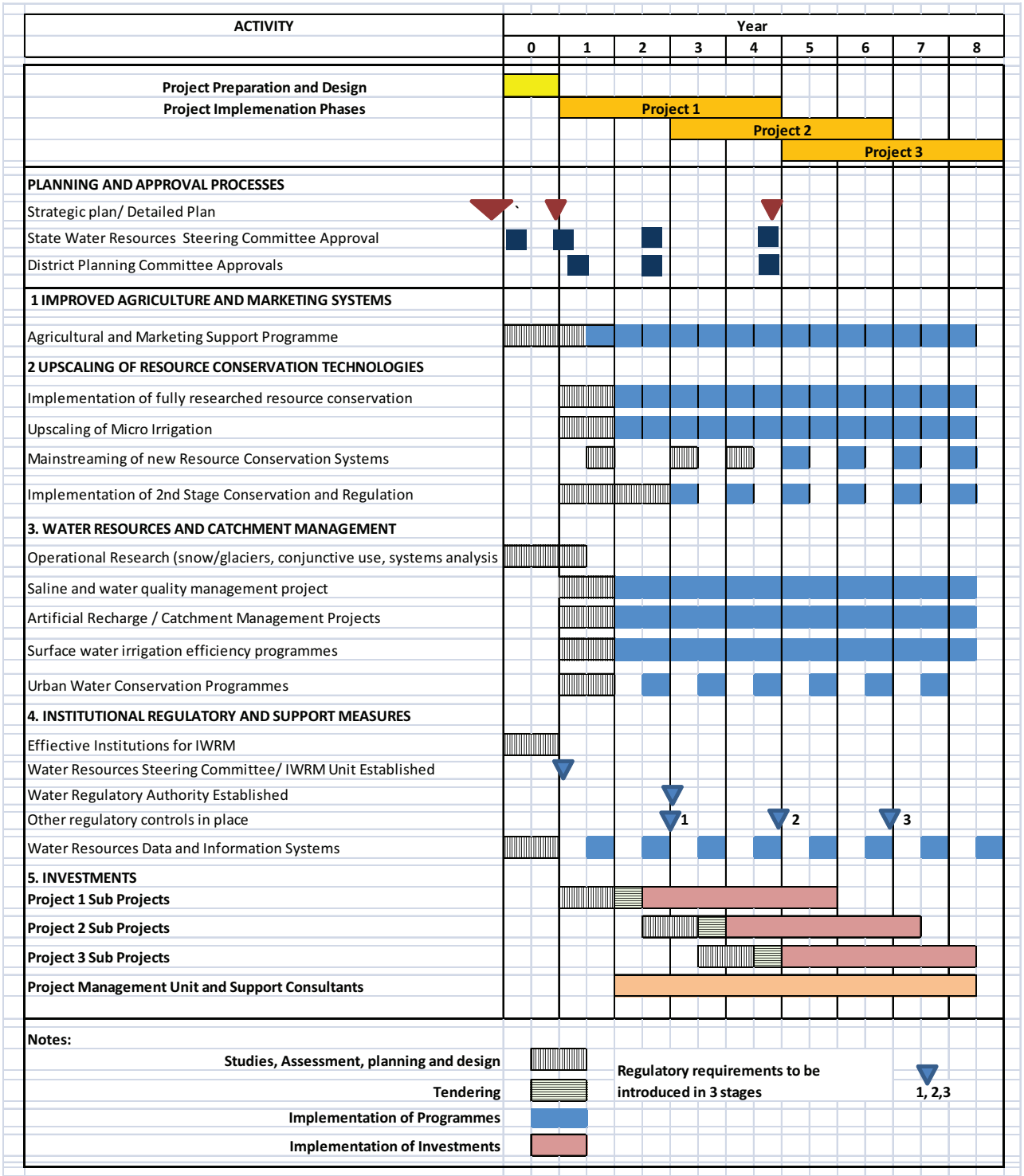
467. Sub projects and programmes would be selected to be taken up based on follow on detailed planning and project preparation. Sub project design would incorporate factors to accommodate climate impacts; for example projected increases in rainfall and intensities might require increased capacities for drainage.

8. Project Schedule

468. The proposed project schedule is summarised in Figure 24. The project is proposed to be run in three phases over eight years. Sub-projects would be identified, planned and designed for Project 1 in year zero with implementation over four years. The need for IWRM and sustainability reforms in place is critical and three stages are proposed including the

establishment of an independent water regulatory authority by end of year two. Water conservation measures would be phased in working in the early stages on tried and accepted measures and gradually upscaling the necessary measures to meet the necessary targets.

Figure 24 Project Schedule Lower Sutlej Sub Basin



Kshipra Sub Basin, Madhya Pradesh

IV. KSHIPRA SUB BASIN, MADHYA PRADESH

A. Sub Basin Profile

1. Introduction

469. The basin has flat topography and very gentle slopes varying from 1 in 1,000 to 1 in 3,000. The entire region is covered by black cotton soil and yellow soil with high clay content. The depth varies from 2 to 5m and after that murrum and disintegrated rock layers are found. Hard rock is found in depth. Recharging of ground water is supported by flat topography and gentle gradients. The population of Kshipra Basin was 1.99 million in the year 2000, of which the rural population was 0.61 million. The population growth rate is about 3.7% per annum. The projected population for 2025 is 3.47 million, of which 1.06 million is expected to be rural.

470. Water shortage is a major issue in the Kshipra: with very limited surface water, groundwater is the key resource and groundwater overexploitation in some parts is a key challenge. Although the yield of surface water from the catchment is more than the area's total human requirement, most of this water is lost as the rainfall in the area is restricted to 3-4 months of rainy season and during monsoon most of the surface water flows down unutilized.

471. The River Khan, a significant tributary of Kshipra, carries sewerage, highly polluted-untreated industrial and the domestic waste of Indore town and nearby areas. It joins Khsipra near the village of Mundla, in Sanwer tehsil

2. Surface Water Resources

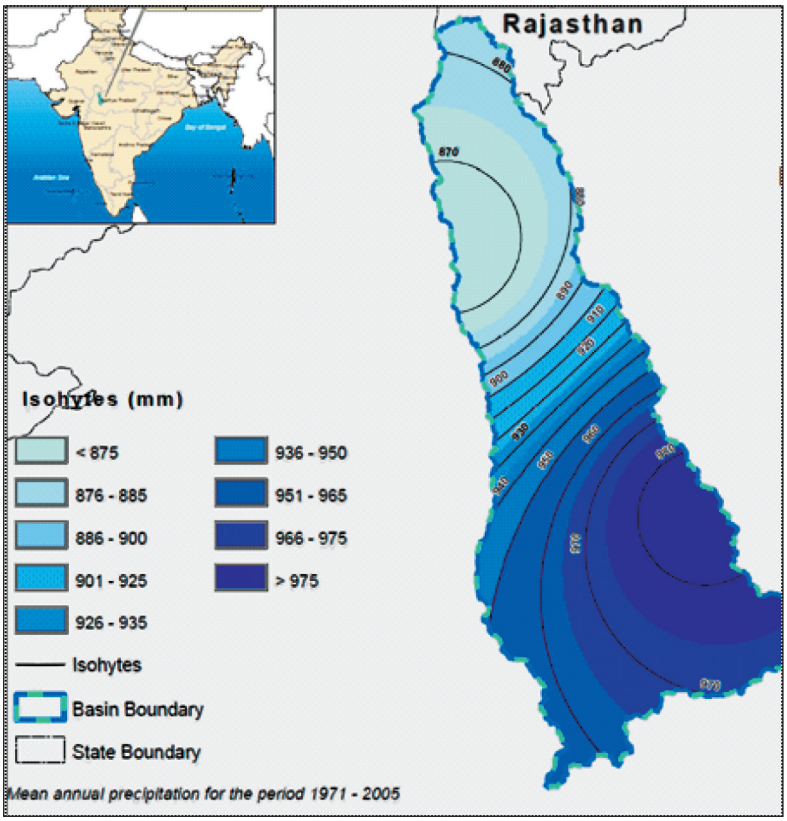
472. The Kshipra sub basin is located in the Malwa Plateau in western Madhya Pradesh (MP). It has an average altitude of 553 meters above the mean sea level (MSL), at a latitude between 22° and 24° N and longitude 75° to 76° E. It is a tributary of the north-flowing Chambal River, originating at an altitude of 560 meters from a hill near Kampell in southeast of Indore district. Flowing from south to north, it traverses 195km to meet Chambal River at the Rajasthan border at an elevation of 440 meters above MSL. The river is one of the holiest rivers in Hindu mythology, and is considered important because it flows by the side of Ujjain city, a holy shrine. The Kshipra sub basin is shown in Figure 25.

Figure 25 Kshipra Sub Basin

473. The catchment area of Kshipra Basin is 4,751 km^2 and is fed by 2 major tributaries, the Khan and Gambhir. These rivers meet Kshipra at 70km and 120km from the origin of the river respectively. The catchment area of these two rivers are 763km^2 and 1,400km^2 respectively, with independent lengths of 64km and 160 km respectively. In the initial reaches, it makes the boundaries of Indore and Dewas districts and then passes through Ujjain, Ratlam and Mandsaur districts of Madhya Pradesh. The basin consists three major cities, namely Indore, Ujjain, and Dewas, having municipal corporations, and also includes several panchayats.

474. **Climate:** The southwest monsoon is the main source of precipitation in the Malwa region. The average annual rainfall, based on the records of the last 100 years, is about 900mm, over 90% of the annual rainfall is received between mid June and mid October. The rainfall is uniformly distributed over the entire catchment area. The minimum and maximum temperatures vary between 6° C and 43° C. The normal average temperature is 26° C. The climatic seasons are moderate. The mean precipitation is shown in Figure 26.

Figure 26: Kshipra Mean Annual Precipitation



475. **Water Quality:** the tributary streams of Kshipra are heavily polluted with untreated urban and industrial waste. There are high levels of nitrate and fluoride in some of the groundwater. 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. The basalt rock and poor porosity also affects the operation of sceptic tanks in some parts.

3. Groundwater Resources

476. **Geology and Groundwater Potential:** The major geological formation is basaltic rocks of diverse origin, with horizontally blanket sheet like Deccan flows covering nearly 80% of the total area. The groundwater occurs within the weathered and fractured zone of underlying multi-layered hard compact basalts. As a result, the groundwater resources in the region are quite variable both in quantity and quality. The groundwater occurrence is divided into four zones, namely:

- Surface zone: ranging from ground level to about 0.5m depth with poor groundwater availability;
- Intermediate weathered aquifer zone: located at a depth of 15-40m. This zone dries in summer due to overexploitation;
- Confined aquifer zone: this is the most potential and prominent water bearing zone found up to depth of 135m. Most of the villages in Malwa depend on this zone for water supply during summer months; and
- Valley fill zone: poor availability of water due to limited thickness and aerial extension

477. The district wise position of groundwater availability in the district of Indore, Dewas and Ujjain covering Kshipra sub-basin is given in Table 44. 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 44.

Table 44: 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 blocks
Dewas	927	46	881	585	66	0
Indore	598	30	569	594	104	2
Ujjain	834	42	793	864	109	3

478. The major expansion of groundwater irrigation has provided significant benefits to the communities, and there is now a large dependency on irrigated agriculture from groundwater to meet household income requirements. Groundwater depths now require the use of submersible pumps because of increased pumping depth. Groundwater resources are depleting, but the rate of depletion is not uniform: in eight out of 16 blocks, the situation is over exploited and critical (>90% stage of GW development), and the other areas fall into semi critical or marginal categories. The stage of development is shown in Table 45 below.

Table 45 : Number of Blocks and Stage of Groundwater Development

District	No 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

479. 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.

4. Agriculture

480. At least two crops are harvested by farmers. The main crops are wheat, soya been, sugarcane, vegetables, grams, groundnuts and other seasonal crops.Major constraints for agricultural activities include hot summer months, low humidity, high evapotranspiration and meagre rainfall during winter and summer months. Irrigation watering is provided mostly through tube wells. The level of groundwater development in relation to the sustainable yield is 104% in Indore, 64% in Dewas and 109% in Ujjain. Individual blocks have significantly higher stages of development. Decline of the groundwater table is becoming a problem in many areas, but not everywhere. 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 are: (i) conservation of water; (ii) recharge of groundwater; and (iii) efficient use of irrigation water. Discussion with farmers[67] revealed that farmers are well aware of the issues of overexploitation, partially aware of water conservation techniques and the linkages to sustainability, but are less aware of the details and the opportunities of new technologies.

481. The classification of land use is as shown in Table 46 below.

Table 46 Kshira Land Use

Geographical Area km²	Forest Land %	Land not available for cultivation%	Fallow land %	Uncultivated Land %	Cultivable land %	Degraded area %
4751	14.85	8.87	1.13	1.58	73.57	4

5. Rural Water Supplies

482. Rural 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. Rural sanitation is poor with 91% of rural households without access to any form of toilets. The urban centres suffer similar problems: in Indore, water from the town supply is severely rationed. The main cities of Indore and Dewas obtain their water supply from the Narmada River throughout the year, which is very costly due to the high pumping heads.

B. Strategic Framework to Address Current Issues

483. The approach for this study is to: (i) assess and prepare a strategic framework to meet present 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.

1. Farmers Perceptions

484. Farmer perceptions have been derived through the participatory rural appraisal carried out by the consultants in 2011. The farmers in the Kshipra have shown that, in general, they are well aware of climate change, and have observed changes in temperature and precipitation but did not report any major impacts. They have observed delays in the start of the monsoon, as well as frost, which in 2010 caused damage to crops. Farmers reported drops in the water table which

[67]NAPPC S-NWM Participatory Rural Appraisal 2011

they partially thought was due to climatic changes including high temperature, erratic rainfalls and increased evaporation. Stakeholders mostly believe that climate change will have perceptible impact on their livelihoods through its effects on agricultural production, human health and livestock. The main areas of vulnerability to climate change are seen to be the agricultural sector and drinking water supply. Other points raised include the need to support watershed works, organic farming, roof top harvesting, lack of maintenance of drainage and support for desilting of ponds and drains.

485. Communities identified a large number of possible mechanisms to support resilience and reduce vulnerabilities to climate change. These include enhanced access to drinking water and irrigation. Drinking water access was a first priority for women groups. Tank irrigation is seen to be very important with support to deepen tanks and construct new tanks. Poor maintenance of tanks is an issue. There is no WUA for the tank command areas in surveyed villages. Desilting of rivers and tanks is considered important; silt material thus removed could be used for road construction.

486. Climate change is beginning to affect farmers; although no very specific problems were identified there was frost in 2010 that led to crop damage. Increased temperatures and CO2 levels may impact on certain varieties of crop. Research and trials need to be implemented to support the development of the most appropriate cropping systems for the Kshipra basin. Support for improved weather forecasting can help farmers plan their cropping. Improved communication could be taken up at district levels and through local radio etc.

487. Farmers felt that drip irrigation should be better supported by creating more awareness amongst cultivators. The present subsidy for micro irrigation should be reviewed as farmers report the highest subsidies are made available only to low income 'Below the Poverty Line Farmers' (BPL) this arrangement excludes many farmers. The level of awareness among the farmers is very low about the new technologies, which may explain the slow rate of take up. In Dewas, some farmers have expressed doubt about the use of sprinklers for agriculture. However, in general, most farmers have supported the use of new technologies. Some larger farmers have directly purchased sprinkler irrigation but the technology needs to be improved for wider use. There is a need for improved training and subsidy on sprinkler and drip irrigation. While farmers showed interest in pipe irrigation for surface water, two problems need to be addressed: (i) the cost of irrigation pipe is very high; and (ii) the rivers dry up in the Rabi season which precludes the use of surface water irrigation. Other issues raised are summarised below:

(i) Many farmers felt that that recharging of groundwater should be made mandatory for all farmers, and roof-top rainwater harvesting should also be made compulsory. Farmers are very supportive of artificial recharge if a subsidy is provided. They also favour more plantation of trees which will improve soil conservation, reduce surface runoff and possibly increase groundwater recharge. There is huge scope of improving the water position through the National Rural Employment Guarantee Act (NREGA). It is not working well in the villages due to some lapses in the policy. There is much delay in the payment. The NREGA policy of not using machinery is causing strain on the labourers engaged in digging because of the hard rock of the region.

(ii) Water quality is an issue: water should be treated properly before it is released into the river.

(iii) Lack of dependable electric power is a major issue in all the districts. People generally receive 5-6 hours of intermittent electricity each day. Farmers are of the opinion that charges for electricity are already very high. Subsidy on electricity is not considered a critical issue; rather, farmers are more interested in subsidy on other inputs which are leading to cost escalation. They want direct subsidy coming to farmers.

(iv) Support Price: There was comment from many farmers about the absence of a support price for soya bean which is the major kharif crop in all districts. Even though there is support price for wheat, farmers are compelled to sell it to private traders in the market because of delayed payments from the Government. The farmers also want a support price for vegetables.

(v) Regulations on groundwater: there is still no regulation for groundwater use. Farmers have mixed views on this issue. Some feel that even without regulation, they will use the quantity of water that is needed. Others feel that regulation is needed to restrict overexploitation.

(vi) Farmers are supportive of short duration crops if the yield and returns are the same. Not all farmers are using short duration crops because of the non-accessibility to secure water supplies. Farmers have mixed feelings about these short duration and high yield crops because high value cash crops that require more water are not feasible in the region. Farmers have, in fact, abandoned sugarcane and cotton cultivation for this very reason.

(vii) More technical assessment is needed to understand feasibility of various options including the use of tanks for irrigation and groundwater recharge. Scientific methods should be used to better understand the groundwater potential.

(viii) Enhancement of non-farm income sources was seen as an important need to support adaptation.

(ix) It was considered that instead of a single solution, a portfolio of solutions is needed; conjunctive use with more groundwater recharge farm ponds, re-excavation of government ponds to enhance water flow, dams on *nallas* are all seen as important.

2. Surface Water Schemes

488. A number of schemes are currently under consideration by the state government and are relevant to this study. These include: (i) Kalisindh Chambal link project. envisages diversion of 820 MCM of water from Kalisindh to the Chambal. This water is to be utilized for the irrigation in the Malwa region and Ujjain district in Kshipra Basin. This project is not progressing due to failure to reach any agreement between Rajasthan and Madhya Pradesh on sharing of water and other issues; (ii) Narmada Irrigation Transfer Project was under consideration but with about a 300m lift it is not a viable option for irrigation supply; and (iii) the Narmada Water Supply Transfer Project: water supply for Indore and Dewas is currently under construction and there is now a proposal for a major new transfer project of Narmada water for drinking water to supply to 1,500 villages and 27 towns in Dewas, Ujjain and Shajapur Districts.

489. Other surface water projects include: (i) Sewarkhedi Dam located on the Kshipra, 22km south of Ujjain with estimated live storage of 157 MCM. The dam would provide supplementary water to Ujjain as well as irrigation of about 25,000ha; (ii) 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 18,000ha, the command area is largely the same as the Sewarkhedi project; and (iii) Chambal-Gambhir Link: a link canal from the Chambal river to be provided by a new diversion barrage on the Chambal to provide supplementary water for water supplies at Ujjain. The gestation time of surface water projects is long and it is important to directly address the issues of groundwater especially in the immediate term. These three projects potentially could however support provision of important supplementary water for multiple use through gravity supply.

3. Agriculture Options

490. There are various agricultural cropping options to reduce water demand including a move to high yield and shorter duration crops, adjustments to the planting calendar to optimise the use of rainfall and reduce evapotranspiration losses, mulching and other practices. With the present fixed electricity rates for pumping, there is no real incentive to economise on pump use. The participatory rural appraisal conducted for the study identified some reluctance to change to short term and high yield crops due to uncertainties in the irrigation supplies. For the groundwater, erratic power was quoted as an issue which increases risk and affects yield. Delaying the monsoon planting until June may offer some opportunities to better use the effective rainfall and reduce consumptive use. Mulching of crop fields is also becoming popular, which helps soil moisture conservation and reduces water demand by the crops.

491. **Farm level ponds:** Subsidies are provided by the government to the farmers for constructing farm ponds in their fields. Various programmes having different names are being supported by the Department of Agriculture; these include Khet Talab Yojna and Balram Talab Yojna. The water conserved in the ponds provides irrigation to the farm lands and effective groundwater recharge. For digging ponds under Balram Talab Yojna programme, every beneficiary is given a 25% subsidy, with an upper limit of Rs 50,000. While the tanks are becoming more popular, there is some reservation amongst smaller farmers who have to allocate scarce land for the tanks. The tanks are most effective on the areas of black cotton soils. NREGA is now supporting the construction of tanks for smaller farmers. Effective mechanisms to promote farm ponds and encourage pond use instead of tubewell use need to be explored.

492. **Micro Irrigation** schemes are becoming popular in the basin. Studies have shown that the financial benefits of micro irrigation schemes to farmers outweigh the costs involved, in addition to achieving water savings. The programme is based initially on a 40% subsidy from central government progress was initially slow. The state added a 30% subsidy for general farmers and 40% subsidy for small farmers and this has increased the rate of uptake. A precision farming development centre has recently been established in Bhopal. The farmers are using drip to grow a wide range of crops including crops not normally considered suitable with drip. It is reported that there is no real evidence that farmers are

switching their cropping patterns once provided with micro irrigation. The growth of sprinklers has exceeded drip, but this is thought to be largely due to the cheaper cost of sprinklers over drip. However, studies show that the water productivity of drip is higher than that of sprinkler. The major benefits of drip include: (i) water savings of about 50%; (ii) increase in the revenue from agriculture with about 20% reduction in labour costs; (iii) a 30% to 50% reduction in fertilizer and pesticide use; (iv) about 20% savings in power bills; (iv) a 2-3 fold increases in yield for many crops; and (iv) a reduction in weed problems and significant improvement in the quality of produce.

493. A recent study has shown that the spread of micro irrigation in the Ujjain, Dewas and Indore districts (Kshipra Basin) is quite low as compared to the adjoining districts in the state. Growth of micro irrigation is restricted due to the following factors: (i) despite the 70 to 80% subsidies, the costs are high (full costs are around Rs 35,000/ha~$800/ha) and affordability remains an issue; (ii) there is limited credit support from banks, high interest rates for private loans, and a lack of insurance support; (iii) there is widespread uncertainty about power supply; (iv) lack of awareness among farmers on crop selection and benefits of micro irrigation and a lack of assured market for produce; (v) drip is not suitable for wheat which is an key crop for the region; and (v) the long processing times for approvals for grants.

494. **Water Saving Benefits of Micro Irrigation:** 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 from evaporation. For groundwater systems it is important to examine the conjunctive surface and groundwater efficiencies; when considering conjunctive efficiency infiltration losses are not fully lost and provide groundwater recharge.

495. **Furrow irrigation** using gated pipe is a less well known option in India. Gated pipe is slightly less efficient than both sprinkler and drip, but is significantly cheaper and works at low pumping heads. By concentrating water into furrows it is possible to reduce evaporative and infiltration losses. The undulating terrain is Kshipra is appropriate for furrow irrigation.

496. Gated pipe and furrow is a system potentially appropriate for the Kshipra sub basin: it is less sophisticated and cheaper than drip and restricting the water to furrows reduces evaporative losses. Losses from furrow irrigation using gated pipe are largely infiltration losses, which in terms of conjunctive efficiency of the surface and groundwater are not lost to the overall system. Efficiencies of gates pipe can be improved by incorporating a system of surge irrigation.[68] It is recommended that economic studies be 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 for different water sources including; tubewells, farm ponds as well as canals which is not the case with drip or sprinkler systems which only operate with very low levels of suspended solids.

4. Groundwater

497. Groundwater in the Kshipra Basin is derived from weathered Deccan Trap basalts. Their characteristics are variable. Typically they have relatively low water storage, which has impacts for sustainable groundwater management and artificial recharge opportunities. In groundwater or combined surface and groundwater systems, it is very important to incorporate the 'conjunctive surface and groundwater' efficiencies into the assessment which are significantly higher than surface water efficiencies. Groundwater availability is very varied depending on the degree of fracturing or weathering of the hard rock basaltic formation.

498. **Groundwater Issues:** 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 polluted with untreated urban and industrial wastewaters. Nitrate and fluoride levels are high in some areas. The Kshipra River has become ephemeral and runs dry for periods of the year. This paucity of water limits other uses including dilution of wastewater discharges, environmental flows and surface water extractions.

499. The basin districts of Dewas, Indore and Ujjain are under significant stress due to expanding groundwater extractions due to strong dependence by stakeholders on use of groundwater resources. A summary[69] of the over-exploited and critical blocks is given in Table 47.

[68]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.
[69]from Central Ground Water Board

Table 47 : Overexploited Block Summary

Districts	District/ Block	Net Annual Ground water Availability (MCM)	Gross Draft for irrigation (MCM)	Gross Draft for Domestic & Industry (MCM)	Total gross draft (MCM)	Stage of GW development (%)
Dewas	Dewas	164.1	151.3	5.6	156.9	96
Dewas	Sonkutch	100.7	95.1	2.4	97.5	97
Indore	Indore	163.7	211.6	12.1	223.7	137
Indore	Sanwer	131.2	170.5	3.7	174.2	133
Indore	Delapur	128.7	117.0	4.1	121.1	94
Ujjain	Ujjain	105.9	150.1	2.8	152.9	144
Ujjain	Ghatia	82.7	81.0	2.3	83.4	101
Ujjain	Badnagar	162.7	269.3	4.8	274.1	168

500. The aquifers of the Kshipra sub basin are in a highly stressed condition. For the continued and sustainable use of this scarce resource, a combination of supply and demand measures will be required within an overall context of better conjunctive use of surface and groundwater.

501. **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. In the weathered basalts with variable and low storage, recharge opportunities can differ significantly depending on the degree of weathering and fissuring. Focused and localised recharge initiatives to meet specific local needs potentially offer better opportunities than a blanket basin wide programme.

502. The CGWB Master Plan for groundwater recharge has estimated that 14 MCM and 32 MCM could be recharged in the Kshipra and Ghambhir Basins respectively through a variety of gully plugs, gabion structures, contour bunds in the upper reaches of the watersheds, percolation tanks, nala bunds in the runoff zones and recharge shafts, and gravity head wells in downstream areas. This would provide approximately 2% of the sustainable draft of the three Kshipra districts.

503. To support the possible efficiency/economic benefits of artificial recharge it is necessary to make full assessments to more accurately delineate potential recharge zones and to evaluate most promising sites in advance of any investment.

504. **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. Anthropogenically derived contaminants such as nitrate should be reduced or eliminated at source. Unlike the alluvial formation the basalt groundwater provides minimum filtering and contamination from faecal and other contaminants is a high risk. Increased mineral salt in the groundwater maybe occurring due to overexploitation of groundwater, pollution and infiltration from irrigation runoff . Leaching of agro chemical fertilisers and pesticides is becoming an increasing issue.

505. Strengthening groundwater management include: (i) a need to link the current approach to groundwater resource assessment with more hydro-geologically sound approaches; (ii) different methodologies for quantifying groundwater recharge should be field-tested in pilot areas to confirm the viabilities and improve the current methodology for groundwater resource assessment; (iii) capacity building 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.

5. Proposal to Balance Irrigation and Water Supply Demands

506. A preliminary proposal to bring the groundwater abstraction to sustainable levels whilst meeting the demand of future water supply and irrigation is shown in Table 14. The figures are indicative and would need to be further refined and researched. The proposal is directed at reducing the irrigation draft through water efficiencies which would free up more groundwater for water supplies. Water balance modelling of surface and groundwater through the WEAP or similar model is proposed.

507. In the hard rock aquifers there is extreme variability in yields and safe levels of abstraction. Eight blocks with abstractions greater than 90% are identified as critical. A stage of development of 70% to 80% is targeted for the typical aquifers in the Kshipra.

508. To meet the needs of over-abstraction, it is proposed to: (i) introduce more efficient irrigation distribution for tubewells; (ii) develop other water saving initiatives including delayed planting, shorter duration crops, improved power supplies and some level of restriction on groundwater use; (iii) development farm level ponds and village level tanks which can be used as alternative water sources.

509. Development potential of surface water irrigation is quite limited but if technically and economically viable should be taken up for development and would provide additional water resource. The proposed Khan reservoir and Sewarkhedi dam should be studied in more depth. These projects could potentially provide important additional supplies to Ujjain for drinking and industrial use, support environmental flows in the Khan river, provide surface water irrigation and support groundwater recharge. The proposed Chambal-Ghambhir river link would appear a good low cost solution to provide some supplementary water supplies to Ujjain; the transfer would be non perennial as the Chambal dries during the summer period. The proposal should be assessed in more depth.

510. There is a potential for water transfer from the Narmada river. For irrigation the capital and operational costs due to the high lift (around 300m head) would be extremely costly and not a viable option. The Narmada water scheme to supply Indore is in operation, with on-going expansion works supported by ADB provide the only real option to meet the very high water needs of Indore city; it is assumed that all long term needs for Indore city and the Indore peri-urban areas would be supplied from the Narmada.

511. **Narmada Multi VIllage and Town Transfer Scheme:** There is currently a proposal for a new Narmada transfer scheme to provide potable water from the Narmada to supply villages and towns in Dewas, Ujjain and Shajapur Districts[70]. The project cost is estimated at around Rs3000 crore ($650 million) and involves lifting water about 400metres from the Narmada river at Nemawar. The scheme would have capacity of 700mld provide about 180 MCM per year to 1500 villages and 27 towns in Dewas, Ujjain and Shajapur. From data on groundwater of the 16 blocks in the three districts of Indore, Ujjain and Dewas all the blocks except 8 critical blocks would be able to meet the needs of potable water to 2035. It is understood that the groundwater situation in Shajapur district is overexploited with the stage of groundwater at 114%, the district has five overexploited blocks and one critical block.

512. The total demand for the eight critical blocks in Indore, Dewas and Ujjain for potable water and industry is estimated to be 77MCM; assuming Indore city needs are met by the existing Narmada transfer then the water supply demand for the remaining seven blocks is 38MCM. The potential savings of irrigation management and conservation (micro irrigation, farm ponds, management) is estimated to be 500MCM as shown in Table 48. Supplementary water could potentially be sourced from the Khan (live storage 85MCM) and Sewarkhedi Dam (live storage 157 MCM). Hypothetically the cost of equipping all the 319,000ha of groundwater irrigation with drip in the three districts would cost of the order of 1250 crore ($280million), at a conservative water saving of 10% this would provide a total saving of the order of 197MCM. It is not possible at this stage to give a comparative analysis on the options of: (i) maintaining a decentralised system by reducing groundwater consumption and developing supplementary sources including the Khan reservoir, Sewarkhedi dam and the Chambal-Ghambir link; or (ii) developing the Narmada multi village and town scheme; or (iii) a hybrid option. A comprehensive feasibility study is proposed.

513. The potential for artificial recharge is estimated to be about 2% of the sustainable draft. The costs and benefits need to be assessed. Viable and cost effective systems should be taken up for implementation low maintenance systems, and systems that have some direct economic benefit and should be given priority. In the hard rock aquifers there would appear to be scope for small local artificial recharge projects to meet specific local needs for example around village water supplies. The indicative water saving proposal for critical blocks is given in Table 48 below.

[70]Integrated Water Supply Project for Villages and Towns of Dewas, Ujjain and Shajapur Districts

Table 48: Indicative Water Saving Proposal for Critical Blocks (MCM)

			Present 2010 (MCM)				Future (MCM) 2035			Proposed Plan to 2035								
District	Block	Net Annual Ground water Availability (MCM)	Gross Draft for irrigation	Gross Draft for Domestic & Industry	Total gross draft	Stage of GW devpment	Estimated draft for WS and Industry to 2035	Future gross draft	Stage of GW devpment	Reduced demand by irrigation efficiency	other initiatives	Farm ponds/ tanks	revised irrigation draft	water supply draft	total draft	artificial recharge	net draft	Stage of GW devpment
Dewas	Dewas	164	151	6	157	96	10	162	98	15	15	23	98	10	109	3	105	64
Dewas	Sonkutch	101	95	2	98	97	3	98	97	14	10	14	57	3	60	2	58	57
Indore	Indore	164	212	12	224	137	39	251	153	32	21	32	127	12	139	3	136	83
Indore	Sanwer	131	170	4	174	133	6	177	135	26	17	26	102	6	108	3	106	81
Indore	Delapur	129	117	4	121	94	7	124	96	18	12	18	70	7	77	3	74	58
Ujjain	Ujjain	106	150	3	153	144	4	154	145	23	15	23	90	4	94	2	92	86
Ujjain	Ghatia	83	81	2	83	101	3	84	101	12	8	12	49	3	51	2	50	60
Ujjain	Badnagar	163	269	5	274	168	5	275	169	40	27	40	162	5	167	3	164	101
Total		1,040	1,246	38	1,284	970	77	1,323		179	125	187	755	49	805	21	784	

1. Irrigation demand would be reduced by introducing improved irrigation efficiency; drip, sprinkler, furrow gated pipe etc. Irrigation efficiencies could be improved by up to 40% but net conjunctive efficiencies would be lower, of the order of 10 to 15% saving. All groundwater irrigation would require to install new efficient systems and government would provide adequate grants. A net saving of 15% of the present draft has been estimated.

2. Other initiatives would be applied including delayed planting, mulching, shorter duration crops, improved power supplies and some levels of restriction of GW abstraction. A 10% reduction in demand has been estimated.

3. Farm ponds-small farm ponds would be developed to reduce the demand for GW. All medium and large farms would be encouraged to have ponds and appropriate grants would be provided. Smaller farms the use of ponds would likely be less popular. Farmers use ponds during Kharif and part of Rabi season. In addition larger tanks would be rehabilitated to reduce the dependency on GW. Where feasible surface water schemes would be taken up. A 15% reduction of the present draft is estimated.

4. The CGWB estimate for artificial recharge from the Kshipra and Gambhir catchments is 31MCM or 2% of the total sustainable draft and this has been applied for the water saving proposal. The potential for artificial recharge will be reviewed and all viable options would be developed to maximise the quantity from AR. Local artificial recharge would be developed to provide localised protection for village water sources.

5. Water supply demand would be met as per the CGWB projections with the exception of Indore. It is assumed that Indore would source water from the Narmada river. Water supply demand for Indore would largely be met by water transfer with the GW need estimated to remain at 2010 levels.

C. Institutions

1. Present Arrangements

514. The apex institution in Madhya Pradesh for development & management of water resources is the Department of Water Resources (WRD). The World Bank supported Modernisation Project is promoting the establishment of IWRM functions through creation of a new and separate water resource agencies. A State Water Resources Agency (SWaRA) has been established has recently been established to provide state level capacity for inter-sectoral water allocation, planning and management based on comprehensive and socially and environmentally sustainable river basins.

515. The State with World Bank support has recently established two pilot river management boards; in the Sind and Tons basins; these boards have been created (under the umbrella of SWaRA) and strengthened to operationalise the concept of integrated water resources management in a basin framework with decentralized basin development and management. These boards are not interstate boards (Tons is a non controversial interstate river and Sind is an internal river). The boards are expected to be focal points for "shared vision" water resources planning and management in the selected basins. Support would be provided for infrastructure, technical advisory services and operating costs.

