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Prepared by Joint Venture of SMEC International Pty. Ltd., Rehman Habib Consultants Pvt. Ltd. and Engineering General Consultants, and in association with Asian Advisory Services

Punjab, Pakistan

For Punjab Irrigation Department

Asian Development Bank

Punjab Irrigation Department

ADB
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Institutional Transformation of the Punjab Irrigation Department to a Water Resources Department

Reference No.: CDTA 9255-PAK

FINAL REPORT

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ABBREVIATIONS AND ACRONYMS

ABBREVIATION/ ACRONYM	DESCRIPTION
ADB	Asian Development Bank
AP	Affected person
AWDO	Asian Water Development Outlook
CDTA	Capacity Development Technical Assistance
the Consultant	SMEC International
DB	Design and build
DBB	Design, bid, build
DSS	Data Support System
DRM	Disaster Risk Management
DTW	Depth to Water
EIA	Environmental impact assessment
EMP	Environmental management plan
EOI	Expression of Interest
E-R Model	Entity Relationship Model
FGD	Focus group discussion
GoP	Government of Pakistan
GW	Groundwater
GWP	Global Water Partnership
ICT	Information and Communication Technologies
IT	Information Technology
IEE	Initial environmental examination
IWRM	Integrated Water Resources Management
m	meter/s
MAR	Managed Aquifer Recharge
MOU	Memorandum of understanding
MOM	Management Operation and Maintenance
MPW	Ministry of Public Works
NGO	Non-government organization
PMO	Project Management Office
PMU	Project Management Unit
PMIU	Project Monitoring and Implementation Unit
PIAIP	Punjab Irrigated Agriculture Investment Project
PIDA	Punjab Irrigation and Drainage Authority
PID	Punjab Irrigation Department
PPP	Public private partnership

ABBREVIATION/ ACRONYM	DESCRIPTION
PS	Provisional sum
PWA	Punjab Water Act
PWP	Punjab Water Policy
PWRC	Punjab Water Resources Commission
PWSRA	Punjab Water Services Regulatory Authority
QA	Quality assurance
RAP	Resettlement action plan
RBA	River Basin Authority
RBP	River Basin Planning
ROW	Right of way
RP	Resettlement plan
RPF	Resettlement policy framework
SDD	System Design Document
SDG	Sustainable Development Goals
SRD	System Requirement Document
SRS	System Requirement Specifications
SW	Surface Water
TA	Technical assistance
TBA	To be advised
ToR	Terms of reference
WHO	World Health Organization
WRD	Water Resources Department
WRIS	Water Resources Information System
WRIMS	Water Resources Information Management System
WRMP	Water Resources Management Plan
WRRA	Water Resources Regulatory Authority
XENs	Executive Engineer

EXECUTIVE SUMMARY

General

This report is prepared in accordance with the Terms of Reference for CDTA 9255-PAK: Institutional Transformation of the Punjab Irrigation Department to a Water Resources Department, specifically Deliverable No 15: Final Report.

The Final Report addresses the following themes:

- Water Vision 2050
- Support Implementation of the Punjab Water Policy and Punjab Water Act
- Groundwater Management
- Integrated Water Resource Management
- River Basin Planning and Management
- Design of Water Resource Information System
- Upgrading of Irrigation Research Institute
- Capacity Building and Training

Punjab Province is transitioning from a historically developed, sector-driven and exploitation-oriented approach to water resources management based on IWRM principles. This report assists PID with the transition process by presenting proposals for (i) an overall provincial IWRM Governance Structure; (ii) a provincial IWRM Work Process; (iii) a future Organization Structure for the Punjab Irrigation Department (PID); and (iv) an Organization Structure for the Water Resources Department (WRD). These are key elements of the needed IWRM Framework.

This report presents a synthesis of the information contained in a number of other technical reports required under the TOR that deal with specific themes that are required for effective project implementation. The study identifies the challenges and opportunities for water resources management in Punjab leading to recommended solutions for integrated development of the basin water resources. The project included a number of thematic studies which consider a range of different challenges and how to address them. The individual thematic reports for all deliverables can be consulted for detailed outputs.