516. Establishment of new organisations for the IWRM management functions separate from the the sector departments has some advantages; it does however raise issues of how to mainstream the outputs into workable programmes and can leave the boards without any of the necessary leverage to enforce and mainstream management recommendations.

2. Institutional Proposals

517. Water governance changes are needed to move the largely uncontrolled groundwater extractions into a better coordinated, directed and sustainable strategy. Government departments and communities need to work together to develop mechanisms for sustainability, combined with maximum productivity from agriculture as well as high levels of service delivery of potable water. Power for pumping is also a factor and viable strategies for conserving power have also to be incorporated into the planning process. The state departments have to integrate their efforts , the key water sector agencies include; irrigation, potable water, agriculture, groundwater and power (for pumping). Coordinating their activities to develop holistic planning and strategies is essential. It is important that planning of the rural and urban sectors are better integrated.

518. The current functions of the various water sector departments in their present form do not provide adequate operational basis for implementing IWRM. The Kshipra water resources are 95% from groundwater and the institutional arrangements must be adapted from the top heavy surface water management to a harmonised and integrated bottom up management of the surface, groundwater and water use systems. Groundwater use is almost entirely individual farmer led and appropriate management mechanisms need to be developed. The requirements for groundwater management are indirect, with a focus on supporting more water efficient cropping systems, micro irrigation and catchment management and artificial recharge and the introduction of support mechanism and regulatory controls. There is also a need to improve the integration of agriculture and horticulture departments, many farmers now cultivate a mix of agricultural and horticultural crops; new initiatives for micro irrigation need to address needs for both agriculture and horticulture.

519. **IWRM under Existing Institutional Structure:** The recommended approach is to build IWRM as far as possible under the existing institutional structure. These proposals include the establishment of a state steering committee, an IWRM unit as a part of the Water Resources Department and empowerment of the district planning committees and the sector departments at district levels.

520. **Water Regulatory Authority:** There is now significant support for the establishment of State Water Regulatory Authorities (WRA) which would provide an institutional mechanism to regulate the allocation, management and utilization limited water resources through a participatory approach. The existing institutional set up is characterized by multiplicity of roles being performed by the state water departments and agencies and the water boards wherever it exits. The IWRM requires to incorporate a high level of stakeholder and community participation as well as a clear separation of the roles of a) regulator, standard setter and auditor b) resource management and c) operator and service provider The WRA would be responsible to oversee and regulate both surface and groundwater management as well as parallel initiatives for conservation including crop and power management.

521. The 13th Finance Commission report 2009, has mandated the establishment of state water regulators by mid 2012 to address injudicious inter-sectoral and intra-sectoral distribution of water amongst various categories of water users, low water use efficiency, fragmented approach to water resources planning and development, low water user charges and

meagre recovery are some of the major problems associated with the management of water resources. The water regulator must be truly consultative and participatory in its composition and functioning, and that representatives of civil society are associated with it at all levels The water regulatory authority would have more powers and independence than the State Water Resources Agency. The establishment of an effective and independent water regulator is complex and requires discussion and understanding of the benefits of a regulator. State agreement and support for the regulator is essential.

522. The portfolio of measures indentified for water resource management require a strong coordinated approach with full support of Government at State, District and Panchayat level and stakeholders. To meet all these requirements requires an approach to build on the existing institutions, providing coordination and devolvement of powers. Further review and discussion is required to better define the most appropriate approach. For the effective functioning of WRA, it needs to be supported by a competent resource agency as its Secretariat. Consideration should given to adjusting the role of SWaRA to form the secretariat for the Water Regulator.

523. A new **State Water Resources Steering Committee** (WRSC) is proposed to support improved coordination of the sector agencies. The State Steering committee would be chaired by the Chief Secretary and the convener being the Principal Secretary (Department of Water Resources). The other members of the steering committee would be the Principal Secretaries of the various sector departments including agriculture, horticulture, rural development and panchayat, urban water supply and sanitation and forestry. The regional representative of the Central water Commission and Central Ground Water Board would also be members. The very major issue of power for pumping may merit a representative from the power department to be on the committee. The committee would be supported by experts in relevant fields who can be called on as required. The steering committee would be charged with overseeing fairly significant institutional reforms to meet targets of efficiency, effective service delivery, participative management and financial sustainability through cost recovery for O&M costs. The committee would promote inter-sector coordination and would also advise the proposed water regulator on specific issues.

524. An **IWRM Unit** is proposed within the state Water Resource Department headed by a Chief Engineer. Its main task is coordinated planning for preparation of holistic and integrated planning for water resource management. Planning would be multi sector, participative and iterative. Planning would incorporate appropriate and relevant planning inputs from the key water sector departments. The regional representatives of the Central Water Commission and Central Ground Water Board would also be members. The IWRM unit would communicate with the River Basin Organizations concerning trans-boundary issues. Data management functions would be incorporated into the IWRM unit.

525. The new 'IWRM unit' would include a role in water resource planning including providing guidance to the water regulator about water issues including advising on water licences and permits. The new IWRM management unit would encompass water resource aspects of climate change and would liaise with the Proposed Climate Change Centres being developed by DEST. Staff from the different sector department would be seconded to work with the new unit.

526. **River Basin Organisations:** There is a key need for river basin organisations for interstate rivers with significant trans-boundary issues. Smaller internal rivers or minor trans-boundary rivers should be managed through the IWRM unit. For minor trans-boundary rivers a simple organisation can be established; the CWC regional representatives can help support the coordination of minor trans-boundary issues.

527. **Empowerment of the Districts for Planning and Management of Water Resources:** It is proposed that the District level should take on an increased role in the integrated planning and management of water resources. This would include to the strengthening of the District Planning Committee to oversee the integration of sector programmes as well as ensuring effective stakeholder participation.

528. **Sub Basin Consultative Group:** A lower level consultation process is required to support the basin planning processes. To allow for a collective consultation at the sub-basin level; it is proposed that a sub-basin level consultative group is formed, the group representatives would be nominated by the various Panchayat Raj within the sub-basin with representation from the various stakeholder groups. The consultative group can advise and inform the Water Regulatory Authority on water issues in the basin.

3. Community Management

529. **Community based Management:** There are questions of capacity, financial management and effective participation of stakeholders. Long term sustainability and better demand-driven services and infrastructure have been the major objective of involving communities in the management of the resources. 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 policy development for sustainability.

530. The Water User Associations in the Kshipra are limited and not well developed; As about 95% of the irrigation is from groundwater. WUA are only relevant to surface water systems; groundwater irrigation is primarily at individual farmer level with really no role for a WUA. The mechanisms to implement various water management and conservation initiatives need to be further reviewed.

4. Cooperatives

531. Cooperatives through their role as participative socio-economic organizations at the village level can play an effective role in realizing sustainable village development programs. The importance of the cooperative sector in supporting agricultural productivity and creating employment can be channelled to support some of the agricultural initiatives required to improve farm productivity as well as initiatives to conserve water. In the largely groundwater dominated irrigation areas of Kshipra the water user associations have less function and are largely not operational, the increased role of the cooperative should be investigated. Despite some areas of poor performance, cooperatives are now playing an increasingly important role in Madhya Pradesh Agriculture.

532. Rural Electricity Cooperatives constitute a very small portion of India's overall rural electrification programme. The Government of India has indicated an interest in utilizing the cooperative model for increasing the reach of rural electrification. There is potential to resolve some of the entrenched dysfunctions in the existing electricity distribution and retail system for agriculture through electricity cooperatives. Electricity cooperatives properly integrated with the agricultural cooperatives might be allowed use a part of the revenue collected to support water conservation and productivity technologies. This approach would appear to offer potentials to achieve acceptability and support in efforts to reduce the consumption of power for pumping.

5. Summary of Institutional Proposals

533. The proposed institutional proposals are shown in Table 49 below. As far as possible the approach is to build on the existing institutional structure. The development of an state wide regulatory authority is proposed as a new institution, other functions would largely build on and empower the existing institutions.

Table 49: Summary of Institutional Proposals

1	Water Regulatory Authority	A Water Regulatory Authority (WRA) is proposed to provide an institutional mechanism to regulate the allocation, management and utilization limited water resources through a participatory approach. The new regulatory authority would build on the proposals by the 13th Finance commission for the establishment of state regulators in all states. It is proposed that some review is made the role of the recently established State Water Resources Agency (SWaRA) and the proposed State Water Tariff Regulatory Commission (SWaTReC). The WRA would include the following functions to: (i) establish and regulate the water tariff system and charges for surface and sub-surface water used for domestic, agriculture, industrial and other purposes; (ii) determine and regulate the distribution of entitlement for various categories of uses as well as within each category of use; and (iii) periodically review and monitor the water sector costs and revenues. The regulatory authority would be an autonomous, inter-disciplinary body, with managerial, professional, mediatory and adjudicatory capabilities built in. The regulator must not be one more government department. It must be truly consultative and participatory in its composition and functioning, and that representatives of civil society are associated with it at all levels. The regulator would support basin-level institutions and basin level decision making.
2	State Water Resources Steering Committee	A new 'State Water Resources Steering Committee'(WRSC) is proposed to support improved coordination of the sector agencies. The committee would comprise of the Principal Secretaries of the departments of Water Resources, Agriculture, Horticulture, Forests, Environment, Panchayats, and Rural Development. The committee would be supported by experts in relevant fields who can be called on as required. The steering committee would be charged with overseeing fairly significant institutional reforms to meet targets of efficiency, effective service delivery, participative management and financial sustainability through cost recovery for O&M costs. The committee would promote inter-sector coordination and would also advise the proposed water regulator on specific issues.
4	Integrated Water Resources Management Unit (IWRM) within Department of Water Resources Development.	The present planning and hydrology sections within the WRDs would be combined, expanded and strengthened with a new mandate and skills to become an "IWRM Unit". The operational functions and resource management functions of the WRD would be separated to reduce the potentials for conflict of interest. The recently formed (State Water Resources Data and Analysis Centre (SWaRDAC) which is designed to collate, verify, analyze and disseminate information needed for integrated water resources management and basin planning would be incorporated into the IWRM unit. The new integrated water resources management unit' would include responsibility for water resource planning including providing guidance to the water regulator about water issues including advising on water licences and permits. The new IWRM management unit would encompass water resource aspects of climate change and would liaise with the Proposed Climate Change Centres being developed by Department of Environment Science and Technology (DEST). Staff from the different sector department would be seconded to work with the new unit. Representatives of CWC and the CGWB would support the IWRM unit.
5	Empowerment of the Districts for Planning and Management of Water Resources	It is proposed that the District level should take on an increased role in the integrated planning and management of water resources. This would include to the strengthening of the District Planning Committee to oversee the integration of sector programmes as well as ensuring effective stakeholder participation.
6.	Stakeholder Consultative Group	There is a need for districts, panchayats, stakeholders including civil society to participate in the basin planning and management processes. It is proposed that the Panachayat Raj of each district would nominate representatives of stakeholders including civil society to review and endorse the strategic and detailed plans and support water resources management. The groups would work at district and lower levels. Representatives of the various groups within the sub basin would meet periodically to address sub basin issues.
7.	Formal and Informal Organisations at the Village Level	The village organisations are critical to implement change including improved ground and surface water management and water conservation. In the Kshipra the most appropriate type of village organisation needs to be defined. WUA are poorly established and in the groundwater dominated irrigation there is less need for a WUA. Consideration of alternative organisations is required; options might include the role of cooperatives including electricity cooperatives to take on a proactive role in promoting water conservation, agricultural productivity, marketing and power management.
8.	River Basin Authority	Functional and empowered interstate river basin authorities need to be established for the Chambal sub basin (which incorporates the Kshipra). and other interstate sub basins.

D. Climate Change Scenarios

534. For climate change projections in the Kshipra sub basin, the output from one member of the Hadley Centre HadCM3 QUMP[71] ensemble was downscaled using the PRECIS RCM by IITM Pune. Apart from the baseline (1961-1990) which represents the present, two future time slices were investigated: mid-century (2021-2050) and end-century (2071–2100). All three time slices use the SRES scenario A1B. In addition, data were available for the SRES A2 and B2 scenarios for the baseline and end-century and were used for comparison[72].

1. Temperature

535. The 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 and A2 and B2 scenarios are given in Table 50 and Table 51 below.

Table 50: 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 51: 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

536. 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 about 4°C by the 2080s. Increases in the monsoon season would be lower than in the dry seasons. Comparison with the A2 and B2 scenarios show not dissimilar changes. Temperature changes are shown for the A1B scenario are shown in Figure 27 and Figure 28 below.

[71]Quantifying Uncertainty in Model Predictions is an approach which aims to provide probabilistic predictions of future climat

[72]**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.
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.

Figure 27: Change in Average Maximum Temperature (A1B)

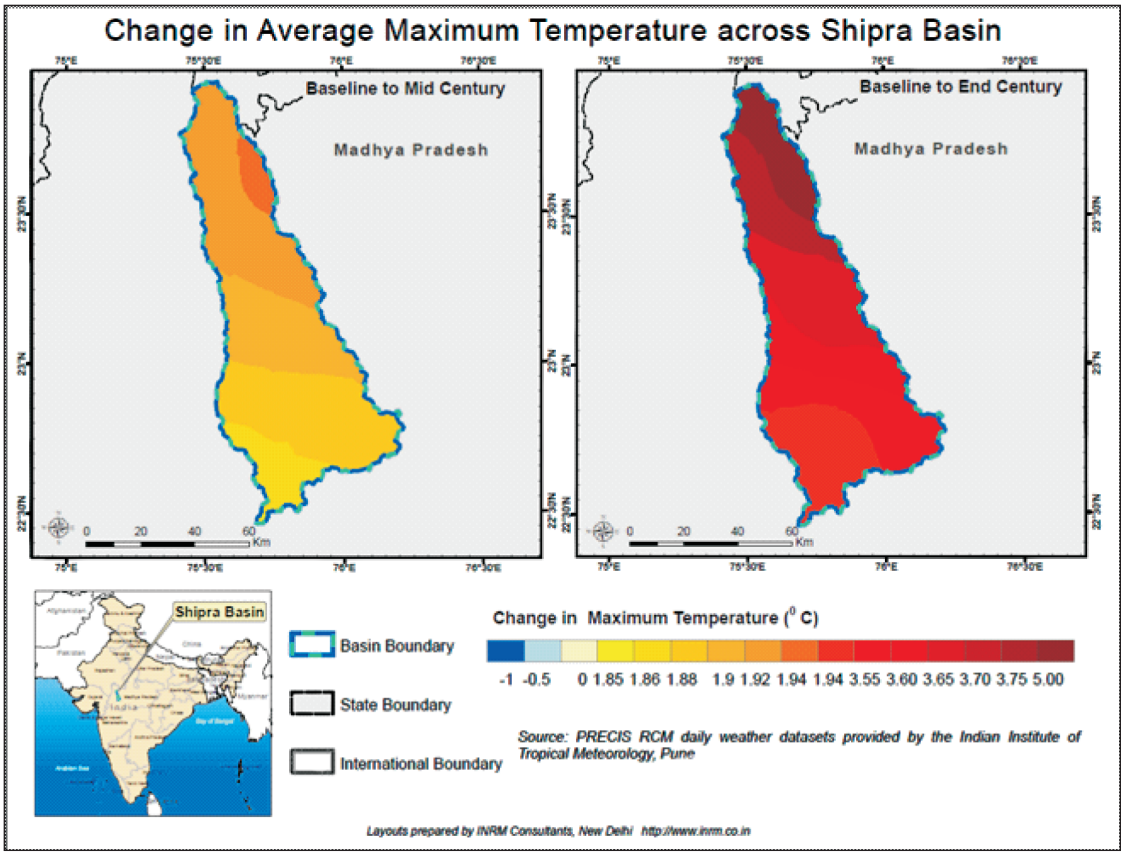
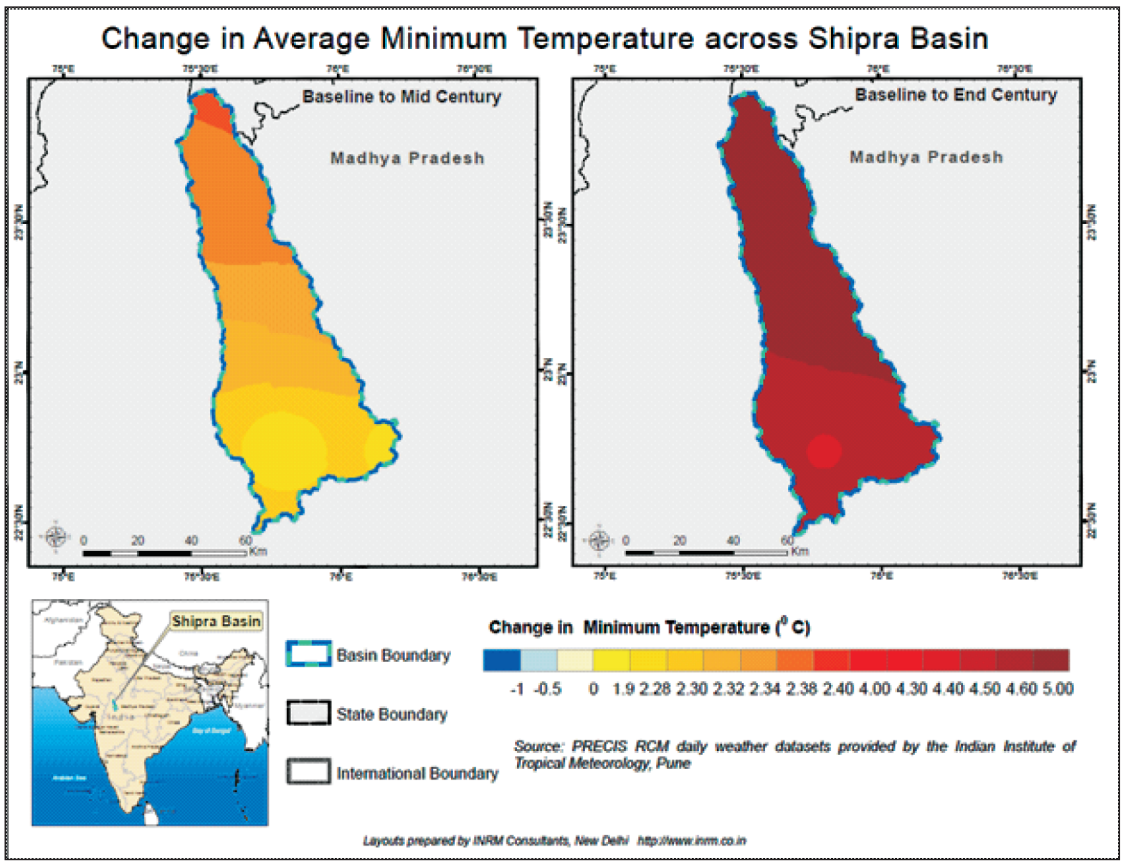


Figure 28: Changes in Average Minimum Temperature (A1B)



2. Rainfall

537. The Kshipra river basin receives most of its rain during the monsoon season, which starts in late June. Data are presented for four seasonal periods: JF - January, February; MAM - March, April, May; JJAS - June, July, August, September; OND - October, November, December The mean seasonal precipitation amounts simulated by PRECIS are as shown in Table 52 below. Table 53 presents a comparison of changes to end-century under the A1B, A2 and B2 scenarios. Figure 29 and Figure 30 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.

538. Under the A1B scenario, rainfall is projected to increase. Mean annual rainfall increases by about 140 mm by mid-century, and by about 175mm 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. All of the increases occur in the monsoon period with some decline in OND and JF rainfall to mid-century under the A1B scenario. Mean monsoon rainfall increases by 173 mm by end-century under the A1B scenario.

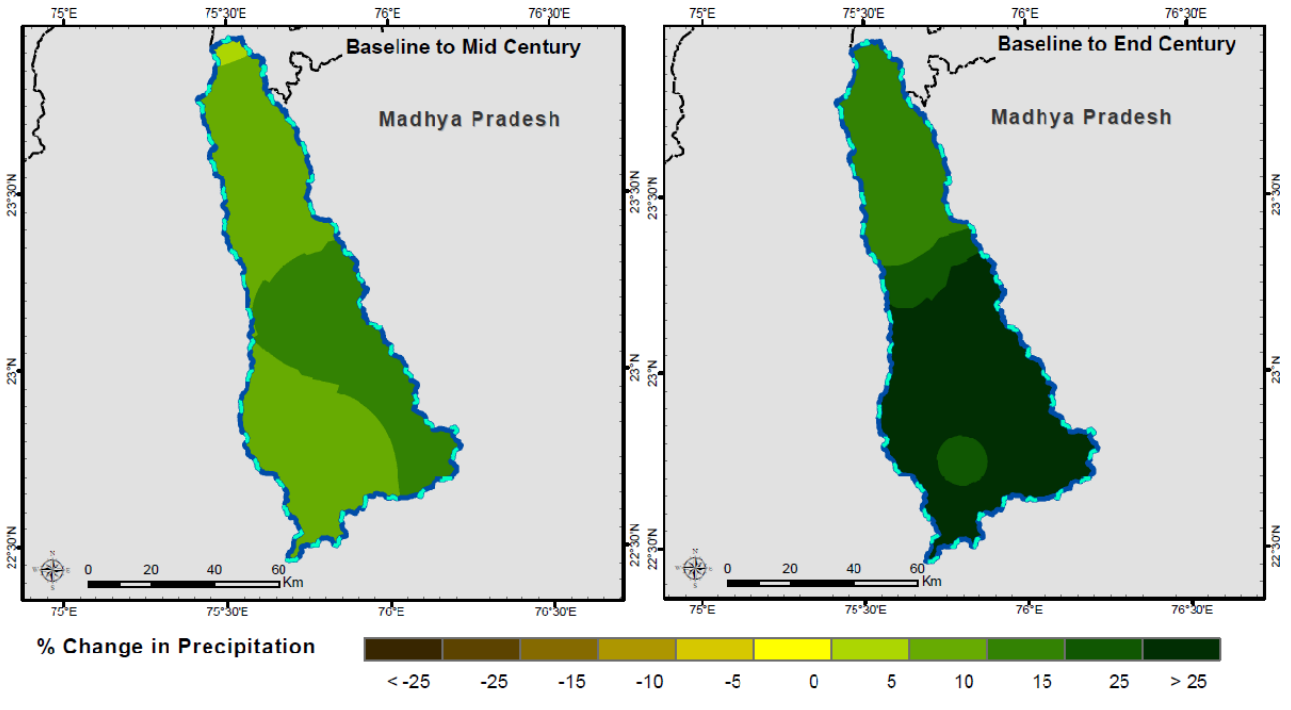
Table 52: PRECIS Simulated seasonal precipitation in the Kshipra sub-basin, A1B scenario (mm)

	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 53: Projected changes in seasonal precipitation under the A1B, A2 and B2 scenarios, to 2080s (mm)

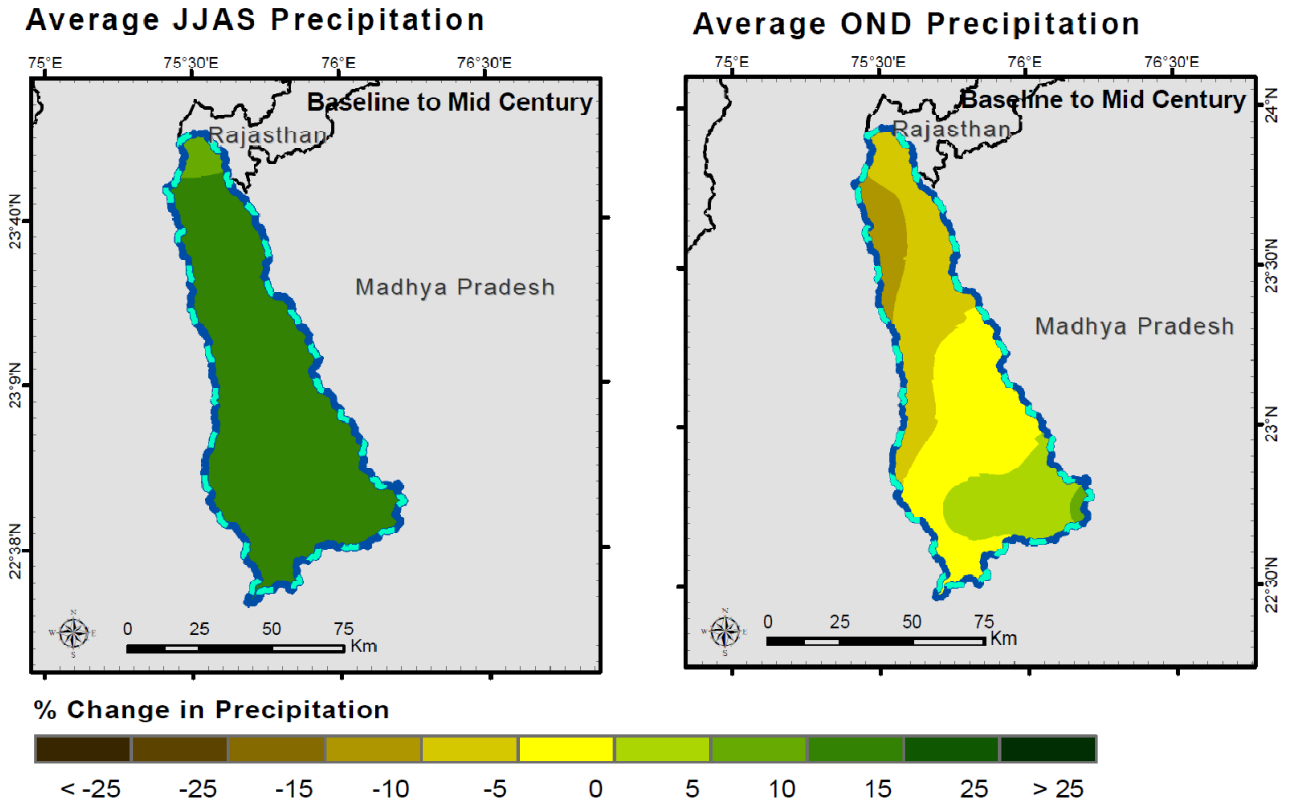
Scenario	JF	MAM	JJAS	OND	Annual
A1B	-12	4	160	29	182
A2	6	10	132	1	150
B2	2	9	79	-19	71

Figure 29: Changes in the Annual Average Precipitation



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

Figure 30: Change in Seasonal Precipitation



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

539. **Intense Rainfall Events:** The analysis did not show any significant change in the number of extreme rainfall events.

540. **Historic Rainfall Trends:** Analysis was made of annual and seasonal rainfall recorded at Ujjain and Indore, to test for evidence of historic trends in rainfall. Analysis was carried out with a composite record using GHCN data and giving 105 years at Indore and 93 years at Ujjain. The IMD data indicated a trend of increasing annual and seasonal rainfall at the 10% significance level at Ujjain, which would not be considered conclusive. However, at Indore the trend of increasing monsoon rainfall was significant at the 5% level. With the composite records, the trend of increasing annual rainfall at Indore was equivalent to 200 mm over 105 years. The increase in monsoon rainfall was significant at the 95% confidence level. Similar results were obtained for Ujjain, although here the results were not as significant statistically. The projected increases in rainfall under climate change are not a departure from the historic observations.

3. Conclusions

541. The forecast increase of about 23% in precipitation to Mid Century (MC) under the PRECIS A1B and A2 scenario are significant 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. At present regional climate models do not represent rainfall well, and only subjective assessments may be possible.

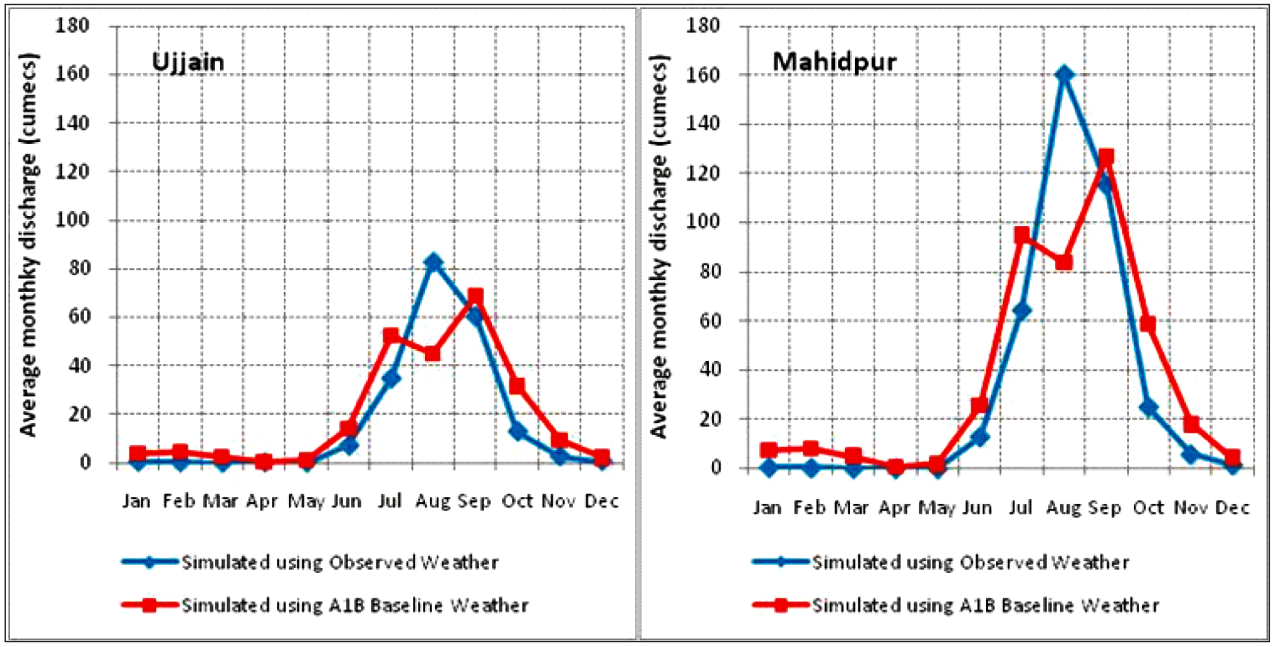
4. Hydrological Simulations

542. 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. 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.

543. 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 0.5o precipitation and

temperature data, and observed flow data from the Central Water Commission (CWC) and state gauging stations at Ujjain and Mahidpur. The calibration achieved with the model was considered to be acceptable, and river flow simulation with PRECIS input data matched reasonably well with river flows simulated with observed weather data, as shown in Figure 31 below.

Figure 31: Comparison of Simulated Mean Monthly Discharges (Observed weather and A1B baseline)



544. The change on the water balance from the baseline to mid century are shown in Figure 32 and Figure 33. The PRECIS A1B scenario indicates an increase in JJAS precipitation in the Kshipra basin of about 23% by mid-century. The model results indicate that around 83 % of this increase in precipitation will be converted to runoff and around 4% will go as baseflow which contributes to stream flow during lean period. About 17% of the rainfall would go to groundwater recharge under the A1B scenario. This should be treated as a very optimistic projection from a water resources perspective[73], but would offer opportunities for increased water harvesting and groundwater recharge. A concern is the potential impact on drainage and on flood risk.

[73]A few assumptions were made for running the scenarios using the hydrological model, like no landuse change and use of current crop management practices for future.

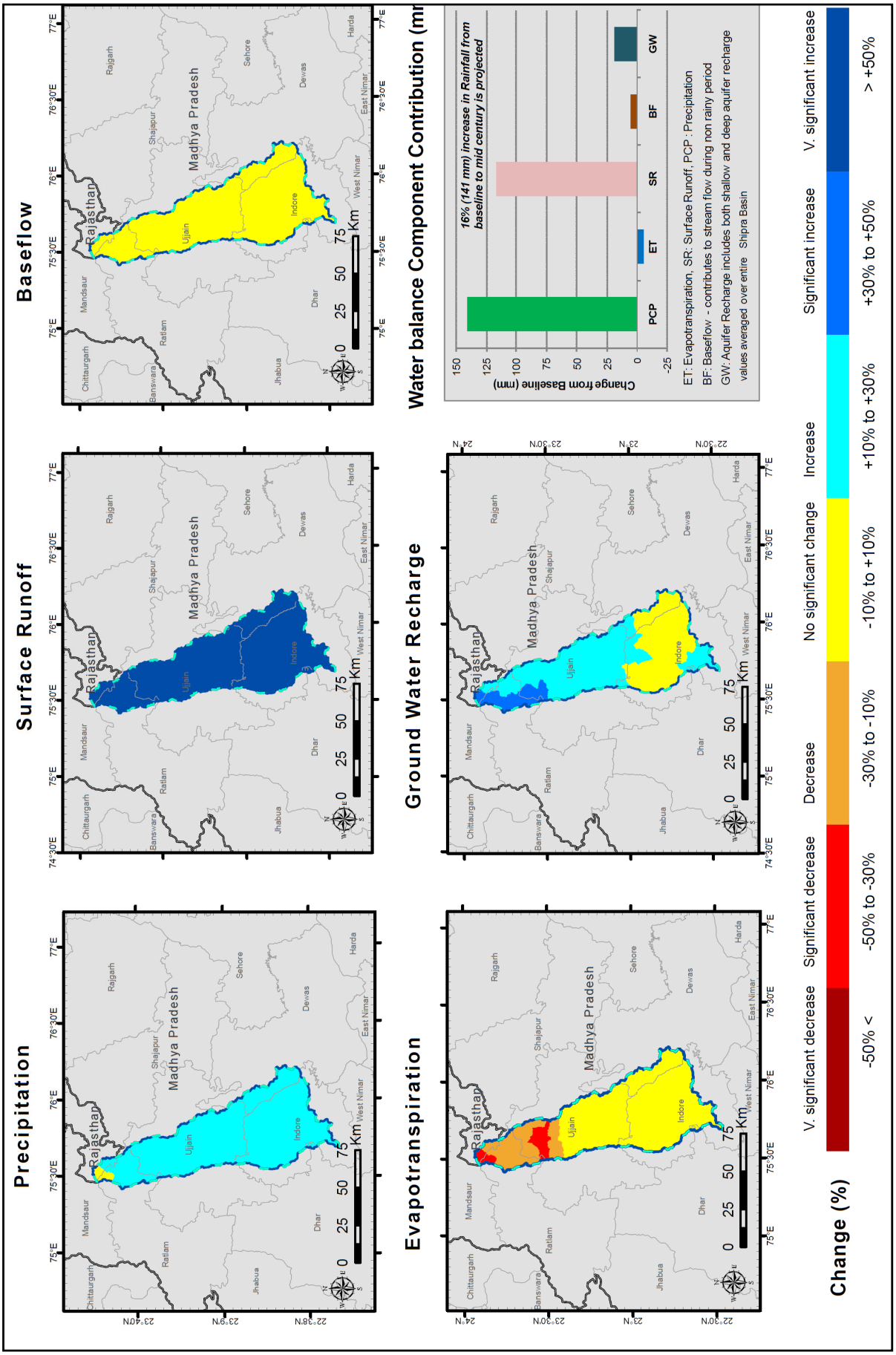


Figure 32: Changes in the Annual Water Balance to Mid Century (A1B)

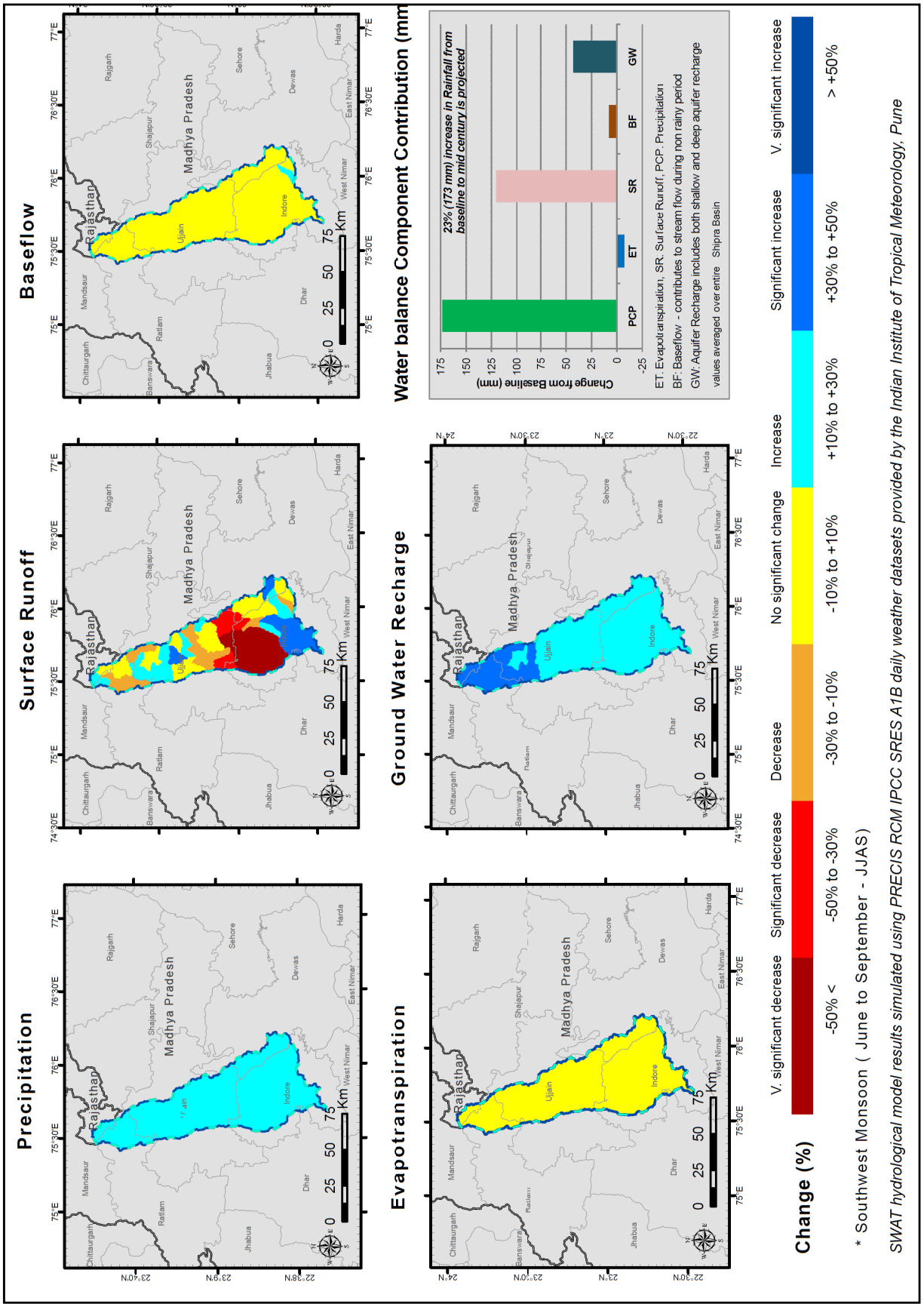


Figure 33 Changes in the Water Balance (JJAS) to mid Century (A1B)

E. Vulnerabilities to Climate Change

1. Introduction

545. Climate change will affect the water systems which will impact on present vulnerabilities. Based on the various climate projections a summary of potential climate impacts and key areas of vulnerability is shown in Table 54.

Table 54: Specific Climate Change Vulnerabilities

	Parameter	Quantitive asssess- ment	Confidence level of estimates	Estimated climate change to mid century	Adaptation proposals
1.	Temperature	Yes	High	+2°C avg. max and min temperature by mid 50s and up to +4°C by mid 80s	Research into crop response and access to temperature resistant varieties to be upscaled. Cropping to be more diversified. Increasing access to crop insurance
2.	Precipitation annual	Yes	Medium	+23 % mainly monsoon rainfall	Upscaling of farm ponds and vilage ponds and catchment management to retain runoff. Drainage design should incorporate increased runoff.
3.	Rainfall Intensities	Yes	Medium	No significant change projected	Upscaling of water retention to capitalise on increased rainfall
4	Evaporation	Yes	Medium	Slight reduction	Initiatives to reduce evaporation losses such as mulching, farm water management
5.	Floods	No	Medium	Increased rainfall and run off will likely increase flood risk.	Catchment management to improve retention of floods. On farm drainage to protect crops. Design of drainage, cross drainage structures and flood management to absorb higher flood risk.
6.	Droughts	Yes	No information	Rainfall variability may increase	Groundwater and storage can buffer against precipitation variabilities.
7	Other Extreme events	No	Medium	Non quantified events-hailstones, wind	Not easy to define. Adaptation should focus on increased farmer awareness, crop insurance and disaster management planning.
8..	Groundwater	Yes	Medium	Some increase in groundwater recharge estimated	Opportunities for catchment management and artificial recharge would be increased through the increased monsoon rainfall.
9.	Surface water flows	Yes	Medium	Approximately 83% of increased precipitation will be as runoff.	Increased runoff and river flows opens opportunities for increasing the role of surface water to support irrigation and reduce pressure on the groundwater.

2. Key Requirements to Meet Climate Impacts

546. The adaptation strategy is based on addressing present and future development needs. Future development needs include boosting agricultural production and raising farm incomes, and meeting the needs of an increasing population. How future climate impacts are incorporated into the strategy are described in this section, which reviews the present and development needs strategies, and examines the requirements and mechanisms to incorporate the projected climate impacts into the framework plan.

547. **The Climate Impacts:** There is still uncertainty about the rate and magnitude of climate change impacts across the globe. Translating global climate projections into a scale appropriate to decision makers remains a challenge. There remains considerable uncertainties in the models which must be borne in mind when assessing the model results.

548. In addition to uncertainty regarding the climate risk, there are parallel uncertainties with regard to future trends and markets in agriculture and social conditions; agriculture is dominated by Government subsidies and government support prices for certain crops, which affects farmer crop choices.

549. **Planning Horizon:** It is important to define the planning horizon for the framework plan. The proposed adaptation measures are all short to medium scale interventions which are designed to meet the short term decadal and medium term needs. Decadal changes would be to 2020. Medium term can be based on the norms of a 25 year period of any investment, and allowing for a five year lead in time giving 30 years. A planning horizon of 30 years is proposed which would effectively be to 2040. The projections are for mid century which would approximately equate to the planning horizon.

550. **Storage as a Buffer for Climate Impacts:** In the Kshipra, groundwater storage is providing about 95% of the needs of irrigation and most of the potable and industrial water supplies. The Kshipra Basin is highly dependent on groundwater storage. Understanding, planning, management and conserving of the groundwater is a critical part of the plan. The projected increases in rainfall can offer some opportunities for agriculture; the water balance indicates that most of the increased rainfall will be lost as runoff with minimal amount for groundwater recharge. How runoff can be retained for groundwater use or retained in ponds is a key area to be addressed.

551. **Flexibility of the Adaptation Strategies:** All the proposed adaptation strategies are quite flexible to adjustment and change. Refinements can be incorporated as improved climate projections become available, including the exploration of climate resilient adaptation options. Planning must be iterative and it is proposed that plans be updated about every five years.

552. **Temperature:** Farmers are already reporting increased temperatures. The PRECIS projection for future temperatures by mid century is a rise of about 2°C of the daily maximum and minimum temperatures. There is no specific information on the impacts on crop suitabilities under the increased temperature situation. Further study and research into optimum cropping with an +2°C rise in temperature is required. Other indirect effects such as CO^2 and ozone levels can affect crop viabilities. These can be investigated further using a crop response model such as DSSAT (Decision Support for Agricultural Technology).

553. **Precipitation:** In the decadal period to 2020 precipitation levels are likely to increase slightly. The projected rainfall to mid century is plus 23%, and nearly all of this increase would occur in the southwest monsoon period. The projected trend is an increase in precipitation which could improve the water situation depending on the intensity and the inter-annual variation.

554. **Surface Water Availability:** The indications from the SWAT modelling carried out are that under the A1B scenario to mid century that about 80% of the increased rainfall would form runoff. This would improve the viability of small reservoir irrigation/water supply schemes.

555. **Ground Water Availability:** The projected increased monsoon rainfall could have benefit to the groundwater; it is estimated that 17% of the increased rainfall would support recharge of the aquifer. The increased recharge would help provide some support the sustainability of the groundwater.

556. The projected increase in monsoon rainfall and related impacts on surface water and groundwater could open increased opportunities for rainfed farming in the dry land areas as well as reducing dependence on groundwater in the irrigated areas. The increased precipitation would increase the viability of the farm tanks, surface water irrigation schemes and catchment management and artificial recharge to support irrigation and reduce dependency on groundwater.

557. The projected increase in precipitation will likely improve water availabilities towards the end of the planning horizon around 2030s to 2040s. This will be generally beneficial and should reduce the pressure on the groundwater irrigation demand. The core adaptation focus for 'present issues' is to meet the long term needs of sustainability and to reduce net groundwater consumption by about 30-60% in overexploited blocks; this is considered to still be valid under climate change, and is certainly required to meet the decadal needs. For the medium term 2020 to 2040 increased water availability from precipitation could reduce somewhat the pressure on groundwater. In terms of strategy it is proposed that policy should be to bring groundwater extractions into equilibrium within the next decade; involving an indicative reduction of 5% annual reduction in the net groundwater use per year in the critical and overexploited blocks.

558. Medium term increases in precipitation may offer some additional water resource which could be used to replenish the aquifer or some possible relaxation of abstraction restrictions. At this stage, the level of knowledge on precipitation changes is not good enough to bank on the potential for increased water availabilities in the medium term. It is recommended that targetted reductions of net groundwater abstractions are initiated as soon as possible in the overexploited or critical blocks. After 5 years, the target could be reviewed based on monitoring, additional studies and improved projections. The annual reduction targets can be adjusted upwards or downwards at that stage.

559. **Flood:** Increased rainfall intensities may increase flood flows. Flooding, although not a very significant issue at present, may become more significant in the future. Farm drainage to reduce crop damage must be balanced with the need for supporting recharge.

560. **Uncertainty:** The projections of the models are designed to give the best possible estimate of climate projections within the present level of knowledge. At present different models produce different results with regard to precipitation in many areas. Uncertainties in these projections remain and increased variability in the weather patterns remains likely. Government has limited capacity to handle significant climate variations and creation of strengthened community institutions to promote self reliance at the community level is considered an important adaptation requirement.

561. The indicative impacts of the climate change on the strategy are discussed above. The climate projections and the associated SWAT model analysis indicate the possibilities of higher temperatures and increased rainfall. There are potential areas of vulnerability associated with these including crop yield reduction, pests and disease, but also the increased precipitation could support agriculture. The implementation of small and medium water storage and catchment management could allow for increased agricultural productivity and reduction in the levels of groundwater abstraction.

F. Framework Plan for Climate Adaptation and Sustainable Water Resources Management

1. Analysis of Problems and Opportunities

562. Agriculture in Madhya Pradesh is the potential driver to reduce rural poverty and support employment; the importance and opportunities of agriculture are now becoming apparent. Agriculture in the Kshipra basin is developing but agricultural intensities and yields are significantly lower than the potential. There are reports of salinisation due to over irrigation and some decline in soil fertility due to the repeated cultivation of soya bean. There is very limited surface water and about 95% of the irrigation water is derived from groundwater much of which is over exploited. Heavy monsoon rainfall can cause soil erosion

563. The State agriculture plan is directed at; modernisation and intensification of agriculture, farm mechanisation, increasing the cropping area and cropping intensity, crop diversification, cultivation of cash crops, improving rural infrastructure roads and power, increasing access to irrigation including public private partnerships to support agricultural extension services and diversification from low value crops to high value crops with renewed emphasis on horticulture; encouragement of supplementary sources of income for small and marginal farmers, including dairying, animal production, horticulture, fisheries and aquaculture to supplement incomes. Agricultural development has a heavy reliance on irrigation, although rainfall levels are adequate to support rainfed cropping in the kharif season.

564. Industrial development is creating additional water demand and creating issues of pollution. Drinking water problems were one of the most pressing issues reported in the rural appraisal surveys.

565. Sustainability of water resources especially groundwater is one of the most pressing issues for the basin, there are quite limited potentials for additional supply and water conservation is seen as one of the key ways to maintain sustainability. State plans to provide adequate water supplies and the needs of industrial expansion require detailed studies to assess the options. Potable water and industrial demand are presently about 5% of the irrigation abstraction from groundwater.

2. Strategies for Climate Change

566. The experience of this study shows that while climate change projections contain many uncertainties and in some areas are insufficient to concrete adaptation decisions, it is important however that development planning and design should factor incorporate the projections into the decision making processes at an early stage.

567. Annual rainfall is projected to increase by 10-15% by mid century, mainly in the southwest monsoon, and would appear to offer opportunities to support further intensification of agriculture. This additional rainfall will be of benefit to both rainfed and irrigated agriculture, and would help support water harvesting, small storage schemes, catchment management and artificial recharge.

568. Increased vulnerabilities will also likely occur; temperature rises together with associated risks of pests and disease, increased floods, and increased variabilities in the rainfall patterns all pose risk. The strategy for climate change adaptation in Madhya Pradesh and the Kshipra will be to capitalise on the possible opportunities of increased rainfall through; conservation of water demand through water use efficiencies of small farm tanks and small surface water irrigation as well as meeting potential vulnerabilities. Increasing the financial viability and net returns to farmers is a key issue to reduce vulnerabilities.

3. Plan Objectives

569. The strategy for Kshipra requires a portfolio of different actions. The framework plan is designed with five objectives:

(i) Reduce the groundwater over-abstraction; through micro irrigation, improved agricultural systems to improve productivity and conserve water, development of farm ponds and tanks, expansion of small and medium surface irrigation with storage, and improved catchment management and artificial recharge.
(ii) Improve agricultural productivity and sustainability in the irrigated areas through modern technologies to increase yields, reduce water requirements and reduce vulnerabilities to climate change including temperature increases. Provision of support systems for marketing of crops.
(iii) Develop sustainable and efficient water supplies and sanitation through reduced losses, metering, rehabilitation and upgrading.
(iv) Improvement in water quality in surface and groundwater, through waste water treatment and improved waste management, more efficient use of fertilisers and pesticides and increased base flow in the rivers.
(v) Institutional development; training and awareness at government and community level to support integrated water resources management approach to ensure sustainability and adaptation to climate change.

4. Framework Plan

570. The framework plan is designed around improving agriculture productivity in parallel with addressing requirements of sustainability and conservation of water resources. The plan will also incorporate the very pressing problems of water pollution as well as of improved water supplies and sanitation. Implementation will require cross sectoral coordination and institutional development within government as well the farming communities and other stakeholders.

571. There is no single solution towards meeting the requirements of development, sustainability and adaptation of the Kshipra subbasin and a portfolio of different initiatives will be required. To meet the objectives, five focal areas are identified:

(i) **Sustainable Agriculture and Conservation:** Support for agricultural production systems to improve farmers' incomes together with mechanisms for water resources conservation. Financial sustainability of the agricultural systems will be an essential requirement to effectively address conservation measures as well as provide robustness to climate impacts. The strategy is directed at introduction of resource conservation initiatives in parallel with support for agricultural productivity and marketing.
(ii) **Water Resources and Catchment Management** will focus on water resources supply and management, key areas include; the expansion of small scale irrigation schemes including medium and small scale storage/tank systems for irrigation including rehabilitation and expansion of farm and village tanks, support for catchment management and artificial recharge.
(iii) **Water Quality Management and Pollution Control:** Major issues of surface and groundwater pollution will be addressed through surface and groundwater management, pollution control and improving water treatment and reuse of waste water.
(iv) **Water Supply and Sanitation;** Upgrading of schemes, improving efficiencies and service delivery, integrated solutions to support water supply shortages including improving efficiencies in irrigation to free up scarce water for water supply.
(v) **Institutional, Regulatory and Support Measures:** Implementation of programmes to address productivity and resource conservation and management require to be supported by the establishment of IWRM including establishment of a regulatory authority, a state inter-sector steering committee and improved government support systems.

5. Framework Plan Proposals

572. A five component strategic framework plan is proposed. The plan is designed to meet the key objectives of development needs, sustainability and adaptation to climate change.

Component 1: Sustainable Agriculture and Conservation

573. The component objective is to support development of more efficient production and marketing systems to improve financial returns to farmers and in parallel reduce water consumption through; (i) strengthening and coordination of government extension and support programmes; (ii) support for farmer/cooperative orientated private sector partnership initiatives to support production, diversification and marketing; (iii) special support for productivity and marketing initiatives which demonstrate potentials to support water resource conservation; (iv) support for on farm water conservation systems including micro irrigation, farm ponds, shorter duration crops, adjusted planting schedules etc; and (v) support for adaptive research and pilot up-scaling of productivity and efficiency initiatives.

574. Improving farmer productivity and competitiveness are important elements of the Madhya Pradesh State development strategy. Many farmers are reluctant to move into higher yield and productive cropping systems due to the increased level of risk including uncertainties of water supplies.

575. The proposal is to develop small holder agriculture but move towards a more business perspective involving greater commercialisation of production systems including some elements of agribusiness and diversification to higher return cropping but with mechanisms to ensure participation and security of the small and lower income farmers. Private sector partnerships offer opportunities to meet the full potential of the land and water systems in parallel with limiting the exposure to production risk and market uncertainties. Experiences in agribusiness and contract farming have been mixed. The lack of farmer involvement and local partnerships are seen as major limitations. Emphasis should be directed towards small local enterprise including strengthening of the local cooperatives and farmer groups and improving access to mechanisation and modern technologies.

576. In parallel the component will address the needs of water conservation through significant upscaling of resource conservation measures. This would be carried out in stages with fully researched and accepted initiatives taken up quickly and the less developed and untried measures taken up on a pilot basis. Upscaling of research into new conservation technologies as well as the development of crop varieties, cropping systems resistant to climate change would also be taken up. The objective of the component is to directly impact on the level of groundwater over abstraction, supporting the mainstreaming of new ideas and initiatives and supporting research efforts.

577. Support for changes to new crop varieties including shorter duration, higher yielding crops, support for reducing post harvest losses, and support for improved handling and marketing of higher value crops will be addressed. Research into the need for new varieties that may be more appropriate to temperature increases from climate change would also be taken up. Improving the effective use of rainfall would provide benefits to the rainfed farming in the dry land areas as well as within the irrigated areas.

578. Micro irrigation offers good potentials to improve conjunctive use efficiency, improve yields and financial returns, and reduce the quantities of inputs. The relative advantages and farmer preference of sprinklers and drip need to be assessed but the higher water efficiencies, yield potentials and lower energy requirements of drip would appear to make drip more attractive than sprinkler. There are constraints in the take up of micro irrigation due to the high costs. The introduction of micro irrigation is presently supported by high subsidies. Uptake can be increased through increased awareness and capacity building. Farmers need support to ensure that they are able to maximise the potential of new drip systems including farming methods, marketing and financial support. There would appear to increased potential for increased support from the private sector to promote, expand and support micro irrigation and intensive high return cropping systems. Suppliers of micro irrigation would be encouraged to be more proactive to help source credit and provide increased extension support.

579. Power management is an important and potentially significant conservation measure; power management can support groundwater conservation and also free up government funds that can be better applied in other areas. Minimising power consumption to reduce the states overall energy consumption should be a parallel objective of the planning process.

580. Demonstration of water resource conservation would form an important factor in the evaluation process of potential sub-projects. Funding priority would given to projects that demonstrate elements of resource conservation or support the upscaling new technologies for resource conservation.

581. Marketing and the potential to adapt the government market support system to better meet the needs of farmers as well as resource conservation will be addressed in Component 5. The objective will be to develop a better harmonisation of government support subsidies towards meeting the objectives of water resource conservation and crop diversification.

582. The Kharif rains allow planting of rainfed crops largely without irrigation, on farm soil and water conservation will reduce dependency on groundwater but will also be of benefit to the rainfed farming areas. The projected increase in rainfall should offer opportunities to improve rainfed farming.

583. A summary of component 1 is given in Table 55 below.

Table 55: Sustainable Agriculture and Conservation

Overview	Improved agricultural productivity and marketing together with the upscaling of water resource conservation technologies focusing on agriculture technologies and micro irrigation.
Rationale	Agricultural sustainability requires financially viable production systems that can improve farmers' incomes as well as help support additional costs of water resources conservation. Financial sustainability of the agricultural systems is essential to support conservation measures as well meet the needs reduced vulnerability to climate impacts. There is a portfolio of possible measures to conserve water resources. Farmer adoption of these technologies will require a major support programme including the application of appropriate private sector participation for some aspects. Further research is required to assess into appropriate agriculture and irrigation technologies together with crop research to develop varieties resistant to increased temperature and other climate change.
Description	o Intensification and diversification of production through strengthening of the extension system, promotion of private sector extension efforts, training and support for new market opportunities. o Support for new agricultural production innovations, including cropping, mechanisation etc; priorities would be given to areas where water conservation can be demonstrated. o Upscaling of irrigation conservation technologies including the use of micro irrigation, farm ponds and other water saving systems. o Support for mainstreaming of less tried and tested water conservation technologies. o Adaptive research for new potentially viable technologies. o Support for mainstreaming agricultural research to make research finding more available to farmers. o Expansion of infrastructure facilities including processing, marketing, transport including the upgrading of market yards, storage and cold storage. Support would be directed to strengthen and empower cooperatives. o Improvement in market information systems including, promotion of e-trading, strengthening of the market chain including backward links between the markets and the producers. o Strengthening of the private sector and private sector partnerships to support the opening of domestic and international market opportunities
Studies/ research	o Research into increasing yield and productivity in parallel with reduced water use. o Research into marketing systems and opportunities including review of minimum support prices and discussions with state and central government to develop mechanisms to better support crop diversification (in coordination with component 5). o Research into impacts on climate change on crops including development of crop varieties resistant to increased temperatures and other climate impacts.
Outputs	o Improved infrastructure to support crop processing, storage and markets. o Improved farmer access to markets and opening of new market opportunities. o Increased involvement of private sector partnerships in agriculture. o Major upscaling of water resources conservation measures including micro irrigation o Mainstreaming of climate resistant crop varieties.
Implementing Agencies	o Department of Agriculture. o Department of Horticulture.

Component 2: Water Resources and Catchment Management

584. Water resources conservation and management will focus on supply management and will include the following; (i) development of small and medium scale surface water schemes; (ii) rehabilitation of village tanks and ponds and other water bodies to support recharge; (iii) improved irrigation management to improve efficiencies and levels of service delivery of surface water irrigation; (iv) integrated catchment management together with development of artificial recharge for groundwater. Catchment management should be localised and focused to meet specific local needs.

585. It is widely documented that climate change will impact on agriculture, soil and water conditions in the catchment /basin. Integrated catchment/basin planning is needed to assess the feasibility of models for soil and water conservation and to support climate sensitive agricultural systems. Catchment management needs to address the fragmentation of efforts to more effectively address holistic catchment issues.

586. The conjunctive surface and groundwater systems have to be assessed; over abstraction of groundwater for irrigation needs to be reduced and water savings made to support needs of potable water. Increased precipitation under climate change may offer some support towards meeting a sustainable water balance.

587. Development potential of surface water irrigation is quite limited. There are a number of potential schemes that have been identified and if technically and economically viable should be taken up for development and would provide additional resource. The proposed Khan reservoir and Sewarkhedi dam should be studied in more depth. These projects would provide important additional supplies to Ujjain for drinking and industrial use, support environmental flows in the Khan river and provide surface water irrigation and groundwater recharge.

588. Various proposals exist for water transfer from the Narmada river. For irrigation, the capital and operational costs involve pumping lifts of around 300m and is not considered in anyway viable. The constructed and presently expanded water supply scheme to supply Indore, supported by ADB, provides the only real option to meet the very high water needs of Indore city. It is assumed that all long term needs for Indore city and the peri-urban areas would be supplied from the Narmada. The proposed Narmada transfer project for towns and villages in Dewas Ujjain and Shajapur Districts is extremely expensive and drinking water needs may be better addressed by conservation of groundwater, restrictions on groundwater use for irrigation and minor surface water schemes which might offer a lower cost option. A feasibility study to assess the alternatives is required.

589. The potential for artificial recharge is estimated to be quite small. The costs and benefits need to be assessed. Viable and cost effective systems should be taken up for implementation. Low maintenance systems, and systems that have some direct economic benefit and should be given priority. In the hard rock aquifers there would appear to be the most scope for micro artificial recharge and catchment management to meet specific local needs, for example around village water supplies.

590. A summary of component 2 is given in Table 56 below.

Table 56: Water Resources and Catchment Management

Overview	Implementation of integrated management of water resources and the catchments to support sustainability and conservation of scarce water resources.
Rationale	Although there is no scope to develop major new water sources a number of small and medium schemes for water supply, irrigation and environmental needs have been identified. Catchment management and artificial recharge have scope to support groundwater recharge and reduce flood risk.
Description	o Feasibility studies, design and implementation of various small water resource projects. o Integrated catchment management and artificial recharge investments including rehabilitation of tanks, ponds and other water bodies. o Conversion of marginal agriculture land to forestry with payment from carbon credits.
Studies/ research	o Studies and modelling (WEAP model) to assess the conjunctive use of surface and groundwater and development of simple decision support systems to assess scenarios for conservation and sustainability. o Assessment of conjunctive water use efficiencies and potential to improve the management and service delivery of the surface water supplies for irrigation, industry and water supplies. o Technical, economic and environmental studies to assess viabilities of various catchment and artificial recharge options, including rehabilitation of village ponds and wetlands. o Expansion of small/medium surface water schemes for irrigation and water supplies.
Outputs	o Rehabilitation of tanks. o Improved and expanded catchment management and artificial recharge.
Implementing Agencies	o Department of Water Resources. Department of Agriculture.

Component 3: Water Quality Management and Pollution Control

591. Major surface and groundwater quality problems need to be addressed. These can be tackled through more efficient fertiliser and pesticide use, maintaining environmental flows, improving water treatment and waste management, enforcing waste water regulations. The viabilities of industrial and other water reuse will be investigated; viable options would be taken up for investment. Options of both public and private sector initiatives would be reviewed. Sampling of and monitoring of water quality needs to be taken up to trace and investigate key pollution episodes. Parallel measures to reduce groundwater use and increase surface water availability (component 2) will be an parallel initiative to create permanent base flows in the rivers.

592. Component 3 is summarised in Table 57 below.

Table 57: Water Quality Management and Pollution Control

Overview	Pollution and water quality issues would be addressed through investment and improved water management.
Rationale	High levels of untreated waste water and low flows in the receiving waters are resulting in major water quality issues.
Description	o Upgrading of water treatment. o Increased regulation of wastewater management. o Improved base flows by water projects and conservation. o Expanded water harvesting in urban areas to improve base flows.
Studies/ research	o Detailed hydrological and water quality assessments. o Water quality sampling to identify key pollution paths o Preparation of a water quality master plan. o Design of investment projects. o Studies to assess options of PPP. o Upgraded and extended water treatment.
Outputs	o Water reuse systems.
Implementing Agencies	o WRD. o ULBs. o Environment Department

Component 4: Water Supply and Sanitation

593. The component includes the upgrading of water supply and sanitation; including improving efficiencies and service delivery. The development of integrated solutions to support water supply shortages will be addressed including improving irrigation efficiencies to free up scarce water for water supply as well as artificial recharge described in component 2.

594. Problems of water supply and sanitation were seen as major issues from the participatory rural appraisal especially by women. In water scarce areas such as the Kshipra, efficient water supply systems are essential; including systems in both urban and rural areas. Leakages need to be repaired, defective reticulation pipes replaced, and water use controlled by metering or other mechanisms. Water investments would be taken up to upgrade systems, reduce leakage and improve the quantity of supply. Long term water supply needs would be met by local resources (groundwater, surface water dams and recharge). The water transfer from the Narmada river presently under consideration by the state Government will be assessed through comprehensive feasibility studies. Investment support would be provided to rehabilitate and upgrade the rural and urban water systems and sanitation.

595. Urban water management and conservation is proposed. In the urban areas runoff is almost 100% and there is scope to improve recharge and reduce runoff through roof top and other water catchments. Options exist for water reuse and leakage control; this is especially relevant for Indore where water costs are extremely high.

596. Component 4 is summarised in Table 58 below.

Table 58: Water Supply and Santitation

Overview	Lack of water and poor water supply facilities will be addressed through rehabilitation and upgrading improved service delivery of water supply and sanitation schemes.
Rationale	Poor and inadequate potable water supplies is reported as a major issue; including water supply shortages and poorly functioning water supply and sanitation schemes. Very low access to sanitation in the rural areas.
Description	o Major upgrading, expansion and improvement of service delivery of urban and rural water supplies and sanitation. o Urban water management and conservation (leakage control, rainwater harvesting, sustainable drainage systems, water reuse etc).
Studies/ research	o Feasibility studies to assess water supply options. o Leakage detection to support reduction in losses from water supply schemes. o Prepare proposals to increase levels of efficiency and service delivery. o Prepare master plan for potable and industrial supplies and waste water/sanitation management, including water conservation plans. o Improved water supply and sanitation in rural and urban areas.
Outputs	
Implementing Agencies	Water Supply and Sanitation.

Component 5: Institutional Development and Support Measures

597. The effective implementation of the other components requires to be supported by a series of initiatives relating to water governance. The present institutional, financial and legal frameworks are not adequately directed to meet the needs of water conservation and management . Under this component six key activities are proposed; (i) establishment of IWRM; (ii) agreed support and financing arrangements to meet targets of water conservation and climate adaptation; (iii) agreed power management strategy for agriculture; (iv) agreed regulatory framework; (v) water resources data management systems and (vi) intensive training support for awareness of stakeholders at all levels.; The proposed activities would include:

598. **Establishment of IWRM:** Various options exist but the preferred option would include the establishment of a water regulatory authority, a state water resources committee, an IWRM unit to be established within the Water Resources Department, operationalising of the district planning committee and the district sector departments, and implementation programmes. Water resources planning would be based on the sub-basin plans.

599. **Agreed Support and Financing Arrangement:** The implementation of water conservation and climate adaptation requires a portfolio of investments and programme support measures. To implement these requires an agreed approach to financing and support. There is a need to address wider areas of agricultural subsidies to move from blanket subsidies and price support to more focused subsidies to meet conservation targets. The need to review the MSPs will require to be coordinated with state and central Government. The potential role of PPP to support some of the conservation and productivity programmes needs to be explored. Appropriate public-private sector or community-private sector partnerships offer new opportunities which would not be fully feasible by the government alone.

600. **Agreed Power Management Strategy** is critical to reduce groundwater wastage, reduce the financial costs of subsidised pumping together with requirements to reduce energy wastage. The need to bring in some form of charging system is seen as critical to the conservation strategy; charging linked in some way to the actual power consumed would have the greatest impact on conservation. The approach needs to be agreed and enforcement would be a part of the remit of the water regulatory authority. Farmer support is required and consideration should be given to establishing agricultural power cooperatives with revenues earned directly used to target improved conservation and productivity programmes. Upgrading of power supplies and improved power availability is seen by farmers to be an important requirement. Experience in Gujarat has shown that pumping wastage can be reduced by improved and more reliable power supplies. Improving power supplies in return for farmer agreement to accept a power management initiative would appear logical.

601. **Agreed Regulatory Framework:** A stronger regulatory framework is required to work in parallel with the various support initiatives. New ideas and pilot projects can be supported by support subsidies; at some stage however there is a requirement to bring in regulation to reduce wastage and ensure the long term sustainability of the water resources. Regulation will have to come in slowly and needs to be balanced by support measures and improved productivity to offset

any loss of farmer income. Restrictions in groundwater use for irrigation were strongly supported in consultations and workshops; compensatory mechanisms including farm tanks and micro irrigation should be provided.

602. **Water Resources Data Management Systems** are required to support the planning and management of water resources. Integrated water resources information systems including information on surface, groundwater, catchments, forestry, and environment are required. Information on development including hydropower, irrigation, water supply, floods, agriculture, industry etc. should also be accessible through computerised information systems. Data on finance and project benchmark monitoring and evaluation should be included also. The development of information and management systems through the development and standardisation of databases should build on and integrate initiatives of the different sectors.

603. **Training and Awareness:** The programme requires to be supported by an intensive programme of training and awareness. Areas to be addressed include developing understanding of the importance of maintaining sustainable surface and groundwater resources, the potential impacts of climate change and identification of areas of vulnerability. Communities have to be made aware of climate change impacts and their capacity for self help to adaptation improved, and dependency on government reduced.

604. Component 5 is summarised in Table 59 below.

Table 59: Institutional Development and Support Measures

Overview	Establishment of institutional reforms including regulatory and support initiatives will be required to effectively implement the programmes of productivity, resource conservation and water management.
Rationale	The present institutional and management systems are not adequately focused towards the needs of water resources conservation and productivity. Large scale take up of necessary conservation measures will require to be subsidised or regulated or a mixture of both .
Description	o Establishment of IWRM through improved coordination of sector departments through a water resources steering committee, a water regulatory authority and empowerment of the districts. o Agreed financing strategy to better support targeted initiatives for conservation and productivity. o Support mechanism to promote of appropriate PPPs to support productivity, marketing and conservation initiatives. o Agreement and introduction of a power management strategy. o Agreed regulatory framework and support for phased introduction in parallel with support measures. o Establishment of an integrated water resources information system. o Training and provision of awareness material to support awareness of water resources sustainability and adaptation to climate change.
Studies/ research	o Consultation and studies to support financing strategy. o Review and consultation to support power management strategy.
Outputs	o Functional IWRM strategy in place. o Agreed and targeted financial management of investments and programmes. o Agreed power management strategy in place. o Phased regulatory programme in place.
Implementing Agencies	o All water resources sectors, Senior Government.

G. Road Map

1. Kshipra Sub Basin Water Conservation and Development Programme

605 It is proposed to establish a 'Kshipra Water Conservation and Development Programme ' to address ongoing development, environmental and potential climate issues of the Kshipra subbasin. The programme would put into place wide ranging initiatives, programmes and investments to meet the needs of highly effective agricultural productivity and water resources conservation, water resources and catchment management, water quality and pollution control, water supplies and sanitation and institutional reforms, support and regulation.