This report provides a key source of information for developing an IWRM framework for managing water resources in the Punjab Province, including a review of the current institutional arrangements and a proposed Governance structure which minimizes disruption to PID's day-to-day functions, while meeting the requirements of the Water Act. The report presents a preliminary process flow chart for Achieving the Objectives of the Punjab Water Policy and Water Act 2019. The flow chart and action plan are helpful in generating more insight in what constitutes the major steps in the process.

Vision 2050

A preliminary Water Vision was developed for Punjab for the year 2050 which establishes what stakeholders would like to achieve by the year 2050 in terms of managing the water resources. Water Vision 2050 provides a roadmap on how the vision can be achieved and includes:

- A vision statement that summarizes the overall objective;
- A list of goals which if achieved will contribute to fulfilling the vision;
- Identification of key result areas (KRA's) and strategies which will provide the means to achieve the goals;
- An outline of actions to implement the strategies.

A suggested Vision Statement is:

> *"The Vision is to ensure the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water related risks to people, environments and economies."*

Five key result areas were identified which are:

- KRA 1: Equitable Water Sharing and Resilience to Climate Change
- KRA 2: Sustainable Management of Doab Irrigation Land and Water systems
- KRA 3: River and Environmental Health
- KRA 4: Reducing Risks and Impacts from Floods
- KRA 5: Sustainable Management of Watershed, Hill Torrent and Desert Areas
- KRA 6: Reduce Risk of Water Borne Disease
- KRA 7: Improve Agricultural Productivity

Action Plans

A series of Action Plans were developed to address the issues associated with the KRA's. It is not feasible to implement these actions immediately or all at once, as government resources are limited. As a result, a measured approach is required. The actions have been selected based on an initial assessment of needs with some to be implemented immediately whilst others are to be implemented over the long-term.

Investment Plan

The Punjab Province overall investment plan to implement the Water Vision 2021-2050 are estimated at about US$ 25.44 Billion, that is equivalent to about US$ 848 Million of investment per year.

Integrated Water Resources Management Framework

A Framework was developed for implementing Integrated Water Resources Management (IWRM) in Punjab. The Framework includes four Functional Themes and five Sectoral Themes as below:

Functional Themes

1. Institutions, policies, and intergovernmental cooperation
2. Water resources planning and management
3. Data, Information, and Knowledge Management
4. Stakeholder involvement.

Sectoral IWRM Themes

1. Doab and Irrigation Management
2. Watershed, hill torrent, and desert area management
3. River health and environmental protection
4. Integrated flood risk management
5. Urban WSS and environment.

The IWRM Implementation Roadmap includes actions to be implemented over the next 1-2, 3-5 and 6-15 years in each of the nine themes provided above.

Support Implementation Water Policy and Water Act 2019

Punjab Province is on its way to change from a historically developed sector-driven and exploitation-oriented water resources management to one based on IWRM principles. This report assists PID with the transition process by presenting proposals for (i) an overall provincial IWRM Governance Structure; (ii) a provincial IWRM Work Process; (iii) a future Organisation Structure for the Punjab Irrigation Department (PID); and (iv) an Organisation Structure for the Water Resources Department (WRD). These are key elements of the needed IWRM Framework. They are rigid and suggest that, once adopted and applied, nothing can go wrong anymore on Punjab's path.

However, there are two critical points. The first point is that this governance and institutional structures part of the IWRM Framework has an Achilles heel. For the process to function effectively, it is important that the provincial

government leadership and the agency leaders have actually internalised/ adopted/ absorbed the IWRM-way of thinking. If this is not the case yet, chances are that in the work process the recommendations which the WRD is expected to provide will not be valued. This would then result in the wrong decisions being taken. One can expect decisions that reflect the ‘old style’ of sector-led water resources exploitation. One of the most urgent activities therefore is to assist the provincial government leadership and the agency leaders in adopting the ‘IWRM-way of thinking’.