606. The project would be based on an IWRM approach with a focus to address the sustainable development of water resources whilst addressing the issues of agricultural production, marketing and resource conservation. The sector departments presently lack the flexibilities, capacities and level of integration required to meet the project objectives and an IWRM institutional framework requries to be established including the formation of a state water resources committee, a regulatory authority and empowerment of the district planning committee and district level sector agencies.

607. An eight year programme is proposed and would be implemented through the new IWRM framework. The programme would be integrated involving and working closely with the key water sector agencies, the district administrations and private sector partners. The programme would work under the direction of a newly formed Water Resources Steering Committee, but working closely in coordination with the sector departments at State and District level, District Administrations and Panchayats.

608. The programme would implement field level support programmes within the three districts of the Kshipra Sub Basin. In parallel the programme would address institutional and reform measures over the water sector departments over the whole of Madhya Pradesh state. The establishment of IWRM and institutional reforms is critical towards the long term sustainability of water resources in the State. Institutional reforms would be implemented in stages and would include the establishment of an independent water regulator. The institutional aspects would be implemented in close coordination of the World Bank supported Madhya Pradesh Water Sector Restructuring Project.

609. The project programme would be integrated involving and working closely with the key water sector agencies, the local authorities and civil society working initially through a 'special project agency' but working closely in coordination with the sector departments at State and District level, District Administrations and Panchayats. The project agency would be manned by a small core of carefully selected government staff on secondment including a senior project director of joint secretary or commissioner level. Specialist staff and consultants would be recruited as required. The project agency would strengthen and help develop better coordinated sectors within the three districts of the Kshipra sub basin. The long term sustainability of the project approach is less assured and it is proposed the project would focus on initiating the work and achieving initial targets but would hand back responsibilities to the sector agencies after a period of three years.

610. The project would in parallel work at state level to instigate institutional reforms and strengthen the water sector departments. The establishment of IWRM and institutional reforms is critical towards the long term sustainability of water resources in the State. Institutional reforms would be implemented in stages and would include the establishment of an independent water regulator.

2. Planning Process

611. This strategic plan would require to follow the planning process as described in the India Water Systems section. The importance of having full endorsement of the State Water Resources Steering Committee, the District Planning Committees and the stakeholder consultative groups is critical.

3. Programme Organisation

612. It is proposed that the programme would be a semi autonomous and as a multi sector project, there is a need to coordinate planning and policy decision through a 'Water Resources Steering Committee ' made up of the principal secretaries of the key water sector agencies (Water Resources, Agriculture, Rural Development, Agriculture, Horticulture, Urban Development, ULBs and Public Health, Cooperatives, and Environment).

613. Coordination and optimum use of the different funds would be important. These would include Mahatma Ghandi National Rural Employment Guarantee Act (MNREGA) funds, Central and State Government funds.

4. Requirements for External Support

614. The project would require external specialist support to complement the existing skills of the government and government corporation staff. One key objective of the project is to bring in the development of new ideas and technologies that might be applied to support the development and sustainability of the Kshipra river. It is estimated that specialist support would be required for all components.

5. Programme Scope

615. The programme would involve a mixture of studies and consultation, planning, sub project design, community liaison and participation, institutional development and reforms. The focus of investment would be the three districts of the Kshipra. However, wider institutional strengthening and reform would be taken up to the whole state involving all the water sector departments. The issues of Kshipra are similar to those of the other districts in the Malwa Plateau, and consideration could be given to expanding the follow on conservation and development programme to some other districts neighbouring the KShipra and within Malwa . This could potentially provide a wider base to the programme with potentials for greater impact and some economies of scale. Institutional strengthening and reforms at the state level would benefit from a larger field and investment programme.

6. Investment and Support Programmes

616. Possible areas of investment and support are summarised in Table 60. The programme implementation would require supplementary investment support as well as ensuring coordination of the direction for other ongoing programmes, such as MNREGA. Financial support would be required for investment as well as specialist inputs for research, planning, design and training.

Table 60: Possible Areas for Investment and Support in the Kshipra Basin

SUSTAINABLE AGRICULTURE AND CONSERVATION	
1.	Improved infrastructure for crop marketing including crop processing, marketing, access roads.
2.	Establishment of market information systems, training in marketing.
3.	Funding support for PPP initiatives to improve production, marketing and water resources conservation.
4.	Financial support for upscaling of micro irrigation.
5.	Financial support for farm level tanks.
6.	Investment in improved electricity supply for agriculture (improved voltage stability and supply and introduction of mechanism for cost recovery).
WATER RESOURCES AND CATCHMENT MANAGEMENT	
7.	Investment in new small/medium water projects for water supply irrigation and environment.
8.	Investment in decentralised catchment management and artificial recharge.
9	Investment in forestry in marginal lands with payments from carbon credits.
WATER QUALITY MANAGEMENT AND POLLUTION CONTROL	
9.	Investment in pollution control including water treatment.
10	Investment in new initiatives for waste water management.
11.	Investment for urban water management including rainwater harvesting, sustainable drainage and water reuse.
WATER SUPPLY AND SANITATION	
12.	Support for upgrading and increasing water supply efficiencies in urban and rural water supplies.
13.	Support for upgrading of sanitation and effluent management.
14	Urban water conservation and management (leakage, rainwater harvesting, water reuse, sustainable drainage etc).

7. Studies and Planning

617. The implementation of the plan will require well coordinated activities including studies, participative planning and policy decisions, and implementation of programmes. At this stage, the plan is conceptual and would require careful review by the Government of Madhya Pradesh. More work is required to technically assess and define all the options before moving onto detailed programme design and implementation.

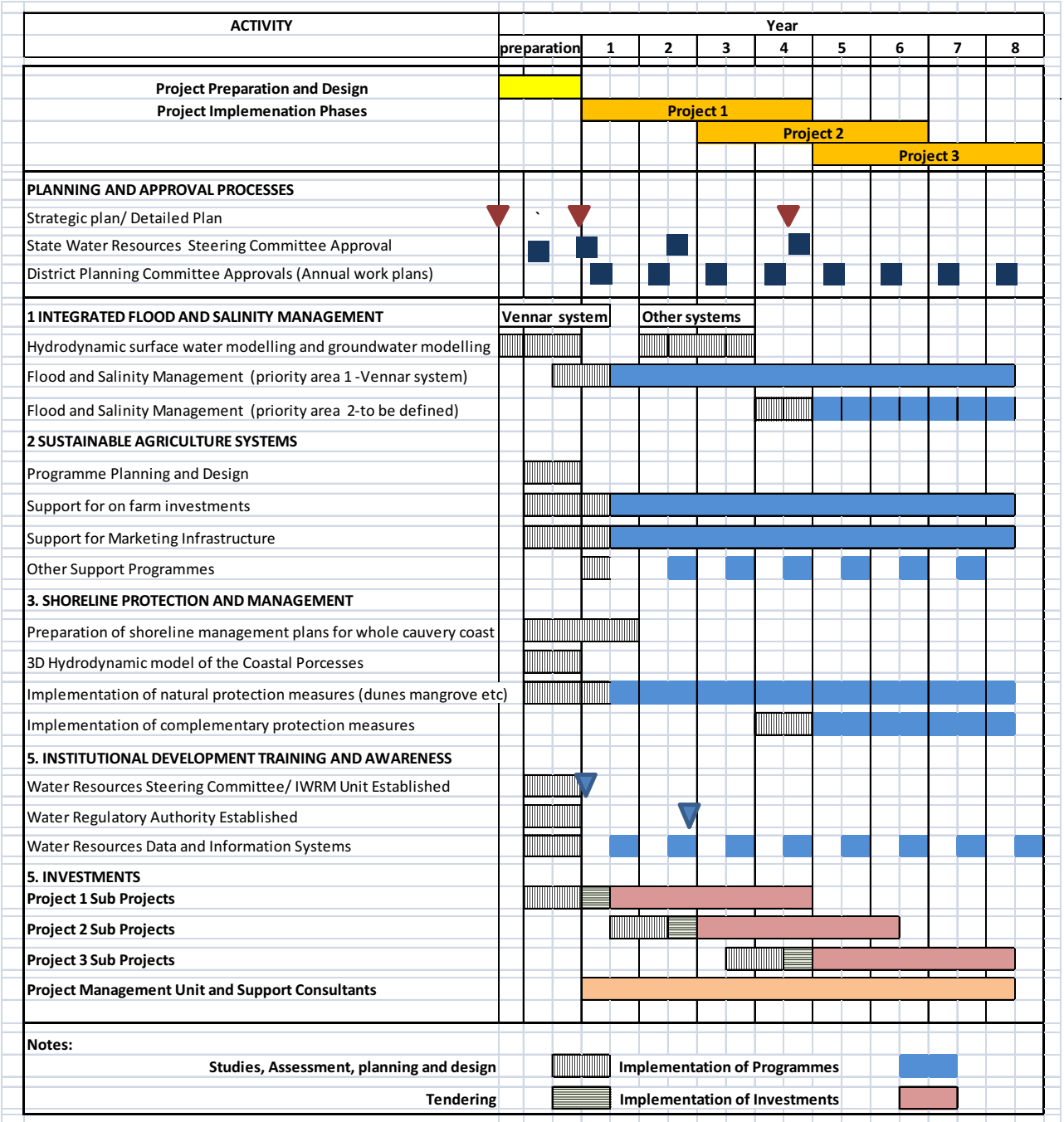
618. Further studies are required to fully investigate the conjunctive surface and groundwater systems and to better assess the benefit of different water saving initiatives before the commencement of full scale programmes. Other studies include viability assessments of different artificial recharge and catchment management systems, marketing studies, urban water management systems etc.

619. Subject to agreement and endorsement of the report, it would be necessary to implement a programme of follow-on studies and design of selected pilot projects. These would be feasibility and design studies to verify the technical and financial viabilities of the proposals including extensive consultation and participation at all levels to ensure acceptability. Visits to other parallel projects would be important to discern the lessons learnt. Based on the outputs of the studies, it is proposed to implement some pilot projects to validate the proposals and make adjustments before embarking on up-scaling. Regular review of the strategy is proposed based on monitoring, studies and improved climate projections.

H. Project Schedule

620. The project is proposed to be run in three phases over eight years. Sub-projects would be identified, planned and designed for Project 1 in year zero with implementation over four years. The need for IWRM and sustainability reforms in place is critical and three stages are proposed including the establishment of an independent water regulator by end of year two. The proposed project schedule is shown in Figure 34 below.

Figure 34 Project Schedule Kshipra Sub Basin



Cauvery Delta Sub Basin, Tamil Nadu

V. CAUVERY DELTA SUB BASIN, TAMIL NADU

A. Sub Basin Profile

1. Introduction

621. The Cauvery Delta consists of four parts: Lower Coleroon Anicut, Cauvery, Vennar and Grand Anicut. The issues of water resources in the Cauvery Delta are complex. There is very limited surface water availability during the south-west Monsoon; the erratic but intense north-east Monsoon causes flooding. There are issues of saline intrusion; with some low lying lands are unable to drain. Groundwater is extensively used to supplement the lack of surface water, but there are issues of overexploitation and salinity intrusion. Coastal erosion in areas is threatening coastal communities while some river mouths block causing problems of sea access for fishing boats and also flooding.

622. Historically, the Cauvery Delta was a major agriculture production area of India. The highly fertile soil, good rainfall and surface water flows were well suited to rice production. Today, the delta suffers from water shortages and uncertainties of climate. The water allocations under the tribunal award are less than earlier availability of water, and agriculture production systems have declined in recent years. The Cauvery Delta modernisation report in 2008 presented a series of proposals to address the decline in agriculture.[74] The population of the delta is estimated to be around 4.8 million, composed of about 73% rural population, the delta covers three districts as shown in Table 61.

Table 61: Population

District	Rural	Urban	Total
Thanjavur	1,467,577	748,561	2,216,138
Tiruvarur	932,231	237,243	169,474
Nagapattinam	1,158,557	1,488,839	330,282
Total	3,558,365	1,316,085	4,874,451

2. Surface Water Resources

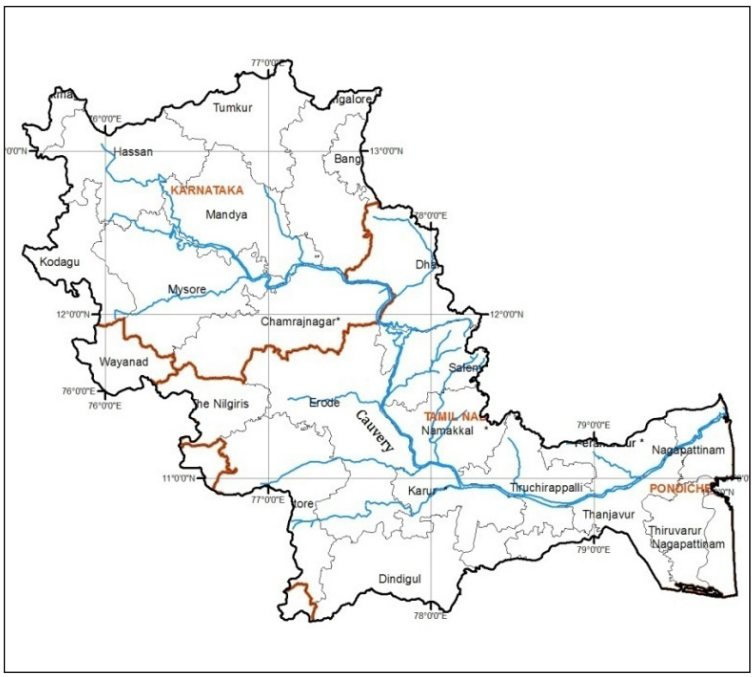
623. Tamil Nadu is heavily dependent on monsoon rains, and is prone to droughts when the monsoons fail. The climate of the state ranges from dry sub-humid to semi-arid. The state has three distinct periods of rainfall; (i) south west monsoon from June to September, with strong southwest winds; (ii) north east monsoon from October to December, with dominant northeast winds; and (iii) dry season from January to May. The Cauvery basin is shown in Figure 35.

624. The normal annual rainfall of the state is about 945 mm of which 48% is through the North East monsoon, and 32% through the South West monsoon. Since the state is entirely dependent on rains for recharging its water resources, monsoon failures lead to acute water scarcity and severe drought [Nathan, 1995].

625. Figure 36 presents isohyets of mean annual precipitation over the Cauvery Basin. Precipitation varies considerably across the basin. The western side of the catchment mainly experiences the south-west monsoon from June to September and the eastern side experiences north-east monsoon from October to December. The rainfall during the rest of the year is insignificant. The total rainfall in the basin across the year can be segregated into parts; about 50% is received during the south-west monsoon, about 33 % in the northeast monsoon, roughly 10% in the pre monsoons and the rest in the winter months. Annual precipitation varies from about 700-900 mm in the interior to 1200 and above in the eastern and western edges of the basin.

[74]Commissioned by the Tamil Nadu Water Resources Department

Figure 35: Cauvery Basin



626. The Cauvery Delta lies at the bottom of the Cauvery river basin. The river Cauvery is the fourth largest river of southern region and flows from north west to south east. Cauvery Delta lies in the eastern point of Tamil Nadu between 10:00 N to 11:30 N Latitude and between 78.15 E to 79.45 E Longitude. The Cauvery Delta consists of four districts of Nagappatinam, Thanjavur and Thrivarur and parts of the district Trichy, Cuddalore and Puddubbottai in Tamil Nadu. Cauvery Delta has a total geographical land area of 1.45 million ha which is equivalent 11% of the area of Tamil Nadu state.

627. On its total course of about 800 km, the Cauvery travels through the states of Karnataka, Tamil Nadu, Kerala and a Union Territory of Pondicherry before falling into the Bay of Bengal. The Cauvery has a total drainage area of 81,155 sq km (2.5% of the total geographical area of the country). Of this 42% lies in Karnataka, 54% in Tamil Nadu, 3.5% in Kerala and the rest in the Karaikkal region of Pondicherry. The Cauvery Delta Sub Basin map is shown in Figure 37.

628. The Cauvery river originates in the Mercara District of Karnataka in the Brahmagiri range of hills in the Western Ghats at an elevation of 1,341m above mean sea level. The river enters the state of Tamil Nadu at the Metter dam (1934) impounds 95.6 TMC of water for use in the Cauvery Delta area. At Upper Anicut, about 177km from Metter dam the river splits into two branches the northern branch in called the Coleroon, a flood carrier and the southern branch in the main Cauvery which carries water for irrigation.

Figure 36: Mean Annual Precipitation

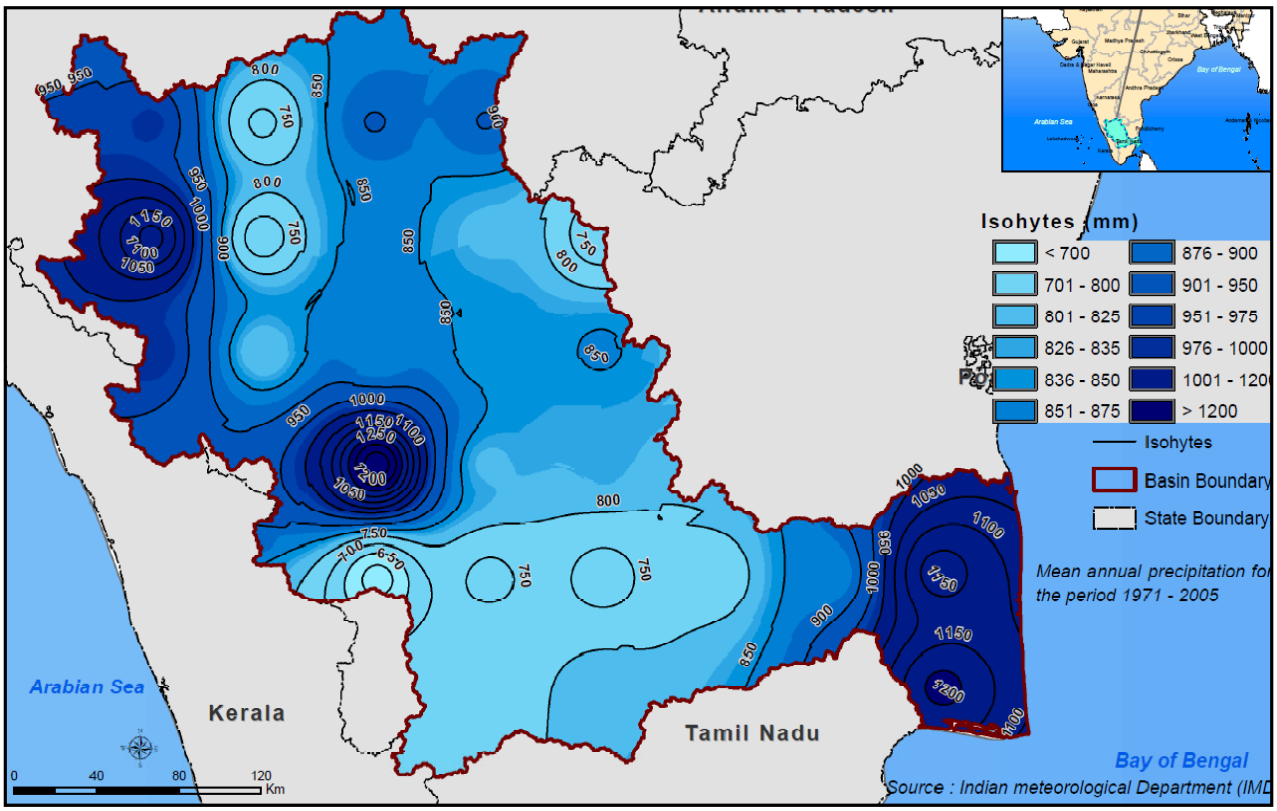
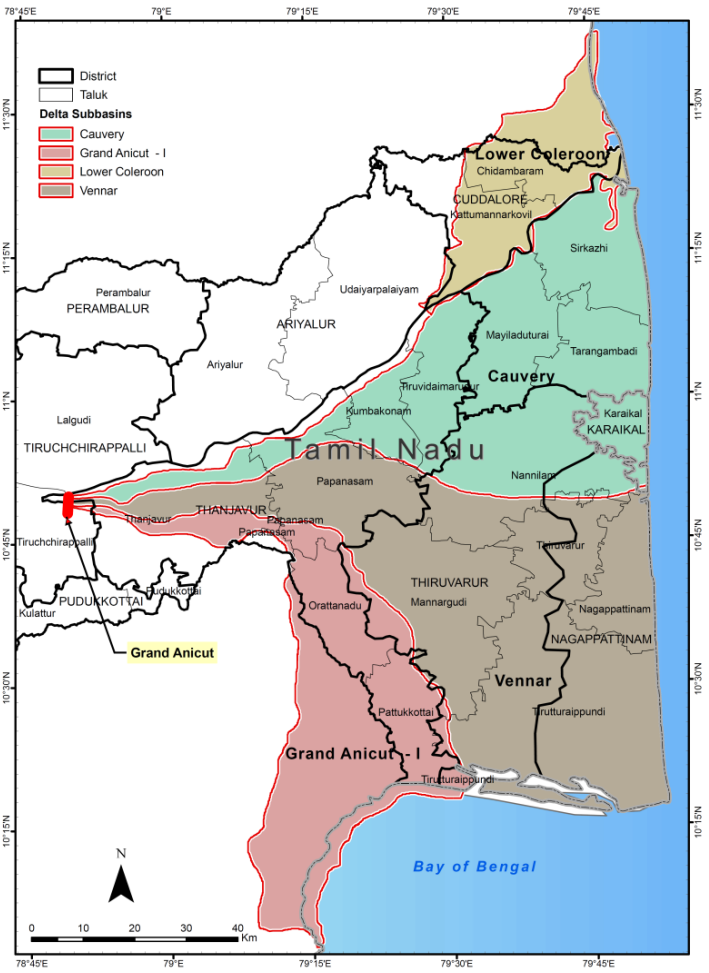


Figure 37: Cauvery Delta

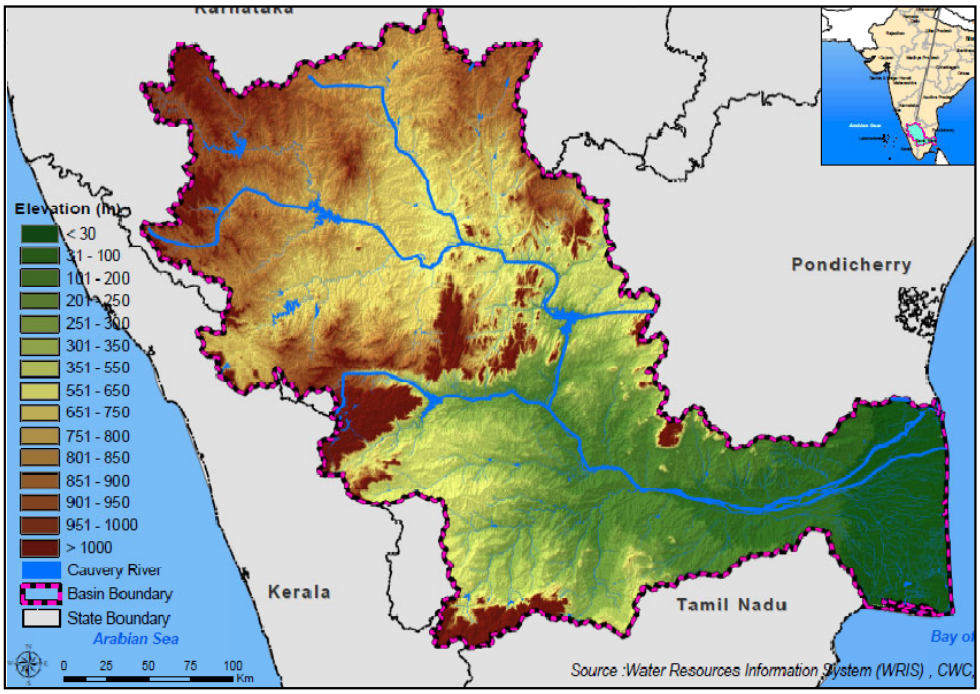


629. The Grand Anicut (Barrage) is constructed on the main Cauvery river. At Grand Anicut complex, the river Cauvery splits into two branches Cauvery and Vennar . These two rivers act as the main irrigation canals with the help of head regulators provided on the both the rivers separately. These rivers in turn, divide and sub divide into number of branches which form network all over delta and distributes the Cauvery water in the vast irrigation system. These channels also carry the drainage water and act as irrigation cum drainage channels in the lower delta.

630. The northern branch of Cauvery namely the Coleroon bifurcates at the Upper Anicut from the Cauvery is the main flood carrier and it continues to flow in a north-easterly direction to enter the Bay of Bengal south of Porto Novo at the confluence of Vellar in the north. The Lower Coleroon Anicut (LCA), which is the last point of utilisation of Cauvery water, is located about 110km below the Upper Anicut. More than 50% of the area irrigated in Cauvery Basin in Tamil Nadu comes under Cauvery Delta, the total area is 560,000 ha with four systems of canals; (i) Lower Coleroon Anicut system (49,000ha) (ii) Cauvery System (200,000ha); (iii) Vennar System (190,000) and the (iv) Grand Anicut System (121,000) as shown in Figure 37.

631. The Cauvery basin location and key topographic and drainage features are shown in Figure 38.

Figure 38: Cauvery Basin Elevations



632. The average annual surface water potential of the basin has been estimated[75] to be 21.4 km3. It has been further estimated that 19.0 km^3 is utilizable. Present surface water use in the basin is 18.0 km^3. The principal soil types found in the basin are red soils, black soils, laterite, alluvial soils, forest soils and mixed soils. The major soil type is red soils. Major land uses are the agriculture and forest. The cultivable area in the basin is about 5.8 Million ha, which is 3% of the total cultivable area of the country. The land under cultivation is 48%. with about 24% of the cultivable area is under irrigation. The major crops grown in the basin are paddy, sugarcane, ragi, jowar and cash crops of coffee, pepper, banana, betel vine, gingili, onion, cotton, black gram. The hydropower potential of the basin has been assessed as 1,359 MW at 60% load factor.

633. The issues of water resources in the Cauvery Delta are complex. With very limited surface water during the south westerly monsoon and erratic but intense northeast monsoon rains that can give rise to flood and drainage problems. There are issues of saline intrusion and low lying land is in parts unable to drain. Groundwater is extensively used to supplement the lack of surface water but now there are issues of overexploitation and salinity intrusion. There is no statistical evidence of climate change but farmers report increased levels of salinity, reduced freshwater flows and some changes of the timing of the seasons. Climate change will likely have significant impacts on the delta region including sea level rise. There are localised issues of naturally occurring hazards and other contaminants. The Cauvery Delta consists of four parts; Lower Coleroon Anicut Cauvery, Vennar and Grand Anicut

634. Water supply and industry have now increasing demand for water supplies; these are being sourced from the groundwater and surface water and are now at levels that are significant to the water balance and must be factored into the water planning.

3. Groundwater Resources

635. The Cauvery Delta region incorporates the districts of Thanjavur, Thiruvarur and Nagapattinam. These districts are underlain by different aquifers namely Archean, cretaceous and Eocene, Miocene and Quaternary alluvial aquifers. The aquifer characteristics are given in Table 62.

Table 62 Aquifer Characteristics

Aquifer	Depth range(m)	Thickness(m)
Quaternary alluvial (approximately)	0-45m	5-25m
Pliocene aquifer	30-100 m	10-35m
Flowing zone aquifer	100-200 m	10-35 m
Miocene aquifer orthonadu aquifer	150-300 m	30-70 m

636. The CGWB report on Cauvery Basin (2002) provide the following summary aquifer characteristics from exploratory wells in the main Tamil Nadu and Pondicherry districts are given in Table 63 below.

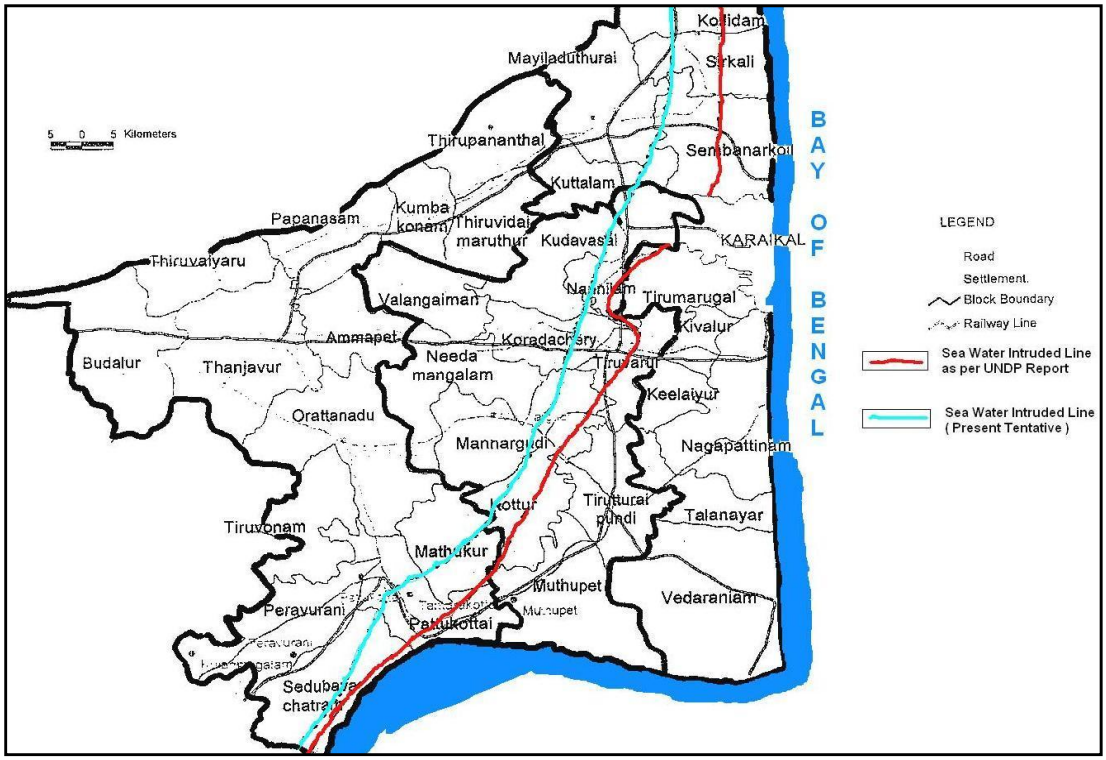
Table 63 Aquifer Characteristics from Exploratory Wells

District	No. of Exploratory wells	Specific Capacity (lps per metre of drawdown	Transmissivity (m2/day)	Storage Coefficient
Thanjavur	16	0.3-11.7	59-3002	4.7 X 10-4 to 6.09 X 10-2
Nagappattinam	11	0.3-14.5	32-1672	9.91 X 10-3
Thiruvarur	16	0.2-7.4	8-1202	4.8 X 10-4
U.T. of Pondicherry	5	0.4-4.9	39-2640	1.2 X 10-4 to 1.02 X 10-3

637. **Groundwater quality:** groundwater is predominantly alkaline. The saline-freshwater boundary map indicates a steady migration inland. In geological history, the low-lying coastal sedimentary aquifers the Cauvery Delta have been flooded during marine transgressions[76]. More recently over-abstraction of groundwater, land use, surface water ingress of sea-water and changes to upstream surface water discharges and have resulted in land-ward saltwater intrusion. Water logging and salinity is also prevalent around the Grand Anicut and other parts of Delta; the extent of sea water intrusion is presented in Figure 39.

[75]Cauvery River Basin: An overview: http://www.indiawaterportal.org/node/24
[76]Frank van Weert, Jac van der Gun and Josef Reckman (2009) Global Overview of Saline Groundwater Occurrence and Genesis. Utrecht, Report nr. GP 2009-1

Figure 39: Sea Water Intrusion



638. District wise position of groundwater resource availability, draft and overall status of the district in terms of overexploitation in Cauvery delta is given in Table 64 below:

Table 64: Dynamic Ground Water Resources by District (2004)

S,No.	District	Net Annual groundwater availability (MCM)	Annual groundwater Draft (MCM)	Extend of groundwater use (in %)	Number of ground water overexploited blocks
1	Thanjavur	776	527	72	3
2	Thiruvarur	324	268	83	1
3	Nagapattinam	181	232	128	4

639. **Main Problems and Issues** include (i) flooding and inundation due to back water and flood; water logging of soils around Grand Anicut and other areas of Delta; (ii) increased in salinisation of land; (iii) saline groundwater intrusion in coastal aquifer due to sea water ingress and over-exploitation of groundwater; (iv) a steady increase in groundwater over-exploited blocks in delta area districts of Nagapattinam, Thiruvarur, and Thanjavur; (v) reduction of in potentiometric head of the Orthoanadu Aquifer (Miocene) around Grand Anicut;(vi) aquaculture farms adding contamination to water sources; (vii) potential rise in sea level; (viii).problems of salinity, sodicity and water logging in Nagapattinam and Thanjavur district; (ix) H2SO2-toxicity, sodicity, salinity and deficiency of nutrients are constraints for rice production; (x) reduced surface water inflows in delta area, ground water use is intensified resulting in saline water intrusion close to coastal area; and (xi) uncertainly in availability of Mattur Dam water in delta area.

4. Agriculture

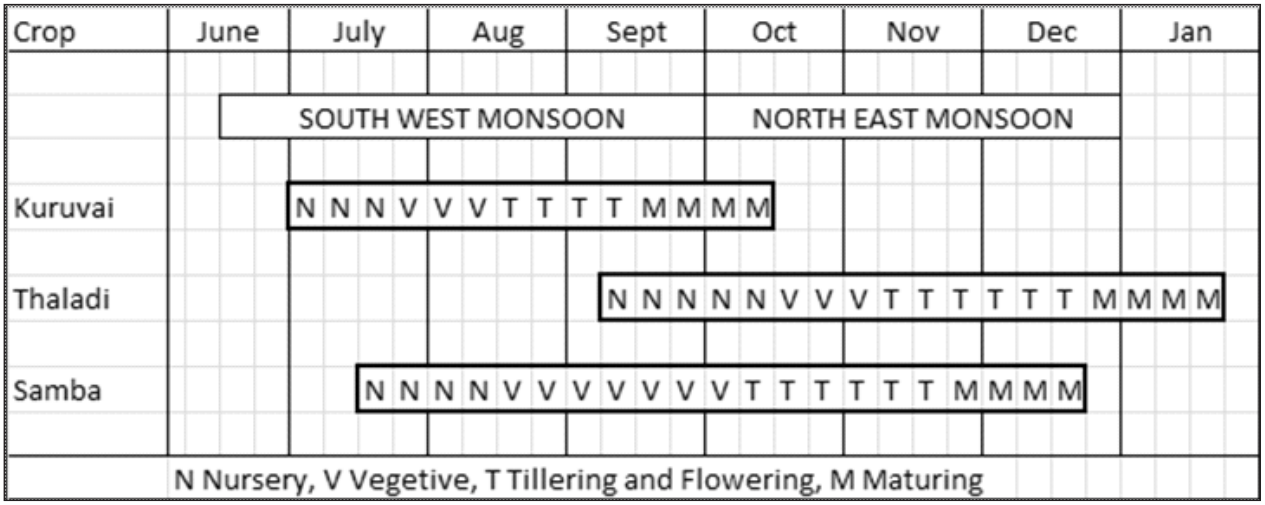
640. In the Cauvery Delta rice is the principle crop; it is either single or double cropped. A third rice crop is also grown during summer in some small parts. Because of plentiful rainfall during North-East monsoon and good irrigation facilities, rice is the most suitable from September to December. Pulses are the next important crop after the rice harvest and is grown through, out the delta regions from January onwards. Black gram and gingelly (sesame) is sown in April with summer irrigation and some summer showers. Vegetables are also grown during summer months in some areas depending upon the availability of water. In different scattered places coconut trees and bamboos are also grown. Many places fruits like mangoes, guava, citrus fruits, jack fruits, banana and cashew are grown as longer duration crops occupying the land

for more than one year for successive returns. Similarly sugar cane, rose, crusade and arali are also grown at many places. The cropping calendar is shown in Figure 40 below.