The second point concerns the further detailing of the above IWRM Framework elements. PID has expressed that it needs a holistic (comprehensive) plan for the introduction of IWRM and its transformation process to a WRD. The CDTA ToR reflects this need in its detailed requirements. Illustrative is ToR Para 20, which requires a proposal for capacity development of PID; identification of new PID positions; job descriptions; and person specifications. Para 21 asks for duty statements and selection criteria for positions for personnel within the governance structure. Before these details can be produced, clarity is needed about the larger elements in the IWRM Framework, such as the provincial IWRM governance structure; the envisaged provincial IWRM work process/mechanism; and the principal roles and responsibilities of the IWRM-related provincial agencies. For the Government of Punjab Province to decide and reach consensus on these important large elements will require deliberations and thus time.

Groundwater Management

Groundwater abstraction has gradually increased since the 1960s with groundwater recharge being substantially increased due to seepage from irrigation canals and irrigated fields. Groundwater now provides approximately 50% of irrigation water supply and a significant proportion of urban water supply. Groundwater quality has been steadily declining due to contamination by infiltration of polluted surface waters that have been polluted from untreated sewerage effluent, untreated industrial effluent and agro-chemicals associated with irrigation. Furthermore, over extraction of some aquifers has allowed brackish ground water to migrate into freshwater zones. Groundwater extraction tends to exceed recharge across much of the Punjab, especially adjacent to cities where extractions for urban water supply are large. It is recommended that more groundwater monitoring stations be installed to measure levels and water quality and that groundwater models be established and calibrated to assist in understanding groundwater behavior and informing management strategies. It is essential that groundwater extractions be adjusted to match extractions to recharge. A range of managed aquifer recharge pilot studies have been designed with the intention being that similar schemes will be widely implemented to increase groundwater recharge. Improvements in water quality will largely be achieved by requiring treatment of industrial and sewerage effluents and working with irrigators to control the use of agro-chemicals.

Water Resources Information System

PID has developed an excellent array of information systems over the years and has laid the foundation for an integrated WRIS with the development of a number of systems - WRMIS, RTFMS, DSS and public website. These systems are functioning very well independently and being used by different operational teams within the PID.

A review of the existing systems identified the need for an integrated product that allows management of Punjab’s water resources in a holistic manner using IWRM principles. The integration design involved consultation with PID, in-depth analysis, development of data flow diagrams, identification of future requirements and an integration and transformation strategy to bring all systems into a single platform.

The proposed integrated WRIS design consists of WRIS and DSS Tools:

- Real Time River/Canal Network Model
- Groundwater Management
- Drought Management
- SCADA
- Asset Management

- Water Demand Management Module
- Flood Management System
- Reservoir Operation System

The following steps have been proposed to upgrade and implement the WRIS design:

- Consultation with all stakeholders to confirm the proposed WRIS design
- Develop a realistic implementation plan – consider pilot development and refinement before implementing at the Indus Basin level
- Identify capacity building requirements and potential international/national partners
- Execute the implementation plan

Upgrading Irrigation Research Institute

The irrigation Research Institute (IRI) was established in 1974 and currently consists of three directorates for:

- Hydraulics
- Physics and
- Design

The IRI is a Government owned institution. In its early days the IRI played a key role in design of hydraulic structures for irrigation and hydro-power projects associated with large scale development projects in the Indus River Basin. As the water resources development projects have wound down so too have the activities of the IRI. This has led to a decline in funding, a reduction in staffing levels, diminishing expertise and dwindling capabilities. Due to lack of maintenance the facilities have become rundown and lack of funding has meant that the IRI has not adopted the latest approaches and equipment. Furthermore, the needs of the water resources community are very different to the needs in 1974 when the IRI was established.

The IRI needs to be revitalized. This will require a new vision, sustainable business plan, upgrading existing capabilities and capacity and addition of new capabilities to meet the future needs of Pakistan's water sector. These will require substantial international inputs, training and upskilling of existing staff, strategic recruitment of new staff and acquisition of new equipment. This is not likely to be achieved under the existing funding arrangements and therefore a new business model is required encapsulating a more commercial approach.