641. The short duration (105-110 Days) rice varieties Kuruvai is most popular among the formers. This is first crop of paddy cultivated in June –July, followed by Thaladi (135 days) as the second crop of paddy in the double crop lands, while in the single crop lands long duration Samba paddy (150 days) grown. Samba is being grown under dry and semi dry conditions also. The ground water tapped with small tube wells is mainly used for raising advance paddy nurseries and for meeting crop water requirements during the late maturity of the crop. The main problems faced by the delta farmers can be summarized as below.

- Because of overall water shortage in the basin and lack of assurance about the Mettur Dam releases, cultivation planning is not systematic.
- Torrential rainfall during North-East Monsoon hinder both Kuruvai harvesting as well as Thaladi transplanting.
- Lack of storage facilities of rain water. the number of ponds, check dams, small reservoirs and diverts etc are very limited to control water at times of heavy inundation.
- Lack of drainage facilities in the Delta region. Groundwater recharge is very poor and soil reclamation is not feasible making water unfit for agriculture purposes.
- There are labour shortages during peak season of harvesting or planting. Because of insufficient yield in crop production remuneration to the farmers for rice cultivation are low in many cases, timely field operation are not carried out. Lack of co-ordination between owners and tenants, as well as between farmers and fisherman create social problems.
- Frequent unfavorable weather conditions lead to heavy incidence of pests /diseases to the crops.
- Clear cut policies and planning of contingency cropping sequence in the events of mishaps in the routine cultivation has not been developed. There is a lack of co-ordination between agriculture and PWD officials on water and crop management.
- There are efforts for development of new crops more suitable to the prevailing delta conditions but farmers are not well aware of these opportunities. Non rice crops, vegetables, horticulture are becoming more popular but because of complexity of water soil regime in delta, extensive research and planning is needed to guide the cultivators.
- There are problems of poor cash flow among the cultivators which needs to be resolved by providing micro-credit facilities and insurance services.

Figure 40: Cropping Calendar



5. Irrigation and Floods

642. Surface water allocations to the delta are defined by the Cauvery Tribunal which assessed the mean annual water availability of the Cauvery river basin as 740 TMC (20.9 BCM). Overall Cauvery water allocation by the Tribunal to the State of Tamil Nadu has been fixed as 419 TMC (11.8 BCM).

643. The Cauvery Delta system is different from most other irrigation schemes. The Delta irrigation system is served by numerous distributaries of Cauvery River as natural river courses which serve as combined irrigation and drainage

canals. As the canals are in the regime condition, redesigning of the system with lining is not feasible. The water use efficiency has to be mostly obtained by on farm water management practices and more methodical water distribution. Water allocations are based on timed allocation and not measured due to the lack of measuring structures; the very flat terrain poses technical problems of water measurement. There are reported to be around 39,000 tanks in the Cauvery delta with a total capacity of 540MCM and 23 reservoirs with a capacity of 4379MCM.

644. The surface and groundwater in the Delta are closely linked and it is important to assess the overall conjunctive ground and surface water efficiency, planning must be based on efficient conjunctive use planning. Under such situations the side effects of lining of canal systems is must be assessed; seepage from the canals play an important role in supporting groundwater recharge and salinity control.

6. Cauvery Delta Modernization Project

645. The Government of Tamil Nadu constituted a task force in September 2007 for preparation of a comprehensive report on modernization of the Cauvery delta irrigation and flood control and drainage works. The report of task force[77] along with estimate of proposed works was brought out in November 2008. The Cauvery delta modernization project had also been prepared earlier two times, but the funding required for the project could not be approval by the Central Government because of the dispute on Cauvery water under adjudication in the Cauvery Water Dispute Tribunal.

7. Flooding

646. Floods and drainage are a complex problem in the delta. The Northern-East monsoon starting around the last week of November gives about 700 mm of rainfall. The south-west monsoon giving about 300 mm of rainfall in the delta is easily absorbed in the system this rainfall is fully utilized for agricultural activities. The North-East monsoon is generally associated with cyclones. Because of flow from the upper position of delta and heavy showers in lower region the delta becomes fully congested to drain any water into sea. If the inundation is prolonged for more than 5 to 7 days, there is damage to the standing paddy crops. Some of the lower delta area is below sea level which makes it impossible or very difficult to drain. The speedy drainage of the area becomes important for protection against excessive and long duration flooding to save the paddy crop which can survive inundation for 3-4 days. The tidal variation of the sea is about four feet which also causes a significant ingress of sea water into lower delta during high tide. Another problem being faced is closing of mouth of drainage outlets by sand bars formed by strong littoral currents and deposition of river sediment. Of about 1600 km of river network in Cauvery Delta about 530 km serve as standalone irrigation. The remaining channels function as irrigation cum drainage.

647. The following measures were proposed by the PWD, Government of Tamil Nadu for flood and drainage control:-

(i) Aquatic weeds in the bed and sides of channels require to be removed and further growth and proliferation are to be controlled with proper weed management.
(ii) Reshaping of exiting drains wherever necessary by bringing the section to required standard and strengthening the banks.
(iii) Strengthening the meandering courses and opening of more straight cutting drains.
(iv) Improvement to the cross-masonry structures and providing suitable inlets and outlets with regulating arrangements.
(v) Excavation of additional drains.
(vi) Provision of additional escapes, inlets and outlets structure are to be provided. Place where roads are blocking the drainage water to be identified and culverts be provided or the existing vent way of the culverts to be enlarged.
(vii) Restructuring and improvements in Vedaranyam Canal and strengthening the canal bunds. (the Vedaranyam Canal runs parallel to the sea originally a navigation canal, and acts as drainage water body with complex hydrology).

648. All the tail end regulators at the tail ends of each distributor which in fall into sea are in near total state of disrepair. Potentially the regulators have various functions including (i) lifting the elevation of the water for irrigation (with the gates closed); (ii) allowing free discharging the flood generated inland to flow down the river to in fall into sea with all gates opened; (iii) to prevent the ingress of sea water inland and support the reduction of salinity in the area. There are eighteen tail end regulators requiring to be redesigned with adequate vent capacities and easy operating systems.

[77]Report of the Task Force On The Modernisation of the Cauvery Delta Zone in the Cauvery Basin Of Tamil Nadu November 2008 Tamil Nadu Water Resources Organisation

B. Strategic Framework for Current Issues

1. Farmers Perceptions

649. A participatory rural appraisal exercise for the delta was completed in February 2011. During the PRA farmers intimated during discussions that they have observed some changes in the climate including the longer winter period as well as observed increased salinity, reduced freshwater and some temperature effects; some salinity effects are reported to be as a result of the Tsunami. The interviews demonstrated fairly significant difference in issues depending on the locality.

650. Farmers identified problem areas, including the erratic releases from Mettur dam is affecting crop planning, problems of drainage especially in the low lying areas, lack of maintenance of drains, issues of roads blocking the drainage, issues of the sand bars blocking the river mouths were raised a key issues in the coastal zone. Villagers living in the coastal area had serious concerns about the extent of coastal erosion which was considered to have very serious impacts before too long. Summary points raised during the participative rural appraisal are shown below.

651. **PRA Village 1 Thirmullaivasal[78]:** (less than 3km from coast line): a summary of water management issues by the fishing community and agricultural community are described below.

(i) The closure of the river mouth with a sand bar is a major issue and has become worse due to the reduced flow of water into the sea during dry season. Water flows in both directions from river and from sea are needed for water quality as well as access for fishing boats to move to and from the sea and for spawning of mud crab. With less fish landing the females need to buy fish at higher cost for marketing. Problem is higher for single women as they anyway have to depend on market for fish they take to market. Common practice is male member goes to sea to catch fish and females sort and sell in the market.
(ii) During rainy season it is of less of a problem as there is flow of water and the barmouths remain open but rainy season (November-December) is not the fishing season as sea remains rough, cyclone etc. makes it risky.
(iii) Coastal flood and inundation is major issue . This year they had two flood events . The area is below sea level. Water enters almost 400m inland on an average. .
(iv) There are major challenges in drinking water; drinking water is distributed through piped network managed by panchayat. Demand for this water has gone up with deteriorating ground water quality. The handpumps to extract ground water for household consumption was primary source before Tsunami. Now that serves only non drinking and cooking purpose as piped water supply is less than demand.
(v) There are water supply shortages. Even cooking and drinking demand are also not met in dry seasons. additional storage is needed. Hand pumps are used to extract saline ground water as surface water based supply is inadequate. Pipelines get broken by trucks Females and children spend almost an hour daily to get drinking and cooking water. Water flow is very slow leading to more time spent in collection and leading to disputes

Water Management Issues

(i) Tail end regulators shutters which were damaged during Tsunami can help the better management of river flow.
(ii) Salinity in water they feel will get resolved through piped water supply from surface water. But also feel rainwater harvesting in ponds might help through water percolation as well as that might reduce enhanced salinity of ground water.
(iii) Salinity is increasing in some areas through ground water extraction problem areas are identified and government has regulated that no more tubewells are allowed and only a single samba crop is permitted. They use rain and channel water for one crop. The main issue is to avoid sea water intrusion.
(iv) Farmers all make use of minimum support price. They want other crops but no water availability makes it impossible.
(v) The community is against aquaculture as they feel the profit is taken away by middle man and company who owns. Open sea fishery brings in profit directly to fishing community individually as the individual efforts are determining landing, marketing and benefit flow. Market price for wild shrimp is double than the farm shrimp.
(vi) River bank flood protection is not major issue as flooding happens due to backwater flow from sea. Some coastal protection through stones, boulders and support for barmouth opening might solve the problem.
(vii) Interstate river water sharing management is a major issue. Water releases by Karnataka could be better controlled.

[78]PRA (8.2.2011)was attended by 42 individuals and of whom 10 were women in a thatched roof space on the coast.

(viii) There are designated areas for public ponds. But they have been encroached by villagers as digging has not happened. They are located on revenue department lands.
(ix) People feel close to panchayat as they have easy access to local governance. Panchayat and some elders wanted support to purchase fish finding echo sounders for fishing.
(x) The villagers want ground water recharge to reduce salinity through ponds or any other means unknown to them.
(xi) Weather forecast flow from collectors office office to panchayat through wireless and TV which they consider are good enough and corroborate with their observations and are followed strictly.

652. Possible mechanisms to enhance future resilience and reduce future vulnerability; women want more involvement in drinking water management, their priorities are river mouth opening, drinking water, increased Panchayat's role in water management, ponds may help check floods. There was interest in a jetty.

653. **Capacity building and training needs:** It is important to have common training workshops for all stakeholders followed by customized modules for target groups: (i) for both women and men, training to improve their income and skill during four idle months; (ii) young men are keen on any training but special interest is on fishing effort related training; (iii) women are interested in marketing related training. Fish processing, preservation, packaging and marketing so fishing community can control the market. Easy loan facility especially for single women are high in demand; (iv) panchayat want training in managing the drinking water supply facility maintenance.

654. **PRA Village 2: Voimedu, In Nagapttinam District** (10-12km from coast line): It is at the tail end of river course. Agriculture main occupation. Paddy samba is the only crop. There is a small fishing community as well. 70% agriculturists and 30% fishing community. Land holding size is between 1-5 acres. Current issues: Challenges in agriculture sector-irrigation water access.

(i) 50-70% water demand for irrigation is met by drainage river course water source and through pumping. Electric pumps are used (established in 1962) to lift water 4 meters and then through main canal and tributary canals . Water quality is good as this is the rainy season
(ii) No ground water is used for irrigation due to salinity.
(iii) After January sea water enters through the river so no water is lifted to canals.
(iv) Rest of the time land is used sometimes for grazing and animal rearing fetching some income from milk production.
(v) Only paddy is grown as soil is unsuitable for any other crop. Horticulture and vegetables are not possible, a few past attempts failed.
(vi) Unwilling to move out of agriculture. Aquaculture is acceptable because of possible adverse impact on future agriculture potential, small holding size and community aquaculture is not a feasible solution as people are individualistic and community activity will not be sustainable.
(vii) Coastal flooding is problem for 300 acres of land due to lack of drainage.
(viii) Silting and barmouth closure is major problem. Tail end dredging of rivers along 8 km close to the coast is was a high requested by may water flow.
(ix) Electricity is available for 10 hrs free of cost for water lifting.
(x) Agricultural labour has become high cost and difficult to get. NREGA labour are unwilling to do digging work. NREGA mainly supports road construction.
(xi) Challenges in drinking water; the primary source is Kollidam river based storage and distribution pipelines by Tamil Nadu water Board and secondary sources are saline ground water at 8 ft depth. All pipelines and hand pumps are public standposts. Use of saline water is mostly due to lack of adequate option.

2. Cauvery Delta Modernisation Project

655. Government of Tamil Nadu constituted a task force to comprehensively study the Cauvery Delta irrigation canal system and prepared a Cauvery Delta Modernization Project Report (CDMR) in 2008. The report provides an excellent basis towards meeting the long term sustainability of the Delta. The modernisation plan is very relevant to the adaptation strategy. The modernisation plan has been reviewed and the study has built many of the recommendations on the plan. A summary of the parts and cost Cauvery Delta Modernistion[79] proposal is summarised in Table 65 below.

[79]The costs of the 2008 report were increased by 25% to incorporate for price escalation to 2011

Table 65: Summary of Cauvery Delta Modernisation Proposal (2011 prices)

	Description	Cauvery	Vernar	GAC system	LCA System	Total	Cauvery	Vernar	GAC system	LCA System	Total
		INR crore 2011 price					$ million 2011 prices				
1	Strengthening of river banks	193	135	231	33	591	43	30	51	7	131
2	Strengthening and lining of distribution network	725	636	378	73	1,811	161	141	84	16	403
3	Repairs & replacement of structures	536	619	195	46	1,396	119	138	43	10	310
4	Additional Structures	169	126	109	25	429	38	28	24	6	95
5	Reconstruction/rehabilitation of tail end regulators	9	54	-	5	67	2	12	-	1	15
6	Improvements to drainage system	238	210	59	-	506	53	47	13	-	113
7	Improvements to Vedaranyam Canal	-	13	-	-	13	-	3	-	-	3
8	Improving rehabilitation of straight cuts	-	54	-	-	54	-	12	-	-	12
9	Tank improvement	-	16	-	3	20	-	4	-	1	4
10	Lift Irrigation rehabilitation	-	16	-	-	16	-	4	-	-	4
11	Improvement to inspection tracks	139	54	-	-	193	31	12	-	-	43
12	On Farm Development	111	111	50	2	274	25	25	11	0	61
13	Water users Associations	64	64	29	1	158	14	14	6	0	35
14	Institutional Strengthenin	68	18	8	4	96	15	4	2	1	21
		2,250	**2,125**	**1,058**	**191**	**5,624**	**500**	**472**	**235**	**42**	**1,250**

3. Surface Water Resources Issues

656. As a result of upstream water resources development the pattern of water availability for use in the Cauvery Delta has changed. Reduced inflows to the delta has resulted in increased groundwater use that has contributed in part to the saline intrusion in the coastal strip. There is also impeded drainage in some areas caused by the littoral drift and beach processes blocking drainage outfalls. This is a situation will have been aggravated by reduced surface water flows through the delta which reduces the capacities to maintain an opening of the river mouths.

657. River flows in the lower reaches of the Cauvery no longer rise in response to the southwest monsoon as they did in the past. Past practice had been to plant a first rice crop in June, with irrigation from the Cauvery. There is now uncertainty about the availability of irrigation water in June, and delays in planting can mean that the crop cannot be harvested before the onset of the northeast monsoon, resulting in crop damages and losses.

658. Saline intrusion now affects a coastal strip of about 20 km deep. This may have been exacerbated to some extent by inundation with salt water during the 2004 tsunami. Groundwater abstraction in critical areas has been stopped, but the reality is that saline intrusion may continue if groundwater abstraction is not halted in other areas as well. As a result of the saline conditions, crop yields in many areas are low. In some low lying parts it is not possible to plant due to salinity and drainage problems.

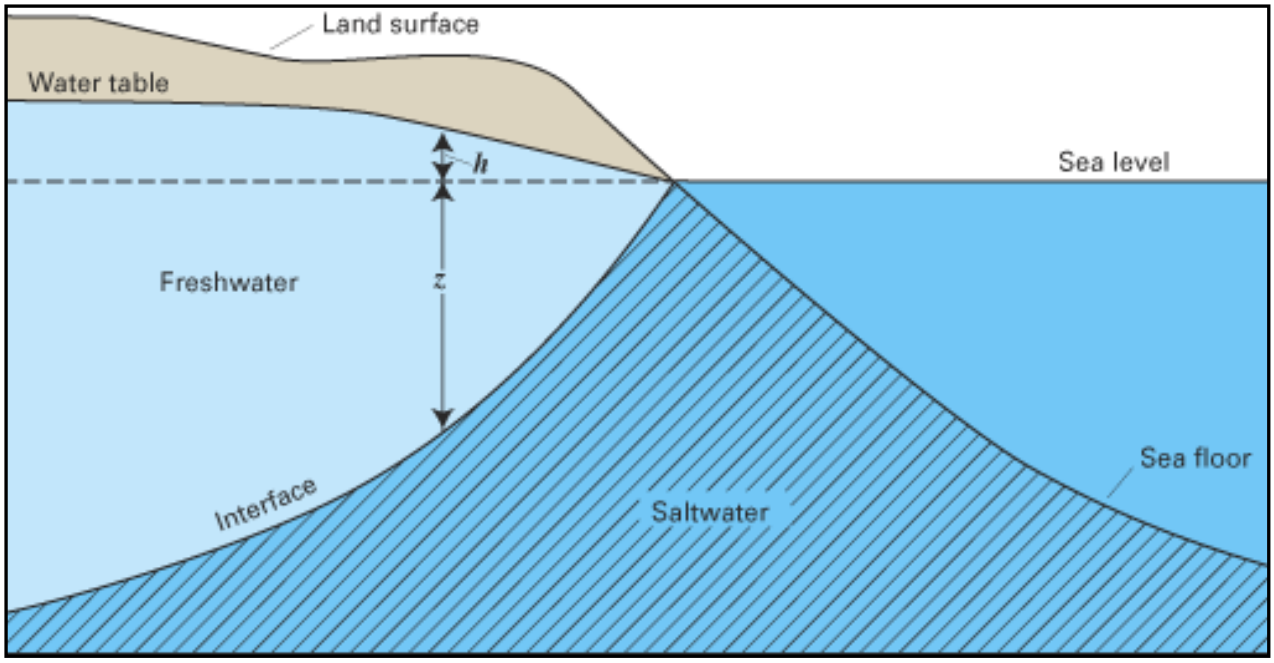
4. Groundwater

659. Emerging issues include saline water intrusion in coastal aquifers due to over-exploitation of ground water, flooding and inundation due to backwaters and floods, increasing salinisation of land, as well as soil related constraints.

660. The over-abstraction of groundwater inland results in a lowering of groundwater table relative to mean sea level and results in a reduction in the hydraulic gradient. This diminishes the ability of groundwater (freshwater) to push the saline water seawards. Therefore any changes in the volume of freshwater discharge will result in a subsequent change in the saline-freshwater boundary. In addition groundwater abstraction close to the coastline may actively induce up-coning of saline waters. Previous research on saline water-fresh water interface have identified that at a given point inland in a coastal aquifer the depth to which freshwater extends below sea level is approximately 40 times the height of the water table (the Ghyben-Herzberg principle) – this is due to differences in densities of fresh and salt water[80] as shown in Figure 41 below.

[80]www.igrac.net

Figure 41: Relationship of Height of Freshwater and the Fresh Salt Interface



661. The height of the water table above sea level and the groundwater hydraulic gradient are key factors in determining the freshwater-saline boundary in a coastal aquifer. In the context of climate change sea level rise will result in a change in the hydraulic gradient (unless there is concomitant increase in groundwater discharge) and therefore a shift of the saline-freshwater boundary inland. It is clear from that this migration inland is well underway.

662. The groundwater dynamics in the Cauvery Delta are closely linked to surface water dynamics both from upstream freshwater discharges and surface ingress of seawater. Lateral seawater intrusion in coastal areas is increased in the river estuaries (greatly increasing the coastline length) if conditions allow seawater to travel inland through these bodies. Salinity protection measures like tail-end gates either absent or not functioning properly. When the shallow fresh groundwater resources are abstracted and land use changes decrease groundwater replenishment, the shallow fresh groundwater head decreases. This can cause up-coning of deeper often more saline groundwater and an inland movement of the fresh/saline groundwater interface. Also decreased estuarine river discharge because of upstream water allocation may increase seawater intrusion; the reduced discharges from Mettur dam would likely have had some impact on this. This anthropogenic induced intrusion can be a relatively fast process depending on hydraulic head changes and the transmissivity of the coastal aquifers.

663. The over-abstraction of groundwater inland results in a lowering of groundwater table relative to mean sea level and a reduction in the hydraulic gradient. This diminishes the ability of groundwater (freshwater) to push the saline water seawards. The state of groundwater resources development Nagapattinam, Thiruvarur and Thanjavur districts is 128%, 83% and 72% respectively.

664. Irrigation in Nagapattinam, Thiruvarur and Thanjavur districts is dominated by canal water with groundwater making up a relatively small amount. However, groundwater reserves have been heavily exploited in Nagapattinam district and all districts have groundwater levels close to mean sea level and sometimes below sea level. The CGWB has prepared notifications to restrict groundwater abstractions in some blocks.

665. 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. Artificial recharge requires good supplies of freshwater and permeable surface soils to permit infiltration to the aquifers. There are various proposals for groundwater recharge There are some concerns over the viabilities of most of these plans in the Cauvery Delta. The costs and benefits accrued through artificial recharge approach will need to be weighed against groundwater resource savings that could be achieved through other means such as demand related savings. Artificial recharge linked to supporting other economic benefits such as tanks are of significantly greater value than stand alone recharge structures, Silting up and lack of maintenance of artificial recharge structures is an issue. Although artificial recharge will be part of the overall solution in certain circumstances, it should not be seen as the panacea for over-exploitation or a justification for not tackling the demand related issues.

666. There are a number of options for dealing with saltwater intrusion appropriate to the Cauvery Delta. The approaches require to be better studied and require monitoring and modelling. Of the many potential approaches, the following would appear to be the most viable for the Delta; (i) tail end regulators; (ii) controlling the volume of groundwater abstraction by regulating the volume pumped or the number of wells or increasing the efficiency of the irrigation, especially reducing the evaporation losses; (iii) development of agricultural systems with lower demand cropping systems; (iv) use of salt tolerant crops (v) promoting the use of ponds and tanks including farm ponds as an alternative to groundwater; village ponds could be desilted (vi) consideration to changing drinking water and industrial abstraction to treated surface water sources.

667. The 1964 UNDP groundwater study identifies the possibilities of increasing abstractions in the shallow aquifers and allowing further lowering of the seasonal water table, the study considered that recharge during the NE monsoon would be adequate to recharge this additional abstraction. It is likely though that existing abstractions level are already significantly higher than at the time of the 1964 study.

5. Surface Water Irrigation

668. There is little possibility of an increased storage or allocation on the Cauvery upstream of the delta to provide supplementary irrigation. There are no further suitable large storage sites in that part of the basin in Tamil Nadu. The main opportunities lie in increasing efficiencies, management of demand and salinity control.

669. Irrigation efficiencies in the delta region require to be improved, further study is required to best assess how this should be achieved. There are options for a complete reconstruction and separation of irrigation and drainage but this is not considered appropriate by the study consultants and also the findings of the Cauvery Delta Modernisation Report (CDMR). There would appear to good argument for an intermediate approach of some remodelling including some straightening and creation of separate drains in critical areas.

670. The use of lining is not considered appropriate, lining will reduce the recharge to the groundwater and lining of the large cross section of the drains cum canals is very expensive. Many of the drains and canals suffer from very heavy vegetation growth and cost effective routine clearing should be implemented which would provide significant benefit. The planning of the irrigation systems must be holistic and include both irrigation, drainage and salinity control. Irrigation planning must incorporate both the main system but also incorporating irrigation potentials from tanks, groundwater and lift irrigation.

671. In a conjunctive surface and groundwater use situation the only real savings to groundwater can achieved where modifications to irrigation and cropping-practices reduce the non-beneficial evaporation or non-beneficial discharges to saline water bodies.

672. There is a need to better manage groundwater irrigation especially in the overexploited and critical blocks as well as in the saline areas. Of most potential would appear to be the development of alternative sources to groundwater; options would include; (i) small farm and medium ponds and tanks;(ii) rehabilitation and expansion of small and medium lift irrigation schemes from drains and rivers. Water ponded behind the tail end regulators could be used for irrigation by gravity or small portable pumps. Improved irrigation efficiencies can reduce the groundwater demand with special emphasis to reduce the evaporative losses. Use of SRI, direct seeded rice, shorter variety rice and other agricultural technologies to improve productivity and reduce the water demand is becoming popular.

6. Water Use Efficiency

673. Water use in the Cauvery Delta is a mix of surface and groundwater; the water use can be classed as partly conjunctive as water lost through infiltration is partly available for reuse by groundwater; in some parts of saline groundwater the conjunctive use is not fully defined . Surface water is distributed through large canal cum drains, there is no measurement and allocations are based on timed allocations. Many canals are silted with vegetative growth which increases the water losses. The tail end regulators are either broken or not constructed resulting in significant loss of fresh water to the sea. The system is water short during most of the year but prone to flooding in the northeast monsoon. Water saving by improving the irrigation canals is not easy due to the very large channel cross sections required for drainage; flow measurement and measured water allocations is difficult due to the flat terrain. Improved maintenance of the canals is important.

674. The main scope for increasing water use efficiencies is to retain freshwater to support artificial recharge of groundwater as well as for direct irrigation use. The construction of tail end regulators can reduce some loss of freshwater to the sea, although some allocation of environmental flow maybe required. Water retention and increased recharge during

the northeast monsoon is proposed though farm ponds, tanks and flood alleviation areas which can be used to support water shortage during the non monsoon and south west monsoon period.

7. Ponds and Tanks

675. The Grand Anicut Canal system provides supplementary water to about 700 tanks. In addition there are tanks fed by local catchments. It is estimated that about one third of all tanks are fed by canals and two thirds by catchments; the overall irrigated area from tanks is estimated 33,000ha. In addition there are numerous ponds and more informal tank systems all with potential to support irrigation and groundwater recharge.

676. The rehabilitation and expansion of ponds and tanks would appear to offer good opportunities to improve the water supplies for irrigation and support groundwater recharge. There is a need to rehabilitate the existing tanks many of which are silted and have poor canal systems. Tank and pond development should be implemented as an integrated approach with flood relief described below. Irrigation from tanks and ponds could be by gravity or small low head pump systems, or indirectly from groundwater in the periphery. Ponds can provide supplementary water during low rain periods in the monsoon which can be erratic in the Delta area.

8. Lift Irrigation

677. Lift irrigation was developed to supply water to the high level lands in this area that could not be commanded by the gravity systems. There are reported to be 29 pumping schemes which provide irrigation facilities to about 10,000 ha. The operational status of the schemes is poor. The pump schemes require to be made operational; efficiencies are low and maintaining the medium size pump schemes fully operational is an issue. The use of smaller community or individual farmer pumping offers more flexibility and devolvement of operational responsibility. The development of the tail end regulators to raise the water levels which could fill drains offers opportunities for farmers using small portable pumps to irrigate directly to their fields where gravity supply is not viable. Similarly small portable pumps could be used to irrigate from lower level ponds and tanks that cannot be irrigated by gravity. The transfer of management of the lift irrigation to farmer and water user organisations or village cooperatives should be considered.

9. Flood Control and Drainage

678. The flood problems and drainage congestion are caused by northeast monsoon which normally starts in the third week of October. The southwest monsoon occurring in June to September does not cause significant drainage or flood problems in Cauvery Delta; largely as a result of the attenuation provided by upstream storage as well as abstractions.

679. In the Cauvery Delta it is important to consider how flood control measures can be integrated with drainage and irrigation. Flood control would require increasing the strength of the river dykes. In parallel improved drainage and flood diversion should be provided. By combining the functions of flood diversion with some form of retention in tanks or flood relief areas, the parallel benefits of irrigation use and groundwater recharge could be achieved. This integrated approach to flood management incorporating drainage and irrigation provides opportunities to meet multiple objectives. Flood assessments including quantification of design discharge including estimated increases in flood flow and sea level rise under climate change.

680. Strengthening of banks of rivers and providing protective works where required is proposed in the CDMR. These strengthening works include providing gravel roads on top of embankments for inspection purposes as well supporting community needs for roads. Banks should be designed with adequate freeboard to meet increased flood levels from sea level rise, alternatively the base section should be widened to allow for increased height to be added at some time in the future.

681. In the coastal strip there are water logging as well as salinity problems. The tidal range is low (at Chennai, the nearest gauged site with data available, the range is about 0.4 m on neap tines and 1.2 m on spring tides), and this in conjunction with impeded drainage outfalls results in unfavourable conditions. Drainage outfalls to the sea are frequently blocked by sand and is a significant problem for fishermen and contributes to flooding.

682. Sea level rise will aggravate the existing drainage and salinity problems, and will have more impact than would be the case in an area with a larger tidal range. Sea level rise is estimated to be of the order of 0.3 m by mid-century, but potentially could be higher. An aspect that affects the impact of sea level rise is whether or not the land mass is rising or falling. It is not known if the delta land mass is rising (as is the coastline at other locations along the Indian coast), or subsiding through compaction and consolidation of sediments. Depletion of groundwater can cause settlement of the land.

683. Most drainage channels are silted and many are severely choked by weeds. Maintaining the drainage channels is a routine requirement and adequate resources must be provided to do this on an annual basis. Many of the drainage channels also operate as irrigation canals and small check structures are required to achieve adequate head for irrigation; ensuring that these structures do not affect the drainage capacities is critical. Roads cause major problems of drainage and evacuation of flood water, cross drainage structures are inadequate and often blocked or partially blocked due to lack of maintenance. Increased rainfalls and higher sea levels will worsen this situation.

684. The Vedaranyan is an old navigation channel, parallel and close to sea coast. It is no longer used for navigation purposes, but provides a storage buffer when sea is rough with rising tides. It discharges the stored water during low tides. The CDMR proposes the strengthening of Vedaranyan canal bunds and redesigning straight cuts to sea have been proposed also. The CDMR also proposes the removal of flood waters resulting from the northeast monsoon rains from the basin. The viability of these drainage proposals should be confirmed by modelling of the drainage capacities with present and future sea levels.

10. Flood Diversion and Retention

685. A plan exists for additional diversion of flood flows primarily through the Grand Anicut canal, and storage of these in tanks. There are also some major flood diversion schemes including barrages on the Coleroon river These proposals needs to be considered further but the very flat terrain and high flood volumes would make major flood diversion difficult without very large drain sections and significant land acquisition. There would appear to be potential to develop smaller flood relief systems by diverting floods into designated local flood relief zones, medium and small farm level tanks and natural water bodies.. By combining the functions of flood relief with retention for dry season storage for irrigation and support for recharge the benefits of diversion can be enhanced. The retention functions would be achieved by provision of bunds and a gated control structure. Options for flood diversion retention schemes could include use of: (i) small farm ponds located in individual farmers fields; (ii) existing natural water bodies which could be adjusted to improve their retention capacities; (iii) storage in the Vederanyan canal and other major drains; and (iv) the low lying lands presently abandoned due to drainage and salinity problems. Irrigation use from the flood retention waters could be abstracted by gravity or by small individual pumps or indirectly through groundwater in the periphery of the water retention areas. Tail end regulators could help support flood water retention.

11. Salinity Control

686. The provision/replacement of tail end regulators (tidal gates) will support retention of fresh water for irrigation, and reduce saline intrusion. They can also protect inland areas from storm surges.

687. The need for dismantling and reconstructing all the tail end regulators is an important part of the Cauvery Delta Modernisation Report. The existing regulators are all very old and the gates are badly corroded. Tail end regulators can serve three important functions: (i) to head up the irrigation supply adequately with gates closed so that there could be effective withdrawals in the channels above to feed the irrigation lands by gravity or pump; (ii) to allow passing of flood flows to the sea with minimum head loss; and (iii) to halt the ingress of sea water inland to protect farms and communities from salinity intrusion especially at high tides and during storm surges. There are 18 tail end regulators, of which 7 are in Cauvery sub basin and 11 in Vennar sub-basin, and 9 in the Lower Coleroon basin. There may be a need for additional tail end regulators on minor drains. For the tail end regulators to be fully functional may also require some sea side bunds to protect the farms from higher tides and storm surges; effective drainage through the bunds would have to be incorporated into the planning.

688. The location of the tail end regulators is critical to optimise the functions of salinity control and irrigation. Regulators are major structures and would be normally designed for 50 plus years design life (for the main structure) so it is important that sea level rise is factored into the design; design factors might include the change in the salinity regime of the lower rivers which may affect the siting of the regulators as well as the need for some additional freeboard to be built into the design.

689. The regulators would have some environmental impacts especially for water users taking water below the regulator. The river would effectively become saline with possible impacts on the coastal and near coastal communities. Reduced flows to the river mouths may increase the build up of the sand bars; there maybe some potential for occasional releases of water to suppport flushing.

690. Steel gates of regulators in the coastal area are very prone to corrosion and an intensive maintenance will be required using high quality protection paints; there are options for fibreglass gates that have been tried in other parts of India. Rubber dams have been suggested but experience of these is is not good.

12. Agriculture Systems to Meet Adaptation

691. Development of appropriate cropping systems forms an important aspects of adaptation. The Tamil Nadu Agriculture Universally (TNAU), with the support of Government of Norway, is undertaking extensive research on the effect of climate change on rice production and to work out various adaptation measures to safe guard rice productivity in the State; the main aim of the project called 'Climarice' is assessing climate variability and its impact on water availability and rice production system in Cauvery river basin. There is very limited use of saline tolerant rice varieties which could potentially alleviate some of the salinity impacts on the rice crops; improving farmer access to the most appropriate seed varieties requires to be addressed.