A new organizational structure has been proposed that includes three new directorates in the following themes:

- Mathematical Modelling
- Integrated Water Resource Management
- Groundwater

Several different potential business models were assessed, and a preferred business model recommended. The recommended hybrid business model would be well suited as it would be minimal disruption to the current IRI operation. It would also provide the institute with adequate time to develop a detailed business model, find collaboration partners and other interested parties such as investors and clients.

Indus River Basin Plan

The key to the implementation of improved water resources management in the Indus River Basin is the development and implementation of river basin plans. A typical structure of river basin plans was established and is illustrated in **Figure 6-1**. The most effective plans are developed with input from a wide range of stakeholders including Government Agencies, irrigators, industrial water users, urban water users etc. This requires an extensive process of consultation with all stakeholders required to agree on the Plan objectives and the Plan actions required to achieve the objectives. A planning process designed to achieve effective consultation and Plan development was established and is illustrated

in **Figure 6-2**. Plans are required to be developed for each Doab or canal irrigation command area, the Pothohar Plateau and each Hill Torrent Area.

Capacity Building and Training

The capacity of current PID staff and future needs were assessed during the project. It was identified that the PID need improved capacity in the following areas:

- Water resource planning and management;
- Development research and operational management;
- Management of irrigation and drainage;
- Water related disaster management;
- Management of River ecosystem;
- Groundwater management; and
- Marginal quality water management

A training program was then developed to address these needs. During the study three training workshops were held.

1 INTRODUCTION

This is the Final Report for the CDTA 9255-PAK project, which concerns the Institutional Transformation of the Punjab Irrigation Department (PID) to a Water Resources Department (WRD) to enhance its capacity to holistically management water resources, whereas its traditional role was concerned only with delivery of irrigation water.

1.1 PROJECT BACKGROUND

Punjab faces major challenges in managing and regulating its water resources including: (i) growing water shortages which impacts agricultural production, human health and constrains industrial production; (ii) progressive deterioration of irrigation infrastructure which affects the ability to supply water efficiently; (iii) existing arrangements provide inadequate supplies to farmers at the tail end of canals who resort to exploiting marginal quality groundwater; (iv) low water use efficiency; (v) lack of transparency and inequities in access to groundwater due in part to water quality constraints; (vi.) lack of capacity within existing institutions for monitoring, modelling and management of surface and groundwater resources; (vii) the need to strengthen capacity to implement the Punjab water policy and Punjab water act; (viii) water quality concerns for surface and groundwater particularly in urban areas due to disposal of untreated industrial and municipal effluents; and (ix) over exploitation of groundwater with extractions exceeding recharge; (x) lack of environmental flows.

The PWP identifies these challenges, sets out a direction for institutional transformation and identifies several opportunities for improving water management and water availability in a sustainable manner. It recognizes the need to improve water governance, water institution responsiveness and services delivery and sets and identifies the need for strategic planning, transformation of PID to a WRD and capacity building.

Punjab has already commenced actioning the transitions outlined in the PWP including setting up of a Water Commission and Water Services Regulatory Authority under Water Act; water reallocation and standardization of some of the water supply functions; and setting a 2050 vision.

1.2 PROJECT OBJECTIVES

The main objective of the CDTA is to assist the Punjab Irrigation Department (PID) to enhance its capacity for transforming its service delivery from a traditional irrigation water deliverer to a Water Resource Department (WRD) that holistically manages water resources in line with the Punjab Water Policy (PWP) and Punjab Water Act (PWA), 2019. Through this CDTA, PID is expected to acquire improved capacity in:

- Water resource planning and management.
- Development research and operational management.
- Management of irrigation and drainage.
- Water related disaster management.
- Management of River ecosystem.
- Groundwater management.
- Marginal quality water management.

These objectives will be achieved through: assessment of water related sub-sectors; implementation support for PWP and PWA; institutional arrangements for efficient service delivery; Implementation of the Punjab Water Vision (PWV-2050) and associated investment program; adoption of the integrated water resource management (IWRM) framework; implementation of the Indus River Basin plan (IRBP); implementation of the water resource information system (WRIS). The strengthened research and capacity will provide a sound basis for the envisaged transformation as a responsive institution.