692. The changing climate situation and problems of flood and salinity may require adjustments of the crop calendars and crop diversification. Zonalisation of the Kuruvai crop is one aspect being considered to reduce water demand. Medium term weather forecasts could assist farmers with their crop planning; this work is being coordinated with the support of National Centre for Medium Range Weather Forecasting (NCMRFF). Tamil Nadu Rice Research Institute (TNRRI) is conducting diversified research activities to formulate an Irrigated Water Management Strategy for rice. Other research activities in the institution includes; (i) maximizing rice productivity under droughts and floods conditions; (ii) potential for mechanization of rice-cultivation in the delta; (iii) development of technologies for direct seeded rice.

13. Fresh and Brackishwater Aquaculture in Low Lying Saline Areas

693. Large low lying parts of the coastal area struggle to grow any crops due to drainage problems and salinity. Some areas are never cropped and other areas are cropped but with very low yields. Sea water rises of up to 30cm by mid century will result in expansion of these low lying non or low productive areas. Some of the areas unsuitable for rice cultivation have been converted by farmers for fresh and brackishwater shrimp and fish farming. Shrimp farms have shown mixed results and there is significant local objection to outsider investors buying land for shrimp culture. Conflicts have also developed between farmers and shrimp cultivators because shrimp is reported to be causing enhanced salinity in the adjoining farm lands. Poorly designed and managed shrimp farms have suffered major losses due to disease. Some local farmers/ fishermen have, however, formed investor groups and using modern technologies with the support of government departments, have flourished with good financial returns. Other farmers are growing fresh water fish in ponds filled during the monsoon.

694. Low lying parts of the coastal area have, and will continue to struggle with salinity and drainage problems and shrimp aquaculture can offer potential opportunities where agriculture systems do not; sea level rise will increase the problems for agriculture in the low lying lands. Well planned shrimp farms with properly designed supply and drainage systems can reduce disease risk and can potentially provide good returns with quite low environmental impacts. Support for local farmer owned enterprises, cooperatives or joint ventures will reduce the social tensions. Well designed demarcation of zones for shrimp and rice can avoid the issues of conflict over salinity.

695. The Mekong Delta in Vietnam is a good example of integrated development where in the low lying coastal lands lying on the sea side of tail end regulators farmers grow shrimp; above the tail end regulators farmers grow rice. There is an intermediate zone where farmers grow wet season rice and then switch to dry season shrimp. The potentials and appropriateness for shrimp culture needs further research and consultative planning. The siting of the regulators and protection dykes has to be carefully planned considering optimum land use both present and in the future.

696. There are proposals for thermal power plants which are under consideration along the coastal zone. The optimum location to site these plants needs to be incorporated into the planning to ensure they don't affect the drainage and natural coastal processes. There would be advantages if the power plants were located in areas of poor agricultural potential including areas of poor drainability.

14. Potable Water

697. Potable water for the rural areas is sourced from shallow tubewells with hand pumps as well as piped water from the Coleroon river. There are major challenges in drinking water; drinking water is distributed through a long distance piped network managed by the Panchayat. Water is abstracted from the river bed using infiltration wells. Water is supplied to house connections and public standposts. The handpumps to extract ground water for household consumption used to be the primary source of supply before the Tsunami. Presently the tubewells only serve for non drinking and cooking purposes. The supply from the piped system is less than the demand and villagers have to use the stand pipe. During the dry season even the combined pipe and standpipe systems run short.

698. The long term and sustainable water supplies have to be sourced from river wells above any salinity risk, potential salinity changes under sea level rise should be confirmed by modelling. Without major urban areas, the overall water demands are quite low compared with irrigation and water sources would indicatively be adequate. Water supply systems require to be upgraded to provide adequate properly treated water to Government standards to provide all water needs as it is possible coastal wells will become increasingly saline.

15. Coastal Protection and Management

699. The coastline of the Delta including the four sub basins (Lower Coleroon, Cauvery, Vennar, and Grand Anicut) stretches for about 220km. Coastal erosion is an issue affecting parts of the coast along the Delta. The littoral drift is to the north and the coast is made up of quite wide expanse of sand and dunes in the northern part and mud in the southern parts. Erosion rates vary along the coast and the PWD has been implementing intermittent rubble mound protection works along the coast at the critical points as well as construction of groynes. The use of rocks on the beach can have severe impacts on the natural beach process and cause loss of beach and therefore are not complementary protection measures. The use of soft more environmentally appropriate measures should be investigated. The reasons for the coastal erosion are not clear but the reduced sediment in the rivers is reported as one of the causes. Harbours and breakwaters may also be affecting the littoral drift.

700. Alternative solutions are being developed but these are not fully tried and tested. Nourishment with reinforced earth has been considered in Cuddalore Devanampattinam coast. The Institute of Hydraulics and Hydrology Poondi, Tamil Nadu is carrying out some coastal model studies and is carrying out coastal observations at various sites. The use of offshore artificial reefs is being proposed in Karnataka and Maharashtra; the reefs break the waves and can support accretion of the coast in the shadow of the reefs. It is proposed that the environmental effects of coastal protection works should be studied through numerical modelling. Many of these new protection methods are not fully developed or are still at pilot stage and it may be difficult to take these up on a large scale in the near future. The very high costs of coastal protection against the low value economic values of the land must be factored into the planning and lower cost economically viable solutions need to be identified,

701. Natural coastal restoration methods like dune restoration, beach nourishment, restoration of littoral drifts, protection and restoration of mangroves etc should also be considered as potential measures for protection which are environmentally sound and provide lower cost solutions most suited to Cauvery coast. An example of planted and managed dunes is shown in Figure 42.

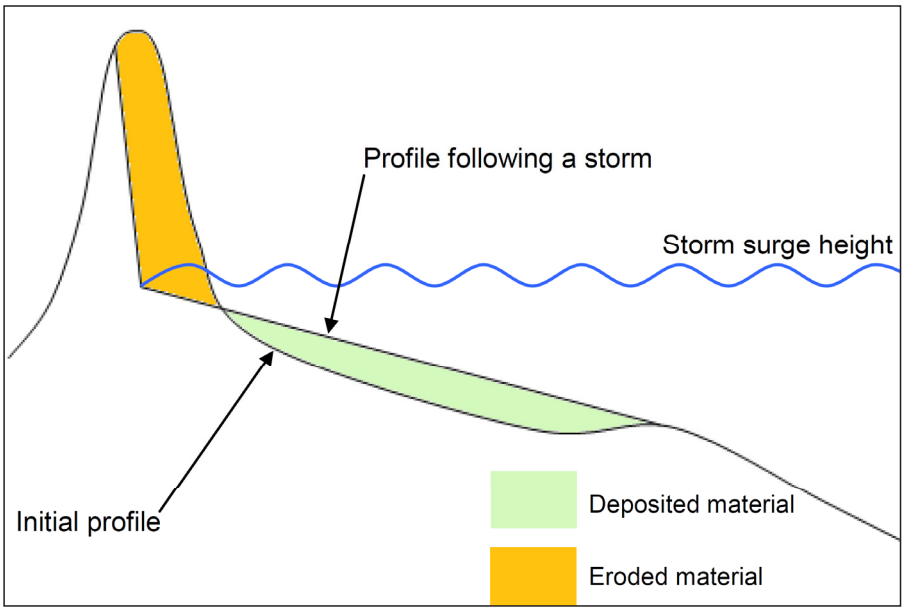
Figure 42: Planted and Managed Dunes (Latvia)

702. **Dune Rehabilitation and Beach Management:** Sandy beaches form the natural process in dissipating wave energy. However sandy beaches are in a constant state of flux, because they continuously react to constantly changing wave climates and sea levels. As such, the volume of sand held upon a beach is constantly fluctuating. During periods of low beach volume, the shoreline is susceptible to erosion and it is at these times, that sand dunes can be particularly valuable as a store of sediment which can be accessed in order to satisfy erosional forces. This compensates for the sand removed from a beach and helps to maintain wide, sandy beaches which will continue to dissipate incoming wave energy. After storms the sand removed from the dunes and the beach are deposited in the underwater part of the beach profile which can also dissipate energy. The beach profile after a storm is shown in Figure 43. Dune rehabilitation and beach management can be taken up when the natural sand supply is depleting and involves.

- Building up the dune by beach nourishment by dredger from offshore or dredged material from harbours or river mouths, a lower cost option is beach scraping involving bulldozing material from the lower part of the beach to the dunes. This is generally continuous process which requires to be completed periodically.
- Planting of the dunes with suitable material to provide protection
- Excavation or training of meandering nallahs and river mouths which can cause turbulenece and local erosion.

703. Dune rehabilitation and beach management may not be sufficient in themselves to protect the beach, the littoral drift may remove deposited material, complementary measures may be required to better hold the sand in place. These are required to be studied.

Figure 43: Beach Profile after a Storm



704. Blockages of river mouths by sand bars is an issue reported by both farmers and fishermen, the blockages can cause flooding at the beginning of the monsoon as well as interfering with access to the sea for fishing boats. Reduced dry season fresh water flows to maintain flushing is the prime cause. The issue needs to be further studied; restricting the width of the mouth with guide walls can help if there is adequate fresh water flow, but this may not work with the very limited flows in the Cauvery Delta. How the increase in sea level and increased risk of cyclones will affect the erosion requires to be determined. Meandering river and nallahs (drains) flows crossing the beach can cause local turbulences which can be an additional cause of erosion. The ongoing but nearly completed World Bank supported bar mouth dredging project should be assessed and evaluated; this project did not however include the delta area.

705. **Economics of Protection Measures:** The extremely high costs of coastal protection and potential impacts of climate change may result in full protection being not economically viable. Lower cost natural protection measures can potentially meet the needs of slow erosion but may not be sufficient in themselves to fully meet the protection needs . Full protection, either using new technologies which are less developed and not fully tried or hard technologies; all are very expensive. An assessment has to be made of the options and there maybe a requirement for planned retreat in certain areas. The preparation of shoreline management plans is proposed, the plans will examine the options; defining the best approach, the plans may require supporting modelling studies. It is proposed initially to assess whether soft solutions (beach and dune management, beach nourishment and river mouth clearing) will be adequate to meet the requirements of current and future erosion under climate change.

16. Disaster Preparedness and Other Aspects

706. Preparedness for coastal hazards has assumed significance in the delta area. Cyclones, floods and drainage congestion have to be tackled with strong community support. The lack of good weather forecasts is major concern expressed by farmers and fishing communities.

707. The CDMR has outlined a range of other initiatives to be taken up. These include on farm development works, formation of water user associations, irrigation flow measurements, performance evaluation of systems, rotational water distribution, ground water management and water quality and environment management.

17. Summary of Planning Issues

708. The sustainability of the Cauvery Delta requires a wide range of initiatives. An overview of the key issues and direction immediate strategies includes:

(i) Drainage issues will be exacerbated by sea level rise, and it will become increasingly more difficult to provide adequate and timely drainage in the lower parts of the delta. However, it is difficult at present to quantify these potential difficulties. Immediate and important actions are: (i) establishment of a permanent tide gauge, preferably in the middle of the delta coastline; and (ii) linking of first order benchmarks to the geodetic network to establish whether the delta is experiencing uplift or subsidence. Planning for the delta will require accurate survey information of land levels as well as cross sections of the rivers, drains and shoreline.

(ii) Following establishment of the tidal gauge, preparation of a hydrodynamic model for part of the delta' is proposed. The priority would the Vennar system which has the most critical drainage and flood issues. The model would assess the needs for drainage under projected climate change conditions (increased sea level and flood flows), assessing the future changes in salinity intrusion and areas of drainage problems which would support future zoning of land use. The hydrodynamic model would require accurate levels of the land and cross sections of the drains and rivers. Differential GPS surveys can provide fast and accurate land levels.

(iii) To address the saline groundwater intrusion problem, it will be necessary to construct a groundwater model of the delta area. It is unlikely that sufficient through flow can be created to restore the situation in any short time scale, if at all. Appropriate levels of groundwater abstractions and the necessity for further groundwater abstraction restrictions can only be assessed with a groundwater model. The approach and resources required for the model would need to be determined.

(iv) Putting the results of items (ii) and (iii) together, it will be possible to identify potential future land uses in different zones of the delta - e.g. bio-drainage, brackish aquaculture, coastal protection belts, flood alleviation and storage zones, and the horizons at which existing practices are no longer tenable.

(v) It will be necessary to have a coastal /shoreline management plan and to have some understanding of likely changes to the coastline over the next 50 years. There may be areas in which a managed retreat is required, and others where land protection zones can be established.

(vi) A sea level rise of 0.3 m by mid-century could perhaps be coped with by local communities gradually raising the standards to which properties and roads are designed to. The gradual establishment of polders might be a solution in the low lying coastal areas, but with increasingly impeded drainage; lift drainage from polders would probably be required, at least during the northeast monsoon. The economics of this would need to be evaluated. Evaluation of this as a strategy would require the modelling of item (ii) above, and the effective maintenance of the drainage channels.

(vii) Planning and design should asses the impacts of sea level rise and increased flood flows. A decision should be made whether to incorporate the necessary factors at this stage or at some time in the future. For example (i) incorporating some additional capacity for a new culvert would be insignificant if factored in at the time of construction but very expensive to retrofit; or (ii) increasing the freeboard of tail end regulators to accommodate sea level rise will be a small cost if taken up at the time of construction .but expensive if addressed later; (iii) flood dykes could be designed for raising at a future date through increasing the base dimensions to allow for future increases in height.

C. Institutions

1. Need for Integrated Approach

709. The sustainable management of water resources in the Cauvery Delta requires a wide range of different approaches involving different sectors. This approach requires an integrated water resources management approach (IWRM). The current functions of the various water sector departments in their present form do not provide adequate operational basis for implementing IWRM.

710. Some transformation in roles/rules and relationship among the institutions is essential to facilitate: (i) holistic water planning; (ii) review of financial instruments like targeted subsidies to support adaptation, crop insurance; (iii) participation of stakeholders in planning and management; (iv) strategizing environmental management and control measures; (v) facilitate full basin planning and management (vi) separation of roles between service provider-managers and regulators; (vii) conjunctive planning and regulation of surface and ground water h) monitoring of quality of water; (viii) effective planning for disaster (flood) management; (ix) revenue recovery mechanisms to be effective; (x) post project performance evaluation (outcome & impacts) to be prepared.

711. An effective coordination body is required for ensuring coordinated and integrated planning and management approach by various water centric institutions. 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 ground water management principles. Improved integration of surface and groundwater resources management is required; for the Delta coordination and integration of the wider coastal area management functions is essential.

712. **Effective Information Systems:** The goal of informed decision-making requires good and 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 and also basin level knowledge centres; (ii) capitalization of knowledge emerging from various initiatives like the Hydrology-II project; (iii) land use information developed; (iv) developing climate related information archives to promote climate literacy among the various stakeholders in general and village panchayat leaders in particular; (v) development of decision support systems for effective water management; (vi) establishment of updated design parameters to incorporate the impact of extreme events due to climate change; and (vii) development of databases related to water and climate to support climate research.

713. **Strengthening of Ground and Surface Water Institutions:** 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. Capacity building and development is an important requirement and training needs assessments are required. Rotation of staff within state Government puts some limitations on capacity development.

2. Present Initiatives towards IWRM

714. The Tamil Nadu Government has made various steps towards IWRM and convergence of various departments. In 2000 a, Multi Department Project Unit (MDPU) was established for coordinated sub-basin planning with planning inputs coming from various departments including WRD, agricultural, fisheries to try and institutional response to various problems associated with the development and management of water resources was through a single window approach.

715. A Water Resources Organization (WRO) has been formed under PWD which initiates of the separation of cadres between water resources management and buildings. Other inititiatives include strengthening of the Institute for water studies and the State Surface and Groundwater Data Center and preparation of detailed spatial knowledge base for water management; setting up of a Reforms Task Force, creation of a multi-sectoral Water Resources Control and Review Council (WRCRC) chaired by the Chief Minister and includes ministers representing all government departments concerned with the development and use of water resources.

3. Establishment of IWRM

716. There are various options for the establishment of IWRM. One approach is to create a separate water resource agency and river management organisation. The complete devolvement of management functions away from the operating functions of the sectors has many advantages it does however raise issues of mainstreaming the outputs into sector programmes. The complete move of resource management functions away from the sector departments at State and District level can leave the Water Agencies and Management boards without any the necessary leverage to enforce and mainstream management recommendations. River management organisations are required for interstate rivers but may not be of such value for smaller rivers or sub basins.

717. The alternative approach is to build IWRM as far as possible under the existing institutional structure. These proposals include the establishment of a state steering committee, an IWRM unit as a part of the Water Resources Department and empowerment of the district planning committees and the sector departments at district levels. The only new organisation would be the proposed water regulatory authority. This is the proposed approach for Tamil Nadu.

718. There also now significant support for the establishment of state Water Regulatory Authorities (WRA) which would provide an institutional mechanism to regulate the allocation, management and utilization limited water resources through a participatory approach. The 13th Finance Commission report 2009, has made it mandatory for all states to constitute WRAs by March 2012 to address injudicious inter-sectoral and intra-sectoral distribution of water amongst various categories of water users, low water use efficiency, fragmented approach to water resources planning and development, low water user charges and meagre recovery are some of the major problems associated with the management of water resources. The water regulator must be truly consultative and participatory in its composition and functioning, and that

representatives of civil society are associated with it at all levels The water regulatory authority for its very purpose shall have more powers and independence. The establishment of the WRA is complex and requires consultations and discussions to ensure the necessary understanding and agreements. State support for the regulator is essential.

719. **A Water Resources Control and Review Council (WRCRC)** has been established chaired by the Chief Minister and includes ministers representing all government departments concerned with the development and use of water resources. The WRCRC was essentially created to handle multi-sectoral water planning and allocation and acts as the state's principle water policy implementation body. The WRCRC can play a support role for the government.

720. The portfolio of measures identified for water resource management require a strong coordinated approach with full support of Government at State, District and Panchayat level and stakeholders. To meet all these requirements requires an approach to build on the existing institutions, providing coordination and devolvement of powers.

4. Community Management

721. Long term sustainability and better demand-driven services and infrastructure have been the major objective of involving communities in the management of the resources. Potentially community management can fill many of the gaps of government management. Effective community management faces many challenges including financial sustainability and institutional and cultural challenges.

722. 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 policy development for sustainability.

723. The Water User Associations in the Cauvery Delta are reasonably well developed with legal authority under the Tamil Nadu Farmers Act 2000 and 2001, but like in most of the states, in Tamil Nadu although the WUAs have been formed but they have not been able to take their full responsibility as envisaged in the acts or policies. The main constraints are system deficiency, a lack of financial viability, technical knowledge, complex operation and maintenance issues, low collection of revenue very low water tariffs, uncertainty of water availability, lack of coordination between WUAs and other water related institutions.

5. Cooperatives

724. Despite some areas of poor performance, cooperatives offer potentially a good organisation to support agricultural productivity and conservation. Some of the proposed programmes could potentially be channelled through the village cooperatives. Some consideration could be given tor rural electricity cooperatives to take on management of power for agriculture. An example is the hand over of the management of small lift irrigation to cooperatives or WUAs.

6. Institutional Proposals

725. As far as possible the approach is to build on the existing institutional structure. The development of an state wide regulatory authority is proposed as a new institution, other functions would largely build on and empower the existing institutions. The institutional proposals are presented in Table 66 below.

Table 66: Institutional Proposals

1	Water Regulatory Authority	A State Water Regulatory Authority (WRA) is proposed to provide an institutional mechanism to regulate the allocation, management and utilization limited water resources through a participatory approach. The new regulatory authority would build on the proposals by the 13th Finance commission for the establishment of state regulators in all states. The WRA would the following functions to: (i) establish and regulate the water tariff system and charges for surface and sub-surface water used for domestic, agriculture, industrial and other purposes; (ii) determine and regulate the distribution of entitlement for various categories of uses as well as within each category of use; and (iii) periodically audit, review and monitor the water sector costs and revenues. The regulatory authority would be an autonomous, inter-disciplinary body, with managerial, professional, mediatory and adjudicatory capabilities built in. The regulator must not be one more government department. It must be truly consultative and participatory in its composition and functioning, and that representatives of civil society are associated with it at all levels. The regulator would support basin-level institutions and basin level decision making.
2	State Water Resources Steering Committee	A new 'State Water Resources Steering Committee'(WRSC) is proposed to support improved coordination of the sector agencies. The committee would comprise of the Principal Secretaries of the departments of Water Resources, Agriculture, Horticulture, Forests, Environment, Panchayats, and Rural Development as well as the regional representatives of CWC and CGWB. The committee would be supported by experts in relevant fields who can be called on as required. The steering committee would be charged with overseeing fairly significant institutional reforms to meet targets of efficiency, effective service delivery, participative management and financial sustainability through cost recovery for O&M costs. The committee would promote inter-sector coordination and would also advise the proposed water regulator on specific issues.
4	Integrated Water Resources Management Unit (IWRM) within Department of Water Resources Organisation.	In Tamil Nadu a water resource organisation has been established to separate the Water Resources Department and the other main functions of the Public Works Department. The present planning and hydrology sections within the WRO would be combined, expanded and strengthened with a new mandate and skills to become an "IWRM Unit". The operational functions and resource management functions of the WRD would be separated to reduce the potentials for conflict of interest. The new 'water resources management unit' would include a role in water resource planning including providing guidance to the water regulator about water issues including advising on water licences and permits. The new IWRM management unit would encompass 'water resource aspects of climate change' and would liaise with the Proposed Climate Change Centres being developed by DEST. Staff from the different sector department would be seconded to work with the new unit. The regional representatives of CWC and CWGB would would also support the unit. It is proposed that the existing MDPU could be redesignated into the IWRM **unit**
5	Empowerment of the Districts for Planning and Management of Water Resources	It is proposed that the District level should take on an increased role in the integrated planning and management of water resources. This would include to the strengthening of the District Planning Committee to oversee the integration of sector programmes as well as ensuring effective stakeholder participation.
6.	Stakeholder Consultative Group	There is a need for districts, panchayats, stakeholders including civil society to participate in the basin planning and management processes. It is proposed that the Panachayat Raj of each district would nominate representatives of stakeholders including civil society to review and endorse the strategic and detailed plans and support water resources management. The groups would work at district and lower levels. Representatives of the various groups within the sub basin would meet periodically to address sub basin issues.
7.	Strengthening of Water User Associations	The Water User Associations are reasonably well supported in the Cauvery Delta and should be strengthened. Their remit should be widened to incorporate surface and groundwater and flood and salinity issues.
8.	River Basin Authority	Water resources management at the basin level is severely constrained by the ongoing water tribunal award which is presently is with the supreme court. The tribunal decision includes the establishment of a River Basin Authority. Steps should be taken to gradually move towards cooperation and improved water resources management within the framework of the agreed tribunal award. Climate change will increase the need for an effective River Basin Organisation. A fully functional Cauvery RBO should be established to coordinate water resources planning and management issues between the states.

D. Climate Change Scenarios

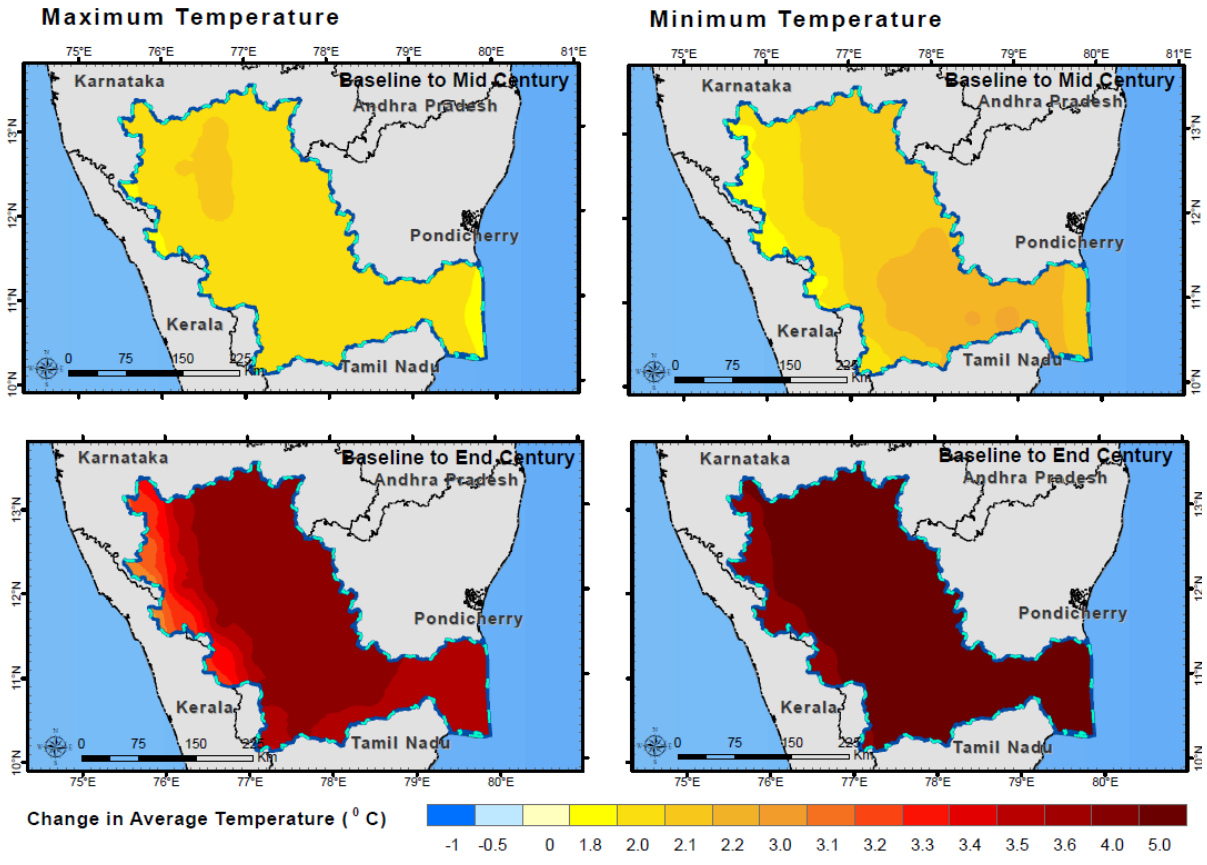
726. For climate change projections in the Cauvery basin, the output from one member of the Hadley Centre HadCM3 QUMP[81] ensemble was downscaled using the PRECIS RCM by IITM Pune. Apart from the baseline (1961-1990) which represents the present, two future time slices were investigated: mid-century (2021-2050) and end-century (2071–2100). All three time slices use the SRES scenario A1B. In addition, data were available for the SRES A2 and B2 scenarios for the baseline and end-century and were used for comparison[82].

1. Temperature

727. An assessment was made of results from the PRECIS A1B scenario for the Cauvery Basin. Figure 44 shows the changes in mean daily maximum and minimum temperatures projected for the middle and end of the century. By the middle of the century the A1B scenario indicates an increase in mean annual temperature of about 2°C. By the end of the century the increase in temperature is forecast to be close to 4°C. Changes in minimum temperatures are generally forecast to be higher than changes in maximum temperatures, resulting in smaller diurnal ranges.

728. Changes in seasonal and annual mean daily maximum and minimum temperatures for the Cauvery basin are presented in Table 67. Table 68 presents a comparison of projected changes in temperatures under the A1B, A2 and B2 scenarios; the different scenarios are reasonably consistent and show increased temperatures by 2°C to 3°C by mid century.

Figure 44: Projected Temperature Changes



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

[81] Quantifying Uncertainty in Model Predictions is an approach which aims to provide probabilistic predictions of future climat

[82] **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.
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.

Table 67: PRECIS Simulated seasonal temperatures, A1B scenario

Time Horizon	Mean daily maximum temperatures (°C)				
	JF	MAM	JJAS	OND	Annual
Baseline (1970s)	31.6	35.0	29.7	29.8	31.5
mid-century	33.5	36.7	31.5	31.7	33.4
end-century	34.8	38.3	33.6	33.0	34.9
	Mean daily minimum temperatures (°C)				
Baseline (1970s)	20.0	23.6	22.6	20.5	21.7
mid-century	23.7	26.3	24.2	22.8	24.3
end-century	26.1	28.3	26.3	24.6	26.3

Table 68: Comparison of projected changes in temperatures, A1B, A2 and B2 scenarios, 2080s

Mean daily maximum temperatures					
Scenario	**JF**	**MAM**	**JJAS**	**OND**	**Annual**
A1B	3.2	3.3	3.9	3.2	3.4
A2	3.1	3.0	3.2	3.1	3.1
B2	2.3	2.0	2.3	2.5	2.3
Mean daily minimum temperatures					
A1B	6.1	4.7	3.7	4.1	4.65
A2	4.1	3.8	3.2	3.6	3.7
B2	3.0	2.6	2.4	3.1	2.8

2. Precipitation

729. Mean annual precipitation in the Cauvery Basin is shown in Figure 45. Annual precipitation is highest in the Cauvery delta and in the northwest of the basin where over 1000 mm occurs. Most precipitation in the northwest of the basin is as a result of the southwest monsoon, while in the delta it is largely associated with the northeast monsoon. Changes in annual precipitation simulated by PRECIS with the A1B scenario are shown in Figure 46, and summarised in Table 69 and Table 70.

Figure 45: Mean Annual Precipitation

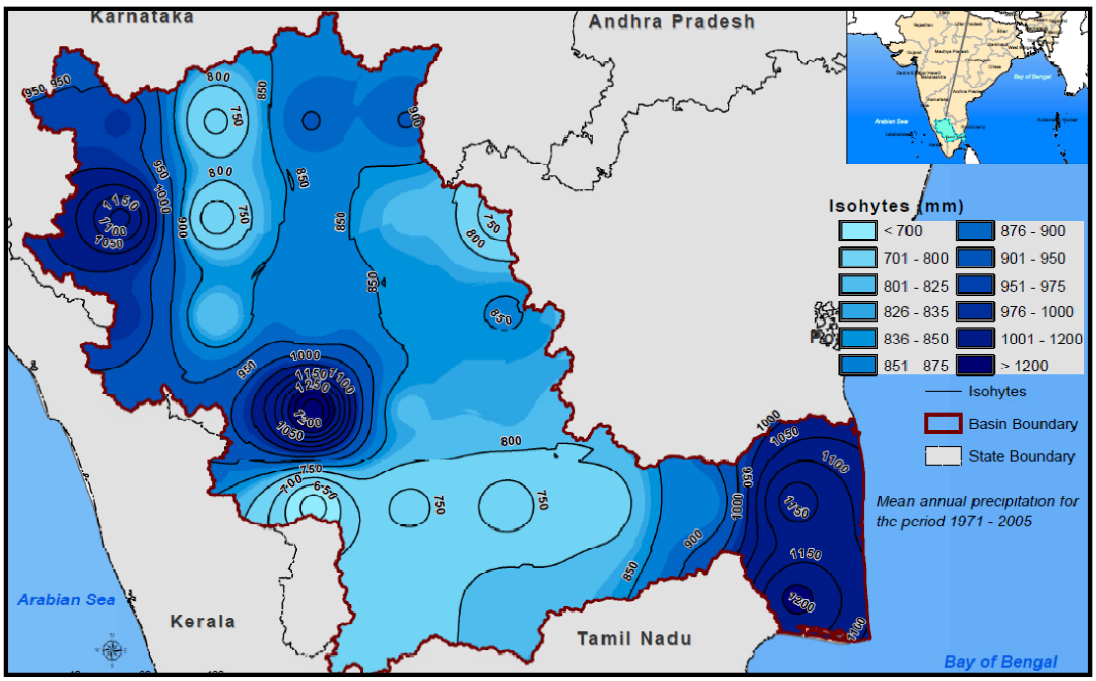


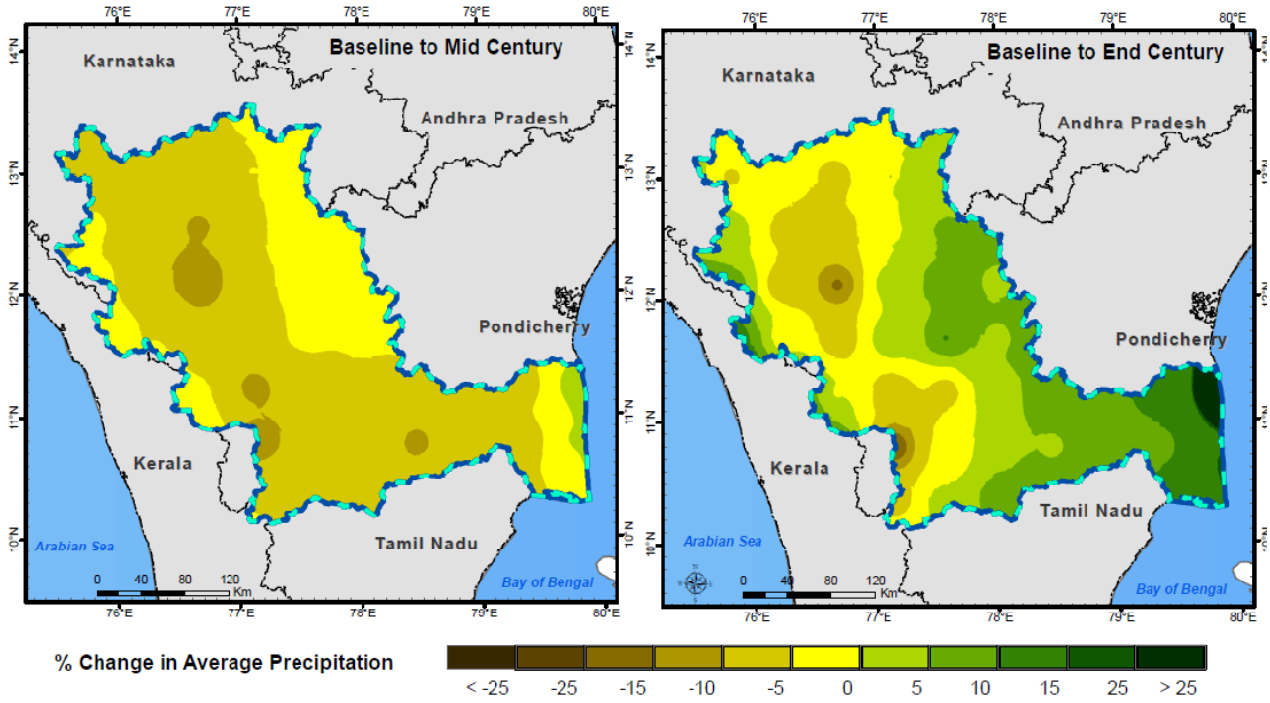
Table 69: PRECIS Simulated seasonal precipitation in the Cauvery sub-basin, A1B scenario

	JF	MAM	JJAS	OND	Annual
1970s baseline	32	146	479	165	822
mid-century	31	155	455	169	810
end-century	52	171	422	230	875

Table 70: Projected changes in seasonal precipitation under the A1B, A2 and B2 scenarios, to 2080s

Scenario	JF	MAM	JJAS	OND	Annual
A1B	20	25	-57	65	53
A2	8	18	29	57	112
B2	-4	39	27	-8.6	53

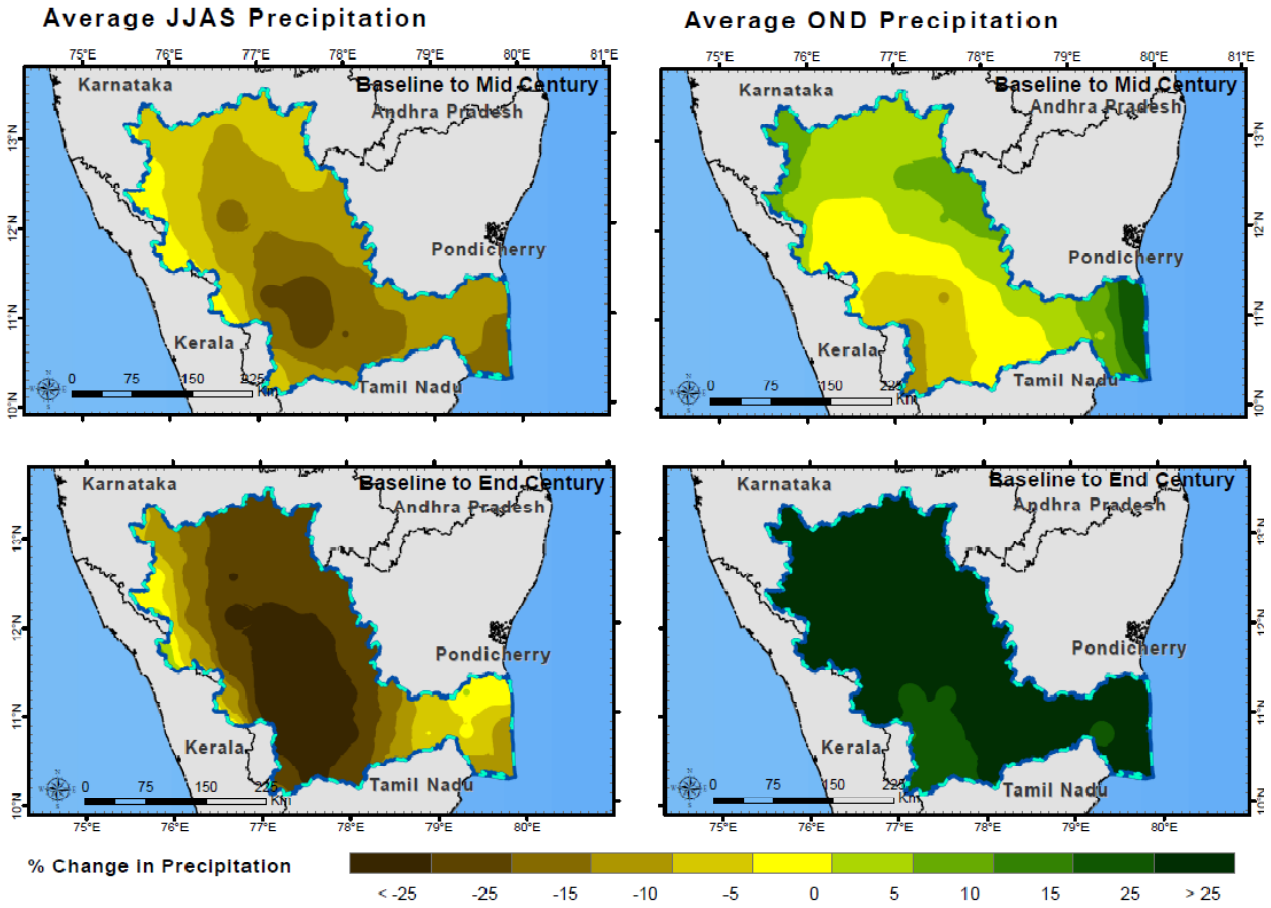
Figure 46: PRECIS Simulated Changes in Mean Annual Rainfall, A1B scenario



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

730. For the A1B scenario no significant change is forecasted in the annual rainfall to the mid century. To the end century some increase in precipitation is indicated for all three scenarios. Although no significant change is projected there would appear to be some shift in the seasonal rainfall pattern; seasonal rainfall changes simulated by PRECIS for the A1B scenario are shown in Figure 47.

Figure 47: PRECIS Simulated Changes in Seasonal Rainfall, A1B Scenario



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

731. The indications from the PRECIS A1B results are that although the annual rainfall would likely remain unchanged to mid century, the southwest monsoon would reduce by about 10% over most of the basin. The implications of these projections are that there is likely to be an increased demand for irrigation water in the upper basin, coupled with a reduction in surface water availability. The surface water resource available to the Cauvery delta is likely to decrease during the southwest monsoon under this scenario.

732. For the northeast monsoon the PRECIS A1B scenario indicates a 10% to 20% increase in precipitation in the Cauvery delta. The precipitation change in the upper catchment would be less significant. The increase is most pronounced in the delta region, however, and could have major implications for drainage. Drainage is already a problem in the lower parts of the delta, and increased northeast monsoon precipitation coupled with higher sea levels will exacerbate the problems.

3. Historic Rainfall Trends

733. An analysis was undertaken of annual and seasonal rainfalls at four stations in the Cauvery basin to test for the existence of historic trends. The stations used were Coonoor, Salem, Pelamedu, and Nagapatinam. Coonoor, Salem and Pelamedu are in the centre of the basin, while Nagpatinam is on the coast at the end of the delta. Daily data were provided by IMD for a period of about 35 years from 1971. For Salem and Nagpatinam, data were available from GHCN[83] that permitted composite records to be created with data from 1901. At Peelamedu there were GHCN records from 1949, and at Coonoor from 1926. The IMD records at Peelamedu and Coonor contained a lot of missing values, and although station histories have not been checked, there is the possibility of changes in gauge conditions following periods of missing data. On the basis of the composite records there is no evidence of statistically significant trend in annual or seasonal rainfall at any location.

734. The composite records for Salem and Nagpatinam provide a better basis for trend analysis. At Salem there is no trend in long term annual rainfall, and no trend northeast monsoon rainfall. At Nagpatinam in the delta, there is no trend

[83] **Global Historical Climatology Network** (GHCN) is a database of temperature, precipitation and pressure records managed by the National Climatic Data Center, Arizona State University and the Carbon Dioxide Information Analysis Center

in either annual precipitation or northeast monsoon rainfall. There is no evidence of changes in precipitation patterns in the Cauvery basin over the last 100 years.

4. Hydrological Simulations

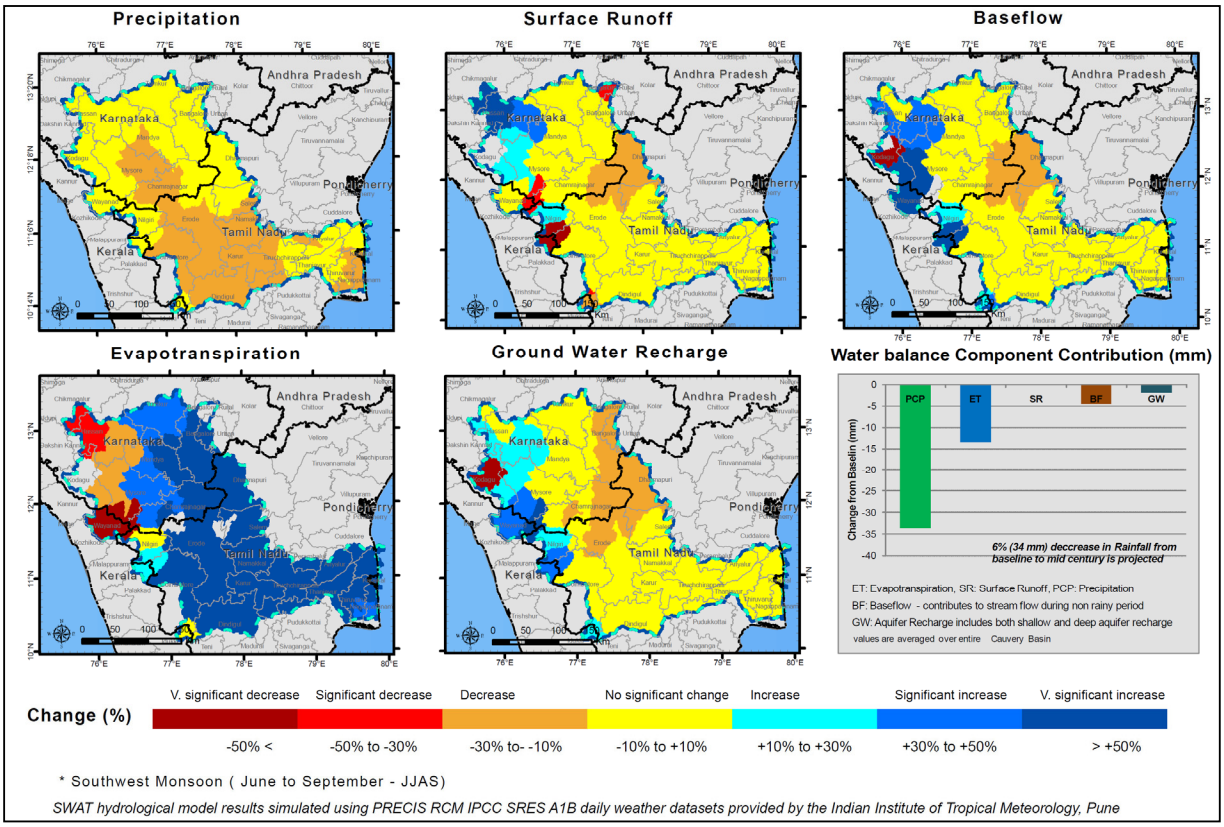
735. Evaluating the potential impacts of climate change on water resources requires the application of hydrological simulation modelling techniques. Hydrological models are driven from scenarios of changes in precipitation and potential evapotranspiration obtained from global and regional climate modelling studies. Precipitation is one of the least well represented processes in climate models and the uncertainty in projections of climate change impacts on water resources is therefore high. 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.

736. The SWAT model was used with climate simulations from the PRECIS A1B emissions scenario as outlined above. The SWAT model was run primarily for the catchment upstream of the delta, but considering only changes in natural runoff response. The current project did not have the resources to model the complex water utilisation that takes place upstream of the delta. The upstream water use patterns meant it was not be possible to properly calibrate the SWAT model. However, performance evaluation of the SWAT simulated hydrologic budget was made using the observed data for the period 1980-1989 at a monthly step for gauges upstream and downstream of Mettur dam. The long-term monthly mean flows were over simulated by the model. This is mainly because upstream reservoirs, diversions and irrigation water use were not included in the model. This simulation can be considered as virgin flow.

737. **Precipitation** for the northeast monsoon simulated by PRECIS in parts of the upper basin was more than three times higher than the estimated observed precipitation, while potential evapotranspiration calculated from PRECIS simulated data was significantly lower. It was concluded that at this time, the PRECIS model is not capable of adequately simulating the northeast monsoon, which is the main rainy season for the Cauvery delta basin. The simulated baseline climate was significantly different from that of observed with precipitation being 65% to 50% lower than observed for the northeast monsoon (OND). It was considered that the results were so different from observations, that there could be little confidence even in simulated changes in climate under future emissions scenarios.

738. For the southwest monsoon the comparisons appeared to be more reliable and the change in the water balance for the southwest monsoon JJAS are shown in Figure 48.

Figure 48: Change in the Water Balance to Mid Century JJAS



739. **Sea Level Rise:** In adaptation design for sea level rise in the Cauvery delta, it is considered prudent at this time to design, in the short to medium term, on the basis of the IPCC AR4 upper envelope projections of 0.3 m by mid-century, and to adopt design approaches that can easily be adapted as projections of future global sea level rise improve, and as better information becomes available on the actual situation of relative sea level rise in the Cauvery delta.

740. The Cauvery delta does experience occasional cyclonic events, but those producing significant storm surge most frequently find landfall in northwest of Bay of Bengal. The INCCA 2010 report considered projected changes in cyclonic activity and storm surge under present and future climate scenarios. They reported evidence of a decreasing trend of cyclonic storm activity in the Bay of Bengal. They did, however, report forecasts of increased storm surge heights north of Visakhapatnam of 15 - 20% for a 100 year event. The increase in storm surge heights is greater in regions with a lower tidal range.

E. Vulnerabilities to Climate Change

1. Overview

741. It is important to understand that projections of some climatic entities are more robust than others, in the sense that many of the GCMs (global circulation models) agree on the direction of change and/or its magnitude. There is generally consistency and agreements in the temperature projections of different models. Some other important meteorological variables, like rainfall, are less well represented. The climate projections and climate change scenarios cannot at present provide a basis for concrete adaptation decisions or a firm basis for development planning. They can, however, be used to give some guidance to decision making. Work on climate change scenarios needs to be further strengthened.

742. For the Cauvery Delta there are reasonably good levels of confidence in temperature projections as well as for an increase in sea level rise. Although the 0.3m increase in sea levels by the mid century is widely accepted, there remains disagreement on the likelihood sea level rises over and above the 0.3m projection. The projections for changes in precipitation are less robust especially in relation the north east monsoon. When looking at smaller regions (e.g. state level or river sub basins), it is often difficult to detect these changes with any confidence. There is a significant global research effort underway to improve the validity of the models. It is likely that there will be better agreement models (both of the models' description with current observations and also between models) when the latest generation are evaluated within AR5 (as part of CMIP5).

743. **Time Scales:** Three time scales are identified: (i) short-term (decadal scale); current climate variability will dominate; planners need to be aware of current extremes and return periods which should be used in design of infrastructure and policy measures; (ii) medium-term (next 20-30 years), the climate change signal will become more pronounced and will be largely independent of which emission scenario the world actually follows – the observed changes will be caused by our current emissions, which are closely following high-end scenarios; and (iii) long term (beyond 30 years): for projects and measures that have lifetimes of 100 years (or into second half of 21st Century), it is necessary to decide which emission scenarios (SRES – in AR4) or concentration pathways (RCP = Representative Concentration Pathways – from AR5 onwards) to take into consideration (currently we are moving along trajectories that will lead to large global warming / climate change).

744. It has already been observed that many of the projections are conservative and that observed changes may well exceed projections. At present, the window of opportunity to keep global average temperature rising below 2°C is diminishing, and scientific thinking suggests that overshoots will be increasingly difficult to reverse.

745. **Confidence Levels of Present Models:** The current (i.e. CMIP3, used in IPCC AR4) generation of GCM climate models lack skill in replicating precipitation/rainfall, both in terms of quantity and quality. In quite a few regions, the models also don't agree on the direction of projected changes. This is in stark contrast to the same models performing well on temperature. The analysis of CMIP5 models in the next few years will provide a new generation of climate models which it should be able to model precipitation more accurately. Processes that are involved in formation of rainfall are being better understood and will lead to improved projection skills. Members of the modelling community are cautiously optimistic that some good progress will be made in the next few years.

746. Climate change will affect the water systems which will impact on present vulnerabilities. Based on the various climate projections a summary of potential climate impacts and key areas of vulnerability is shown in Table 71 below.

Table 71: Specific Climate Change Vulnerabilities

	Parameter	Quantitive asssess-ment	Confidence level of estimates	Estimated climate change to mid century	Adaptation proposals
1.	Temperature	Yes	High	+2°C mean annual temperature	Research into crop response to temperature and improved access to temperature resistant varieties to be provided. Cropping to be more diversified. Increasing access to crop insurance.
2.	Precipitation annual	Yes	Medium	No significant change in annual	Focus should focused on the specific changes in SW and NE monsoons.
3	Precipitation: south west Monsoon	Yes	Medium	Reduction of the order of 10%	Water conservation, salinity management, groundwater management. Strengthening of interstate cooperation to address issues; establishment of a Cauvery Basin RBO.
4.	Precipitation: north east monsoon	Yes	Medium	Increase around 5%	Flood management, increasing storage and groundwater recharge. More research to better define the NE monsoon projections.
3.	Rainfall Intensities	Yes	Medium	No significant change projected	Basin level flood management
4	Potential Evapotranspiration	Yes	Medium	Quite small increase	Will increase crop water requirements-an issue in SW monsoon; NE monsoon effect will be balanced by increased rainfall.
4.	Floods	No	Poor	Increased NE rainfall, run off and sea level rise will increase flood risk.	Flood management including improving drainage, developing flood alleviation areas. Basin wide catchment management Establishment of an enabled RBO to help optimise basin wide planning and management issues.
5.	Droughts	Yes	Low	Non quantified but estimated to increase	Sustainable groundwater can buffer against precipitation variabilities.
6	Other Extreme Events	No	Medium	Non quantified events-flood, storm surge all likely to increase	Not easy to define. Adaptation should focus on increased community and farmer awareness, crop insurance and disaster management planning.
7.	Groundwater	No	Low	Increased salinity risk for sea level rise and reduced SW monsoon	Artificial recharge to be increased to address salinity and compensate for weakening of SW monsoon. Tail end regulators to block intrusion moving up the rivers.
8.	Surface Water Flows	No	Medium		Reduction in SW monsoon to be addressed by water conservation, changes in agriculture, sustainable groundwater.
9	Sea Level rise	Yes	High	Will increase floods and shoreline erosion	Flood management, shoreline protection and management.

2. Key Requirements to Meet Climate Impacts

747. The adaptation strategy is based on addressing present and future development needs which include increased population, boosting agricultural production and raising farm incomes. This section review how the projected climate impacts can be incorporated into strategies for present and future development needs.

748. **Uncertainty:** There is still uncertainty about the rate and magnitude of climate change impacts across the globe; making decision making challenging. The projections of the models are designed to give the best possible estimate of climate projections within the present level of knowledge. At present different models produce different results with regard to precipitation in many areas. Uncertainties in these projections remains and increased variability in the weather patterns

remains likely even within the framework of the projections. Government has limited capacity to handle variations and creation of strengthened community institutions to promote self reliance at the community level is considered important.

749. **Planning Horizon:** It is important to define the planning horizon for the framework plan. The norm for water resource and investment planning is typically directed at a 25 year time frame. The proposed adaptation measures for the Cauvery Delta involve significant investment which would have design lives of 25 years or more; incorporation of the climate projections to mid century are recommended for planning and design for any major capital investment.

750. **Buffers for Climate Impacts:** The Cauvery Delta is very vulnerable to climate impacts, with quite small potentials to buffer against floods, drought, salinity and coastal erosion. Groundwater potentially provides a buffer against water shortage but is overexploited and has issues of salinity. Land use planning, salinity and flood management are identified as key buffers to climate impacts.

751. **Flexibility of the Adaptation Strategies:** Climate change issues are already significant and although there is some uncertainty over the projected precipitation; changes in sea level rise, salinity and erosion are all urgent issues to be addressed. The adaptation strategy for the delta requires decisions on investment as well as land use which are long term with less scope for flexibilities. Adjustments and refinements to the adaptation strategy can be made but a core approach needs to be formulated and agreed. Planning must be iterative and plan updates and refinements about every five years are proposed.

752. One important characteristic of an adaptation strategy is that it should reflect the needs and aspirations of the society or community. Further, adaptation strategies at community level need to be developed including participation of communities in the planning processes to ensure adequate incorporation of the local adaptation requirements.

753. **Temperature:** The PRECIS projection for future temperatures under the A1B scenario is an increase of about 2°C of the daily maximums and minimum temperatures. The Climarice project is currently researching the impacts of climate change on rice. Building on the outputs of the climarice project, further study and research into optimum cropping with an +2°C rise in temperature is proposed. Other indirect effects such as CO_2 and ozone levels can affect crop viabilities. These can be investigated further using a crop response model such as DSSAT (Decision Support for Agricultural Technology).

754. **Precipitation:** Although the annual precipitation is not forecasted to change, some decrease in the south west monsoon and an increase in the north east monsoon are projected. For the southwest monsoon the indications of the PRECIS A1B results are that there will be a reduction in precipitation by up to 10% by mid-century. The implications of this projection are increased demand for irrigation water in the upper basin, coupled with a reduction in surface water availability for the delta part. The surface water resource available to the Cauvery delta is likely to decrease during the southwest monsoon under this scenario. The various storages in Karnataka and Tamil Nadu will be able to provide some buffer to these changes, and optimisation of the operations of the reservoirs could provide significant benefit. The implications of a possible reduction of the southwest monsoon on the delta is critical and measures to adjust to this are important; options would likely be linked to agricultural management changes such as a move towards direct seeded rice, shorter duration rice or diversification to non rice crops. Groundwater can provide a good buffer against shortages and developing sustainable groundwater systems is critical. The interstate tribunal allocation provides for some water stress sharing during periods lower than normal rainfall. It is recommended that Cauvery River Board based on the model suggested by the Tribunal be set up by the Cauvery basin states to take basin level decisions for management of river water, and tackling the optimisation of the water resources and addressing the various crises situations.

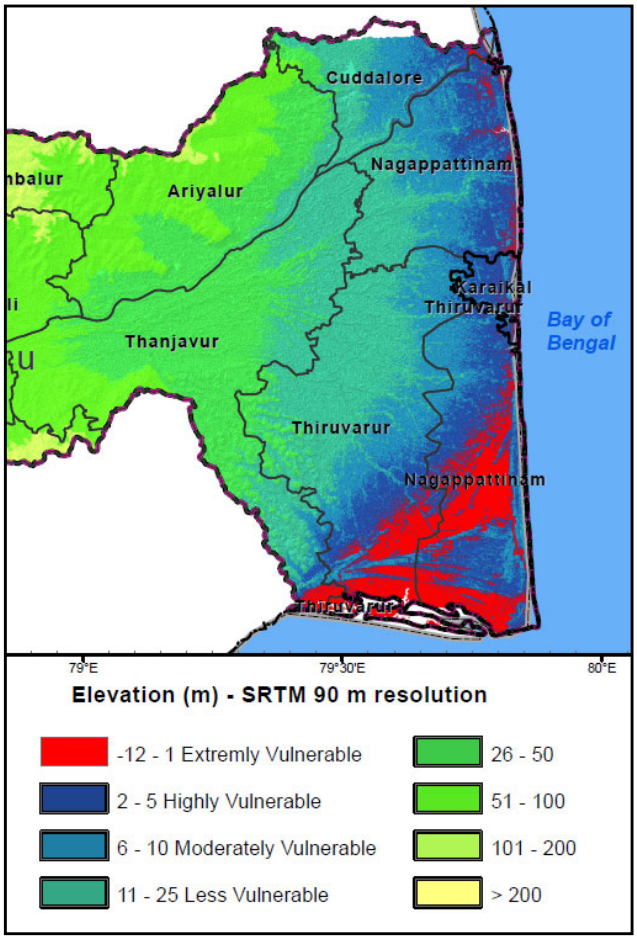
755. For the northeast monsoon the PRECIS A1B scenario indicates an increase in precipitation in the Cauvery delta, and at other locations in the basin by mid century. The increase is most pronounced in the delta region, however, and could have implications for drainage. Drainage is already a problem in the lower parts of the delta, and increased northeast monsoon precipitation coupled with higher sea levels will exacerbate the problems.

756. An evaluation of the quality of PRECIS simulations of baseline conditions has been made. The indications are that PRECIS represents mean annual rainfall reasonably well. Southwest monsoon rainfall is significantly over-estimated in the western ghats, and significantly under-estimated in the east of the basin. Cauvery delta southwest monsoon rainfall is better represented than in the rest of the basin. The northeast monsoon rainfall is generally significantly under-estimated throughout the basin. Variance in annual and seasonal rainfall is also under-estimated by PRECIS. The implication is therefore that PRECIS results should be treated with some caution. Another model could produce results different to those presented here. Infrastructure design should incorporate climate projections. However, it is recommended that the results of different models are reviewed which may give different results. Using the PRECIS results might result in some over

design of the drainage. It is anticipated that in about five years more accurate projections will be available, along with a wider range of RCM simulations for domains over India.

757. **Ground Water:** The estimate for groundwater is an increase in the salinity issues; with no significant change in annual rainfall, groundwater recharge will be largely unchanged. Groundwater demand will probably increase to compensate for the estimated weakening of the south west monsoon. Efforts to support sustainability of groundwater as a means to mitigate the projected impacts of the reduction in the south west monsoon are proposed. Over extraction of groundwater can exacerbate the natural settlement processes of the delta.

Figure 49: Low Land Vulnerabilities



758. **Flood:** Increased rainfall, rainfall intensities and sea level rise will increase flood risk during the NE monsoon. Flooding is already a problem and will likely become more significant in the future. Farm drainage to reduce crop damage must be balanced with the need for supporting recharge.

759. **Sea level Rise:** The IPPC projection is for a 0.3m sea level rise by mid century; this increase is generally accepted as being valid. Sea level rise projections are considered to be more reliable than rainfall projections, although recently some scientists have expressed the opinion that the 0.3m figure might be exceeded. However, at this stage it is considered that a 0.3m rise by mid-century could be used for planning and design.

760. The full impacts of sea level rise has to be assessed based on hydrodynamic modelling of the surface water and 2D modelling of the groundwater and the coastal processes. Strategies for coastal bunds and tail end regulators should be able to meet the 0.3m sea level rise impacts in terms of sea water ingress by raising crest levels. Especially critical is the drainability of the low lying areas. Already quite large parts have significant drainage problems as can be seen in Figure 49.

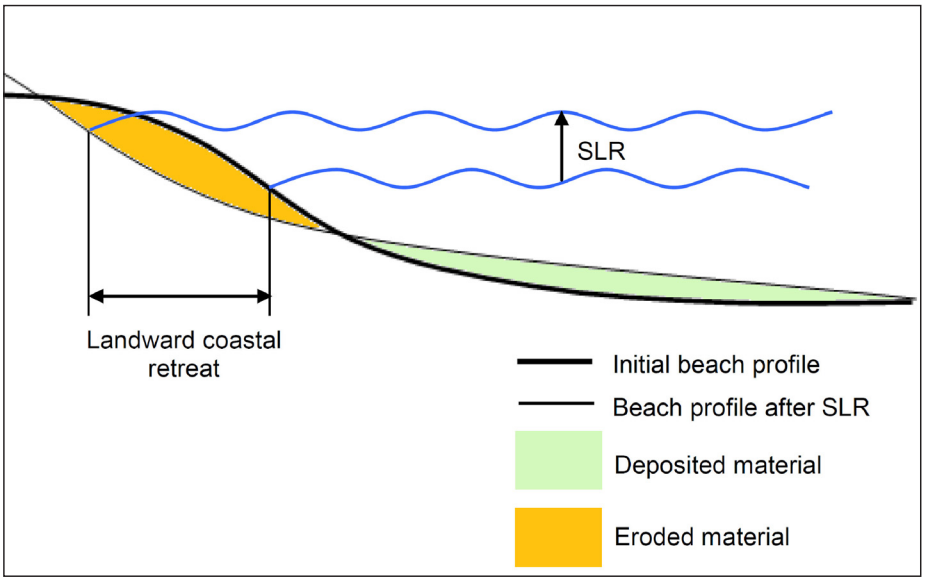
761. The higher sea levels will affect the flood levels mainly in the NE monsoon and crest levels of bunds, dykes and regulators will have to be raised at some stage to meet these increased levels. Hydrodynamic modelling will be able to assess the impacts and must form the key support tool to plan and design the adaptation measures. Sea level rise will affect natural habitats in the estuarine rivers, the changes will affect both water levels as well as the salinity-freshwater balance.

762. **Shoreline Erosion:** The long sandy beaches of the Cauvery delta are currently suffering from slow levels of localised erosion, the problems are largely due to the sustainable supply of sand from the rivers; dams and sand mining have over time seriously reduced the supply of sand to the coast.

763. The effects of climate change and sea level rise are difficult to predict; the responses of different coastlines are very variable. Coastal erosion is the physical movement of sediment away from the shore through wave and current action. The behaviour of the coastal area is very complex and many natural processes will influence beach profile shape and position. A simple theory is the 'Bruun Rule' suggests that shoreline recession is in the range of 50 to 200 times the rise in relative sea level and is caused by a beach's desire to maintain an equilibrium beach. To maintain the equilibrium profile in the presence of sea level rise, sediment will removed from the shoreline, causing erosion. Sediment is subsequently deposited offshore so that the nearshore zone gains elevation at a rate equal to the rise in sea level. As sea level rises, the beach profile adjusts by shifting landwards and upwards by removing sediment from the shoreline and depositing it in the nearshore zone. Hence, the volumes of eroded and deposited material are equal. The concept[84] is shown in Figure 50. Erosion risk may also be increased by increased frequency of storms and associated surges.

[84] Technologies for Climate Change ENEP University of Southampton November 2010

Figure 50: Impact of Sea Level rice on Erosion



F. Framework Plan for the Sustainability of the Cauvery Coastal Area

1. Analysis of Problems and Opportunities

764. Agriculture in the Cauvery Delta currently suffers from water shortage, uncertainties of climate and allocation of fresh water supplies. The allocations under the tribunal award are less than earlier available and the delta agriculture production systems has suffered decline for over recent years. Groundwater abstraction has increased to unsustainable levels partly as a response to the reduced availabilities of the surface water. Torrential rainfall in the northeast monsoon causes flood risk, salinity in the surface and groundwater is affecting production in coastal areas, drainage of low lying land is an issue. Labour shortages seasonally are issues and mechanisation is poorly developed partly due to the small land holdings. Parts of the coast are eroding which is threatening the coastal communities, river mouths suffer from blockages which causes problems for fishing and flooding.

765. Historically the Delta was one of the major agriculture production areas of India; the highly fertile soil, good rainfall and surface water flows were highly suited to rice production. The Cauvery Delta modernisation report in 2008 presented a series of proposals to address the decline in agriculture. The solutions are not simply engineering solutions but integrated approaches incorporate the efforts of all the main water sector departments. There is a need to undertake major initiatives in the Delta to rectify issues from reduced surface water and also to address the potentially severe impacts of climate change.

2. Strategies for Climate Change Adaptation

766. The impacts of climate change on the Cauvery Delta are complex involving surface and ground and sea water systems. The design of adaptation measures require good quality information and studies; projections for precipitation remain indicative however there is now a reasonable level of confidence on projections for increased temperature and sea level. Three key areas of climate adaptation are identified for the whole delta area.

(i) Surface Water Irrigation Systems: Surface water irrigation efficiencies and levels of service delivery need to be improved. The climate change impacts to mid century indicate fairly insignificant changes in the annual rainfall pattern and surface water flow, but decline in the south west monsoon is projected. This is likely to be associated with increased variabilities of the rainfall patterns and some increase in periods of drought and extreme rainfall. Increases in temperature may affect some crops. Adaptation planning for irrigation to mid century would primarily be directed for improving the irrigation efficiencies and demand during the south west monsoon. The impacts of temperature need however to be researched and appropriate crop varieties need to be developed.

(ii) Water Supplies and Sanitation: Water supplies in the coastal area are a mix of piped surface water and shallow tubewells. Salinities in the coastal area will likely increase and sustainable piped supplies to meet all water

supply needs will be required, water would have to be sourced from rivers at abstraction points in the rivers above the salinity under conditions of increased sea levels. Reduced availabilities of fresh water from groundwater will put more reliance on freshwater which in turn will put additional pressure on the already restricted surface water supplies.

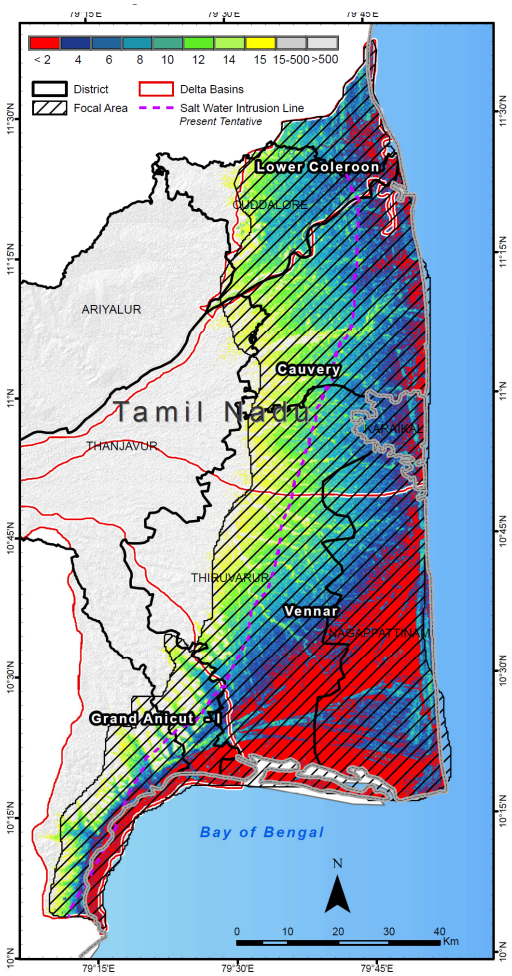
(iii) Sustainability of the Coastal Area: The coastal part of the Delta has very specific problems relating to salinity, flooding, drainage and coastal erosion. Projections are for sea level rise of 0.3m by mid century with a high level of certainty; some estimates put the rise somewhat higher. On going problems of salinity and flooding will gradually worsen. Vulnerabilities are high and the communities have very limited capacities to cope or resist to these hazards. There is an urgent need to develop a firm plan for the coastal area based on a 0.3m sea level rise and initiate programmes of support and investment for climate change adaptation. Support measures would include infrastructure, agricultural systems, institutional development training and awareness.

767. **Priority for the Coastal Area:** There is a need to address all the three aspects; bearing in mind the very definite vulnerabilities of the coastal parts of the delta it is considered that the priority must be to focus on the sustainability of the coastal area. The approximate coastal area, indicatively defined as the land below 15m.asl is shown in Figure 51.

3. Coastal Area Sustainability Objectives

768. There are needs to improve efficiencies of irrigation and also improve water supplies over the whole Cauvery but the priority and the main direction of the adaptation plan is to address the long term sustainability of the coastal area where the most pressing issues and climate change impacts will occur. The objectives of the plan will be to develop and integrated approach to address current and future water issues along the coastal area. The plan will build on the proposals of the Cauvery Modernisation Programmes as well on-going programmes by the Water Resources Organisation, the Department of Agriculture, Clima Rice and other government and non government agencies. The programme will have five main objectives.

Figure 51: Coastal Area Elevations



(i) To reduce the impact of flooding through integrated flood management including flood protection, drainage and establishment of flood alleviation.

(ii) To reduce the impacts of salinity in the surface and groundwater systems including construction and rehabilitation of tail end regulators, increasing fresh water storages and groundwater recharge.

(iii) To develop sustainable agricultural systems through increased yields and robustness to climate and salinity impacts, reduced water use through crop scheduling, shorter period varieties, more water efficient cultivation systems and support for micro irrigation and small farmer managed lift schemes from ponds, drains and poldered flood alleviation areas. The component would also support for community fishing and aquaculture.

(iv) To develop sustainable and environmental appropriate systems for shoreline protection and management, to provide protection from erosion and also support shoreline management activities including river mouths.

(v) Improving the strength and capacities of the institutions and stakeholders including improved capacities and awareness at government and community level to support integrated water resources management approach to ensure sustainability and adaptation to climate change including development of mechanisms to operationalise effective maintenance.

4. Framework Plan

769. A preliminary definition of the coastal area of the Cauvery Delta would be the area subject to salinity intrusion and the main area of flood risk which would approximately be all the land below the 15 m.asl inside the sub basins of Lower Coleroon, Cauvery, Vennar, Grand Anicut. The coastal area would incorporate the whole of Nagapatinam District, Karaikal District in UT Puducherry and coastal area part in Thanjavur District and Cuddalore Districts

770. The framework plan is designed around securing and improving agriculture productivity through flood and salinity management and coastal protection.. Implementation will require cross sectoral coordination and institutional development within government as well the farming and fishing communities and other stakeholders.

771. There is no single solution towards meeting the requirements of development, sustainability and adaptation of the Cauvery Delta Coastal Area and a portfolio of different initiatives will be required. To meet the objectives, five key areas are identified:

(i) **Integrated Flood and Salinity Management:** Flooding will be addressed through flood dykes, drainage, expansion of flood alleviation areas as well as tanks, farm ponds and natural water bodies to absorb floods. Parallel measures of salinity control will include tail end regulators and improving ground water recharge.

(ii) **Sustainable Agricultural Systems** to support increased productivity systems to improve farmers' incomes and resilience to climate change impacts. The programme would include mechanisms for water resources conservation, and minimising impacts of floods and salinity. . Farmer productivity would be supported by appropriate crop varieties, improved cultivation systems to reduce water demands and labour requirements, optimisation of crop scheduling, micro irrigation and support for small scale farmer managed lift irrigation and support for infrastructure to promotes marketing. Support for fishing, fresh and brackishwater aquaculture, fish processing and marketing would be included.

(iii) **Shoreline Protection and Management** would address present and the likely projected impacts from sea level rise on erosion and other shoreline issues. The component will support the development soft and environmentally appropriate mechanisms for protection including addressing planning of coastal development which is major cause of erosion and coastal instability. Management of the river mouths to support access by fishing boats and reduce flooding risk would be addressed.

(iv) **Institutional Development, Training and Awareness** would be provided to support the establishment of an integrated management approach. These would include the effective establishment of IWRM at state as well as in the Delta area to support the necessary field programmes.

5. Framework Plan Proposals

772. A four component strategic framework plan is proposed. The plan is designed to meet the key objectives of development needs, sustainability and adaptation to climate change.

Component 1: Integra ted Flood and Salinity Management

773. Flood and salinity management would be integrated; the proposal is to improve drainage, increase protection bunds, construct tail end regulators and develop flood alleviation basins. Full flood proofing for the delta area is not viable and partial flood proofing would be implemented with low lying lands zoned for flood alleviation and water retention.

774. Flood management would build on ongoing programmes and proposals in the Cauvery Delta Management Report; including increased cross cut drainage, diversion of flood flows and reconstruction of tail end regulators. Schemes would be evaluated and viable and economic proposals taken up for investment. Land requirements for major flood diversion need to assessed, land needs would be minimised where ever possible. There are large areas of low lying and water logged land which is presently unproductive for all or part of the year. Possible utilisation of these low productive areas as flood alleviation and retention basins would be investigated. Water in tanks, farm tanks, natural water bodies and low lying land can be retained post flooding by control structures; water would then made available for dry season irrigation as well providing support for groundwater recharge. The flood alleviation basins could be made more economic by fish stocking, sale of water retained, and planting of crops as flood recede (recession irrigation). Consideration of subsidy for the contribution of retention basins towards flood alleviation, groundwater recharge and supplementary irrigation water should be made.

775. Tail end regulators would be constructed/reconstructed to prevent salinity intrusion, retain and pond freshwater and prevent storm surge. Upgrading of maintenance of the drainage channels would be a critical part of the plan. Drainage bottlenecks including road cross drainage would be assessed and addressed.

776. Expanding of catchment management is proposed; joint efforts to better reduce the rates of runoff should be coordinated and implemented in the lower and upper parts of the catchment. Coordination programmes for catchment management across the whole basin ar proposed.

777. The complexity of the river and drainage systems require integrated planning supported by numerical models of the surface and groundwater systems. These modelling studies need to be implemented prior to development of plans and designs. The models will require to be supported by topographic surveys. Most of the investment projects would involve significant capital investment with design life of 50 plus years so it will be important to factor in climate change, including the projected sea level rise of 0.3m and projected increases in the NE monsoon rainfalls. Depending on the nature of the work and the additional requirements and costs for climate change resilience could be taken up immediately or in a staged manner. A summary of component 1 is shown in Table 72 below.

Table 72: Integrated Flood and Salinity Management

Overview	Reducing the impacts of flood and salinity through integrated flood and salinity management. Programme would include upgrading of drainage channels, flood dykes, flood alleviation and retention basins and tail end regulators.
Rationale	Flooding has been identified by communities as one of the major issues. Projected climate change impacts of sea level rise and increased NE monsoon rainfall will worsen the situation. Sea level rise will increase levels of salinity in the rivers, groundwater and soils. Large areas of land are presently partially or totally unusable due to water logging and salinity, flooding and sea level rise will increase the area of non/low productive land. Poor maintenance is resulting in blocked drains due to weed growth and sedimentation.
Description	o Increasing capacities of drains. o Increased height and strengths of flood dykes o Construction reconstruction of tail end regulators, to limit salinity intrusion, support fresh water retention and protect against storm surge o Development and rehabilitation of flood alleviation basins including natural water bodies, farm ponds, tanks, non and low productive lands. o Provision of control structures for retention of flood waters to support groundwater recharge and farm irrigation. o Integrated catchment management over the whole basin to reduce extreme flood events.
Studies/ research	o Topographic surveys of whole coastal area including river cross sections o Establishment of tidal gauges and a permanent bench marks around the delta. o Hydrodynamic modelling of the surface water systems o 2D modelling of the groundwater o Comprehensive planning and design for flood and salinity management requirements o Land use planning including identification and proposals for management of areas of marginal and non productive land
Outputs	o Reduced flooding through drainage, flood protection and flood alleviation o Reduced salinity ingress through tail end regulators and flood water retention o Increased groundwater recharge from flood water retention o Increased access to irrigation from farm ponds, tanks and flood retention basins.
Implementing Agencies	o Water Resources Organisation o Department of Agriculture and Fisheries o District Planning Committees o Panchayat

Component 2: Sustainable Agriculture Systems

778. The component objective would be to support development of more efficient agricultural production and marketing systems to improve financial returns to farmers, reduce water consumption and increase resilience to climate change. Programmes would include; (i) strengthening and coordination of government extension and support programmes; (ii)

support for farmer/cooperative orientated private sector partnerships initiatives; (iii) support for on farm water conservation and productivity; (iv) support for marketing infrastructure (iv) support for increasing productivities of low lying barren lands including development of aquaculture; and (v) support for adaptive research and up-scaling of climate and saline resistant crop varieties.

779. The proposal is to develop small holder agriculture with a move towards a more business perspective involving greater commercialisation of production systems and diversification to higher return cropping but with mechanisms to ensure participation and security of the small and lower income farmers. Emphasis should be directed towards small local enterprise including strengthening of the local cooperatives and farmer groups and improving access to mechanisation and modern technologies.

780. Upgraded extension support would be provided by government as well as private sector. Farmer and water user groups and village cooperatives would be strengthened, empowered and given increased autonomy. Private sector partnerships would be supported to help provide additional security and financial support to move towards higher return cropping systems including increased access to mechanisation and improved marketing.

781. Improving farmer productivity, competitiveness and financial returns are key requirements for increasing resilience to climate change impacts. On farm investments would be supported including development of farm ponds, improved drainage, micro irrigation, mechanisation, small farmer owned portable pumps. Support for the use of flood retention water for irrigation to relieve pressure on groundwater would be provided.

782. Support for marketing infrastructure including post harvest processing, crop storage, market areas, crop and fish processing, upgrading of farm roads. Parallel institutional support for marketing to provide better harmonisation of government support subsidies towards meeting the objectives of water resource conservation and crop diversification and sustainability.

783. In parallel the component would address the needs of water conservation through significant the use of shorter duration crops, SRI, directed seeded rice, diversification of cropping and adjusting of cropping calendars. Upscaling would be carried out in stages with fully researched and accepted initiatives taken up quickly and the less developed and untried measures taken up on a pilot basis.

784. Changing to new crop varieties including shorter duration, higher yielding crops, support for reducing post harvest losses, improved handling and marketing of higher value crops will all be addressed. The need for new varieties which may be more appropriate to temperature increases from climate change as well as saline resistant varieties would be researched and main streamed. Upscaling of research into new conservation technologies as well as the development of crop varieties, cropping systems resistant to climate change would also be taken up.

785. The component would provide support for possible economic uses for low lying barren and semi barren lands. The potentials to use these areas for flood retention would be investigated including financial support measures, community led fresh and brackishwater aquaculture, support for recession farming using the retained flood water as a water source etc. A summary of component 2 is given in Table 73 below.

Table 73: Sustainable Agriculture Systems

Overview	Improved agricultural productivity and strengthened capacity to improve farm incomes and meet the impacts of flood and salinity and needs for water conservation.
Rationale	Agricultural has declined in recent years and urgent efforts are required to increase the viabilities and sustainabilities of farming systems. Sustainability requires financially viable production methods that can improve incomes of farmers' and fishermen as well as increasing of capacities and resilience to meet climate impacts. Climate change will impact on the viabilities of agriculture, large areas of low lying land are presently semi barren, the area will increase due to sea level rise. New initiatives are required to make these areas productive. including their potential use for flood alleviation and retention. Further research is required to assess into appropriate agriculture and irrigation technologies together with crop research to develop varieties resistant to increased temperature as well as salinity.

Description	o	Intensification and diversification of production to improve financial viabilities of farming
	o	Development of small holder agriculture and fishing through a more business orientated model, strengthening of water user groups, cooperatives and opening of opportunities for small scale private sector participation.
	o	Increased extension support through strengthening of the extension system, promotion of private sector extension efforts, training and support for new market opportunities
	o	Support for on farm investment to improve productivity and conservation through investment in micro irrigation, portable and mini pumps, mechanisation, development of farm ponds etc
	o	Support for marketing infrastructure including post harvest processing, storage, market areas, farm roads etc. Support for cooperatives to support marketing for farmers and fishermen.
	o	Development and upscaling of conservation methods to reduce water demand including shorter duration crops, SRI, direct seeding, adjusting the crop calendars etc.
	o	Development and introduction of new crop varieties to improve resilience to increased temperature and resistance to salinity.
	o	Support for land owners of low lying lands to maintain income levels; support for fish or prawn culture and assessment of opportunities to use the land for flood alleviation and water retention.
Studies/ research	o	Research into increasing yield and productivity in parallel with reduced water use.
	o	Studies to assess marketing systems and opening of opportunities for new crop markets. Studies to support alternative uses for low lying lands including flood retention systems, small holder aquaculture.
	o	Improved and more sustainable farm productivity and farming and fishing systems
Outputs	o	Increased on farm investment to support conservation and productivity
	o	Strengthened farmers associations and cooperatives
	o	Improved infrastructure to support crop processing, storage and markets
	o	Improved farmer access to markets and opening of new market opportunities
	o	Increased involvement of private sector partnerships in agriculture,
	o	Increased economic use of low lying non productive lands
Implementing Agencies	o	Department of Agriculture .
	o	Department of Horticulture
	o	Department of Fisheries

Component 3: Shoreline Protection and Management

786. The shoreline along the Delta stretches for around 220km. The shoreline has a number of issues including erosion, sedimentation, blocking of river mouths. There are also development issues including construction of harbours, development of power stations etc. There is a need to integrate development issues with the shoreline management and protection; nearly all coastal and shoreline issues are manmade. Climate change including sea level rise will increase the vulnerability of the shoreline.

787. The Delta previously under its natural regime was accreting but damming of the rivers has reduced the sand supply, sand mining for construction is also affecting the supply of sand. Infrastructure projects including harbours, groynes and rock protection can also affect the natural equilibrium of the beach and lead to loss of beach and erosion. Any loss of sand reduces the natural capacity of the beach and dunes to protect the land from waves and currents.

788. This component is designed to support the protection and management of the 220km of shoreline in the Cauvery Delta and will include; (i) preparation of shoreline management plans for the whole shoreline; (ii) prepare plans and designs for specific problem areas including erosion, river mouths etc; (iii) develop dune management, mangrove and other natural protection measures on selected areas of erosion and instability to conserve and the natural defences of the shoreline; (iv) implement supplementary environmentally appropriate erosion control mechanisms to supplement if necessary natural protection measures; (v) support the planning and design of coastal development projects including remodelling of existing infrastructure which is damaging the shoreline balance and design support for any proposed projects or activities to minimise impacts on the natural equilibrium ; (vi) review and address issues of the supply of sand from the rivers including the impact of sand supply from dams and sand mining.

789. The issues of the shoreline need to be studied in more depth to identify sustainable and environmentally appropriate mechanisms for protection and management. Natural mechanisms to protect the shoreline should be taken up as a first priority, they may not be adequate in themselves but in terms of cost and sustainability offer the best solutions.

790. Supplementary protection maybe required; these need to be studied and designed based on understanding and address the causes of erosion and where ever possible building and complementing the natural protection of the beach and dunes. Beach nourishment by dredging can offset the lack of sand supply if suitable sources can be identified. Dredging of river mouths and dumping of sand of erosion prone area may offer a solution. The littoral drift may quickly remove nourishment and mechanisms to hold any beach nourishment in place without affecting the littoral drift maybe required. Artificial offshore reefs may offer solutions to support natural accretion in the wave shadow behind the reef. Flow from meandering nallah and river mouths can cause turbulence and increase erosion, managing of river and drain flows by routine excavation of direct exits to the sea can reduce the risk of erosion.

791. Closure of river mouths during the dry seasons is due to the imbalance of the flushing regime from the reduced river flows and the coastal littoral drift which causes the silting and closure of the mouth. Investment in river training to concentrate the river flows maybe possible to provide a permanent solution but this would depend on an adequate level of freshwater flow which is probably not available. The option is routine dredging or excavation of the river mouths. The application of dune management, mangroves and dredging/excavation of river mouths and nallahs are all routine maintenance tasks requiring access to funding on a continuous basis.

792. The economic viability of shoreline protection is an issue; coastal protection is extremely expensive; requiring high capital and maintenance costs. Dune management offers a low cost option. Much of the Cauvery shoreline is low productivity agricultural land and protection costs may not be economically viable and the option of planned retreat may have to be considered.

Table 74: Shoreline Protection and Management

Overview	Addressing the causes of erosion and development of environmentally appropriate mechanisms to protect and manage the shoreline .
Rationale	The shoreline is presently slowly eroding increased sea levels and increased storms will increase the threat of erosion. Ongoing rock protection works are not adequate and also can damage the delicate natural balance of the beach which forms the natural protection measures
Description	o Establishment of natural protection measures as a priority including dune management on a pilot basis on about 30km of beach. o Development of mangrove where appropriate o Identify and develop protection options to complement dune management where required o Remodelling of shoreline infrastructure where it is causing damage. o Investments or alternatively routine dredging/excavations of river mouths
Studies/ research	o Prepare shoreline management plans along the whole coastal part of the Delta o Establishment of tidal gauges o Undertake 2D coastal modelling along critical areas to assess issues and identify solutions. Modelling would incorporate climate change parameters including sea level rise. o Assessment of various new technologies to assess application to the Cauvery o Planning and design of coastal sub projects.
Outputs	o Shoreline management plans prepared and agreed for whole shoreline o Coastal erosion and instability reduced o Sustainable shoreline maintenance including dune management and routine clearing of river mouths in place.
Implementing Agencies	o Public Works o Water Resources Department

Component 4 : Institutional Development Training and Awareness

793. The effective implementation of an integrated strategy for the Cauvery Delta requires to be supported by a series of initiatives relating to water governance. The present institutional, financial and legal frameworks are not adequately directed to meet the needs of the integrated water resource management. Under this component, five key activities are

proposed; (i) establishment of IWRM; (ii) agreed support and financing arrangements; (iii) agreed regulatory framework; (iv) water resources and data management; and (v) intensive training and support for awareness of stakeholders at all levels. The requirements would include:

794. **Establishment of IWRM:** Various options exist but the preferred option is to build as far as possible on the existing institutions. The requirements would include the establishment of; a water regulatory authority, a state water resources committee, an IWRM unit to be established within the Water Resources Department and operationalising of the district planning committee and the district sector departments, implement programmes. Water resources planning would be based on the sub-basin plans. The establishment of IWRM and the Subbasin Planning Process is described in the India Water Systems report.

795. **Agreed Support and Financing Arrangement:** The implementation of water conservation and climate adaptation require a portfolio of investments and programme support measures. To implement these requires an agreed approach to financing of support subsidies. Instigating of change measures proposed for the Cauvery Delta needs some consideration of mechanism to implement and mainstream support subsidies. The framework plan identifies the need to conserve water, the development of flood alleviation and retention basins in low lying areas, fully effective and routine maintenance of drains and the dune and beach management. How these can be implemented and financed on a large scale needs to be defined. Routine and effective maintenance of dunes and drains is required and workable approaches including adequate and regular financing need to be identified.

796. The role of PPP to support some of the conservation and productivity programmes needs to be explored, appropriate public-private sector or community-private sector partnerships offer new opportunities which would not be fully feasible by the government alone.

797. **Agreed Regulatory Framework:** A stronger regulatory framework is required to work in parallel with the various support initiatives. New ideas and pilot projects can be supported by support subsidies however at some stage there is a requirement to bring in regulation to reduce wastage and ensure the long term sustainability of the water resources. Regulation will have to come in slowly and will have to be balanced by support measures and improved productivity offset any loss of farmer income. The establishment of the State Water Regulatory Authority will be an important first step.

798. **Water Resources Data and Management Systems** are required to support the planning and management of water resources requires the development of a GIS based integrated water resources information system including information on surface, groundwater, sea, catchments, forestry, and environment. Information on development including hydropower, irrigation, water supply, floods, agriculture, industry etc. Data on finance and project benchmark monitoring and evaluation would be included. The development of information and management systems through the development and standardisation of databases and building on information and studies being developed by the different sectors.

799. **Training and Awareness:** The programme requires to be supported by an intensive programme of training and awareness. Areas to be addressed include understanding of importance of sustainability of surface and groundwater resources, potential impacts of climate change and identification of areas of vulnerability. Communities have to be made aware of climate change impacts as well as increased capacity for self help to adaptation together with reduced of dependency on government.

800. The requirements for the programme are summarised in Table 75 below

Table 75: Institutional Development Training and Awareness

Overview	Establishment of institutional change and strengthening together with regulatory and support initiatives will be required to effectively implement the integrated development and sustainability programmes proposed for the coastal part of the Cauvery Delta
Rationale	The present institutional and management systems are not adequately focused towards the needs of integrated water resources conservation and management.

Description	o	Establishment of IWRM at state level through improved coordination of sector departments through a water resources steering committee, a water regulatory authority and empowerment of the districts..
	o	Agreed financing strategy to better support and subsidise targeted initiatives for conservation and improving agricultural productivity.
	o	Support mechanism to promote of appropriate private sector participation to support productivity, marketing and conservation initiatives.
	o	Agreed regulatory framework and support for phased introduction of water resources regulation.
	o	Establishment of an integrated water resources information system.
	o	Training and provision of awareness material to support awareness of water resources sustainability and adaptation to climate change.
	o	Viable and sustainable mechanisms to guarantee effective maintenance of drains, river mouths and the shoreline and dunes.
Studies/ research	o	Consultation and studies to support financing strategy
	o	Studies to assess approaches for sustainable maintenance.
Outputs	o	Functional IWRM strategy in place
	o	Agreed and targeted financial management of investments and programmes
	o	Phased regulatory programme in place.
	o	Funding and resources for sustainable maintenance
Implementing Agencies	o	All water resources sectors, Senior Government

G. Road Map

1. Cauvery Delta Coastal Area Sustainability Programme

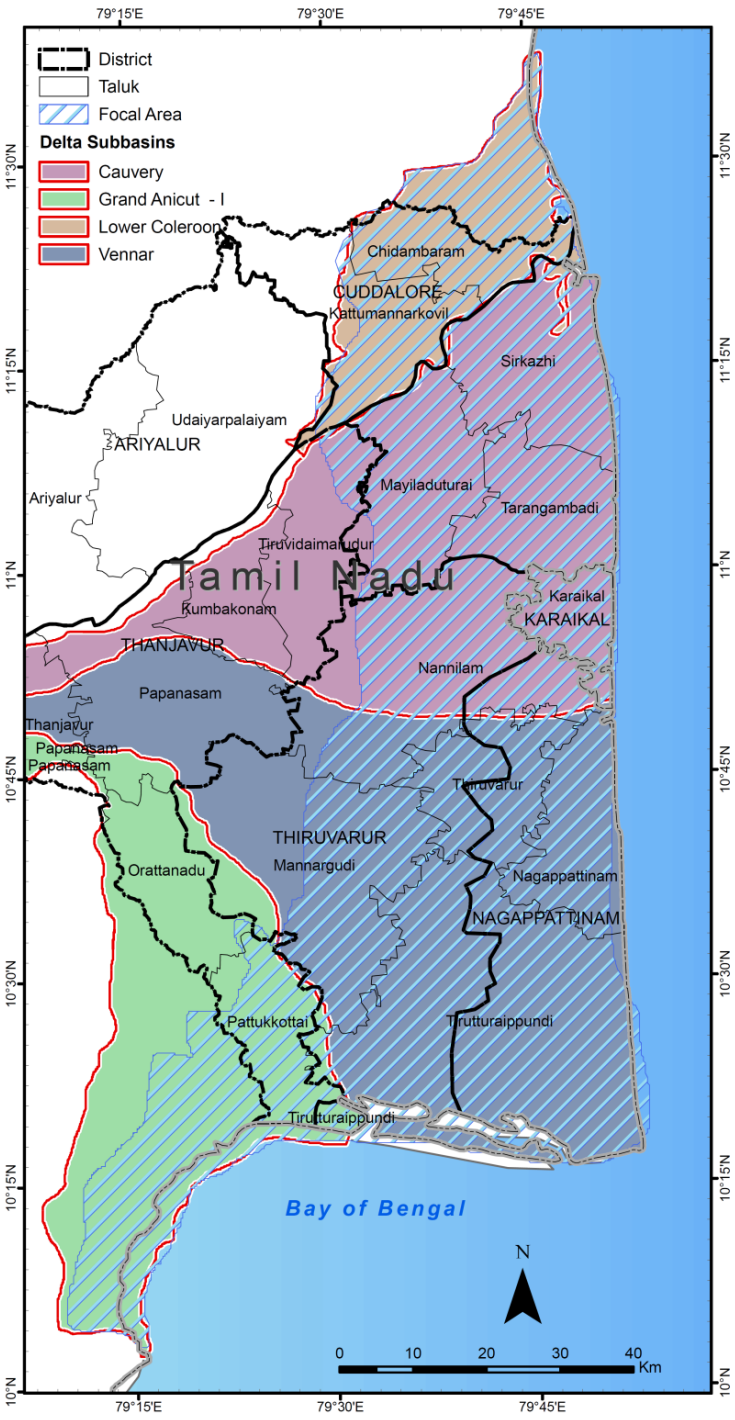
801. It is proposed to establish the 'Cauvery Delta Coastal Area Sustainability Programme' to address ongoing development, environmental and potential climate issues of the Cauvery Coastal Area. The programme would put into place wide ranging initiatives, programmes and investments to meet the needs of ensuring the sustainability of the Cauvery coastal area through integrated flood and salinity management, sustainable agricultural systems, shoreline protection and management and institutional development, training and awareness.

802. The project would be based on an IWRM approach, with a focus to address the sustainable development of water resources in the coastal area. The sector departments presently lack the flexibilities, capacities and level of integration required to meet the project objectives and an IWRM institutional framework would be required to be established including the formation of a state water resources committee, a regulatory authority and empowerment of the district planning committee and district level sector agencies.

803. An eight year programme is proposed and would be implemented through the new IWRM framework. The programme would be integrated involving and working closely with the key water sector agencies, the district administrations and communities. The programme would work under the direction of a newly formed Water Resources Steering Committees but working closely in coordination with the sector departments at State and District level, District Administrations and Panchayats.

804. The programme would implement field level support programmes within the coastal area of the Cauvery Sub Basin. The coastal area is indicatively defined as the area subject to salinity intrusion and the main area of flood risk. This would approximately be all the land below the 15 m.asl inside the Cauvery sub-basins of Lower Coleroon, Cauvery, Vennar, Grand Anicut. The coastal area would incorporate the whole of Nagapatinam District, Karaikal District in UT Puducherry and coastal area part in Thanjavur District and Cuddalore Districts. The coastal area is shown in Figure 52

Figure 52: Coastal Area Districts



805. In parallel the programme would address institutional and reform measures over the water sector departments over the whole of Tamil Nadu State. The establishment of IWRM and institutional reforms is critical towards the long term sustainability of water resources in the State including the delta. Institutional reforms would be implemented in stages and would build on the existing institutional structures including the establishment of an independent water regulator.

2. Planning Process

806. The strategic plan would require to follow the planning process as described in the India Water Systems report The importance to have full endorsement of the State Water Resources Steering Committee and the District Planning Committees is critical.

3. Programme Organisation

807. It is proposed that the programme would be a semi autonomous multi-sector project. Project activities would be coordinated through the 'Water Resources Steering Committee ' comprising of the principal secretaries of the key water sector agencies (Water Resources, Agriculture, Rural Development and Panchayat Raj, Fisheries, Cooperatives, Environment and Forests).

808. Coordination and optimum use of the different funds would be important these would include Mahatma Ghandi National Rural Employment Guarantee Act (MNREGA) funds, Central and State Government Funds,

4. Requirements for External Support

809. The project would require external specialist support to complement the existing skills of the government staff. One key objective of the project is to bring in the development of new ideas and technologies that might be applied to support the development and sustainability of the Cauvery Delta It is estimated that specialist support would be required for all components. The complexity of the water systems requires the use of hydrodynamic modelling of the surface water systems, the groundwater systems as well modelling of the coastal processes. Qualified state or national institute would be required to do this work together with specialist international and national support. Extensive surveys would be required to map the coastal area and topography as well as cross sections of the rivers and shoreline and inshore part of the sea.

5. Programme Scope

810. The programme would involve a mixture of studies and consultation, planning, sub project design, community liaison and participation, institutional development and reforms. The focus of investment would be the coastal area of the Cauvery delta with institutional strengthening and reform would be taken up to the whole state involving all the water

sector departments. It is proposed that the Vennar sub basin would be taken up as a priority due to the more critical flood and salinity issues in the Vennar. A second priority area could be taken up later. Shoreline management plans would be implemented for the whole Delta coastline and specific critical areas would be identified for further study.

6. Investment and Support Programmes

811. Possible areas of investment and support are summarised in Table 76. The programme implementation would require supplementary investment support as well as ensuring coordination of the direction for other ongoing programmes, such as MNREGA. Financial support would be required for investment as well as specialist inputs for research, planning, design and training.

Table 76: Possible Areas for Investment and Support in the Coastal Area of the Cauvery Sub Basin

INTEGRATED FLOOD AND SALINITY MANAGEMENT	
1.	Investment to expanding the drainage
2.	Investment in flood dykes
3.	Construction and reconstruction of tail end regulators
4.	Development and rehabilitation of flood alleviation basins including natural water bodies, large drains farm ponds and tanks as well as low/non productive low lying lands
5.	Provision of control structures to support retention of flood waters to support groundwater recharge and dry season irrigation
6.	Pilot maintenance programmes to clear drains of weeds and sediment
7.	Integrated catchment management over the whole basin to reduce and retain storm runoff
SUSTAINABLE AGRICULTURAL SYSTEMS	
8.	Support for on farm investment including farm ponds, farm drainage and micro irrigation
9.	Support for increased mechanisation including support for mechanisation through cooperatives and PPPs
10.	Support for infrastructure to support marketing including post harvest processing, crop storage, market areas, crop and fish processing, upgrading of farm roads.
11.	Support for operationalising of low and non productive low lying lands; provision of support for development of farming or aquaculture as well as realising the potential use for flood alleviation and retention
SHORELINE PROTECTION AND MANAGEMENT	
12.	Beach and dune management programmes
13.	Dredging of river mouths and beach nourishment
14.	Additional soft and beach friendly protection measures
15.	Mangrove management
16.	Remodelling of existing infrastructure to remove impediments to the natural processes
17.	Support for new coastal infrastructure to support economic development, planned and designed not to affect coastal processes.

7. Studies and Operational Research

812. The implementation of the plan will require well coordinated activities including studies, participative planning and policy decisions, and implementation of programmes. At this stage, the plan is conceptual and would require careful review by the Government of Tamil Nadu. More work is required to technically assess and define all the options and before moving onto detailed programme design. and implementation. Planning would follow the proposed sub-basin planning process described in India Water Systems report.

813. Subject to agreement and endorsement of the report, it would be necessary to implement a programme of follow-on studies and design of selected pilot projects. These would be feasibility studies to verify the technical and financial viabilities of the proposals including extensive consultation and participation at all levels to ensure acceptability. Visits to other parallel projects would be important to discern the lessons learnt. Based on the outputs of the studies, it is proposed to implement some pilot projects to validate the proposals and make adjustments before embarking on up-scaling. Regular review of the strategy is proposed based on monitoring, studies and improved climate projections.

814. **Proposal for Operational Research for the Cauvery Delta:** The complexities of the water systems in the Cauvery Delta requires the development of modelling systems to support planning including simulation of sea water rise, changes in precipitation in the south west and north east monsoon. Three modelling systems will be required (i) a hydrodynamic model of the surface irrigation network; and (ii) a coupled surface/groundwater model to investigate groundwater systems including groundwater to different water management practices and (iii) a 3 dimensional hydrodynamic model of the coastal processes including facilities to assess sediment transport. The modelling would be incorporated into Decision Support System to review various development options for the coastal areas of the Cauvery Delta.

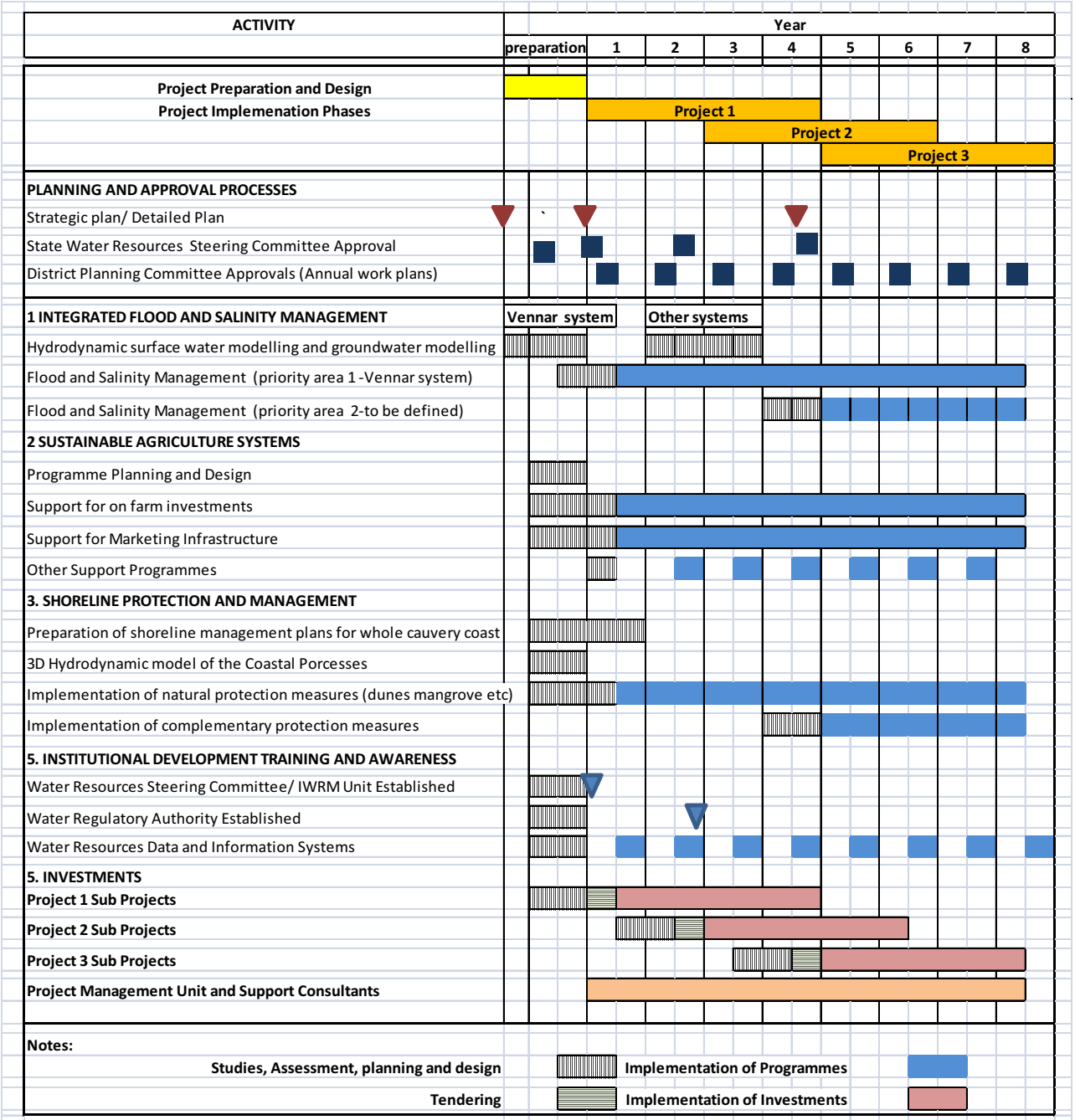
815. To set up a hydrodynamic model for part of the Cauvery delta would require a survey of the canal and drainage network, and some additional observations of discharge and water levels. Wherever possible existing data would be sourced and applied. The extent of the surveys and time requirements would have to be assessed. Setting a coupled WEAP/ MODFLOW model for part of the Cauvery Delta would require considerable effort with respect to the groundwater model.

816. The outputs of the model would be designed to address key issues from climate change including: (i) possible approaches to arrest saline intrusion in groundwater; (ii)) development of sustainable drainage systems; (iii) optimum siting of salinity regulator structures for salinity control; (iv) options to prevent or reduce blocking of the river outfalls to the sea; (iv) support for land use planning with special reference to operationalising of low lying non or poorly productive land; (v) options for flood control and management including dykes, flood alleviation and retentions zones; and (vi) options for shoreline protection and management.

H. Project Schedule

817. The project is proposed to be run in three phases over eight years. Sub-projects would be identified, planned and designed for Project 1 in year zero with implementation over four years. The need for IWRM and sustainability reforms in place is critical and three stages are proposed including the establishment of an independent water regulator by end of year two. The early implementation of the hydrodynamic modelling is a key requirement. The proposed project schedule is shown in Figure 53 below.

Figure 53: Project Schedule Cauvery Delta Sub Basin



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.