The Final Report presents and elaborates upon the nature and outcomes of the thematic analyses undertaken and puts forth relevant key issues related to preparation of the Institutional Transformation of the Punjab Irrigation Department to a Water Resources Department framework.

1.3 PROJECT SCOPE

The scope of works is limited to the Punjab province and covers the activities of PID. The outcome of this project, such as frameworks and principles will be relevant to other provinces and the wider Indus basin.

A brief scope of consulting services as provided in the CDTA Terms of Reference (TOR) is provided in **Table 1-1.**

Table 1-1: Brief Scope of Consulting Services

TASK	ACTIVITY	TASK
1	Support implementation of Punjab Water Policy (PWP) and Punjab Water Act 2019 (PWA)	Analyse options to implement Punjab Water Policy and Punjab Water Act including: • Identification of options to increase water availability, manage groundwater abstraction sustainably, and improve water quality. • Development of strategies to mitigate impacts of floods and drought. • Guidance to improve water governance and financial sustainability. • Review the function, capacity and mandate of the Chief Engineer Flood and Drainage for productive use of rain, flood and drainage water, including groundwater recharge as an option for groundwater management. • Training, capacity building and awareness programs towards effective water resources management within the province.
2	Groundwater Management (GWM)	• Comprehensive assessment of the groundwater resource of Punjab through analysis of historic piezometric data. • Identify and quantify recharge and discharge mechanisms. • Propose options to increase recharge and minimize pumping. • Provide technical expertise in planning and designing, of two pilot MAR groundwater projects. The cost of funding the groundwater projects (capital costs) will be arranged from other sources.
3	Integrated Water Resource management (IWRM)	• Develop an IWRM framework consistent with the Water Act 2019 and propose an institutional structure for implementation of the IWRM framework.
4	River Basin Planning and Management	• Develop comprehensive plans to manage Punjab's rivers and associated link canals considering upstream-downstream uses and users consistent with Punjab's Water Allocation Policies. • Review function, capacity and mandate of Chief Engineer Flood and Drainage for productive use of rain, flood and drainage water including groundwater recharge as an option for groundwater management (para 13 of TOR).
5	Water Vision 2050 and Investment Program	• Prepare Punjab's Water Vision 2050, water use projection for 2050, water balance studies for the current situation and 2050, and identifying gaps and required water resources development. • Support developing proposal of a new project/program or other form of subsequent support to the PID.
6	Design of Water Resource Information System (DWRIS)	• Design a Water Resources Information System consistent with existing databases (WRMIS, RTFMS etc.) that will support the data and information needs of the reformed PID as a Water Resources Agency.
7	Upgrading of Irrigation Research Institute (IRI)	• Provide a plan for capacity building of the IRI to meet the requirements of the Water Resources Department and Water Act 2019.

TASK	ACTIVITY	TASK
8	Capacity Building and Training	• Assess the capacity constraints of existing staff and develop a plan to improve the capacity of PID staff for Integrated Water Resources es management functions.
9	Reporting and Documentation	• Document the main events and prepare and submit reports

The approach and methodology to undertake this CDTA was provided in the Inception Report for each thematic task and also are presented in each thematic deliverable. The thematic reports should be consulted for details including data, analysis and recommendation.

1.4 FINAL REPORT DELIVERABLES

The Final Report deliverables are described in Table 1-2. The thematic studies and analyses for the deliverables listed in Table 1-2 were conducted to ascertain the past and present sectoral situations in the Punjab Province river basins. Consolidated formulations of the challenges and opportunities have also been identified, leading to the recommendation of envisaged solutions as part of integrated development of the basin water resources. Due to COVID19 pandemic affecting several team members the deliverable dates were delayed, as shown in Table 1-2.

Table 1-2: Time Frame for Submission of Deliverables

NO.	DELIVERABLES	SUBMISSION AFTER CONTRACT (MONTHS)	DATE SUBMITTED
1	Inception Report	1	21 Sep 2020
2	Interim Report including 3 & 4	6	26 Mar 2021 4 Jun 2021
3	Action Plan to achieve the objectives of the Punjab Water Policy and Water Act 2019.	6	26 Mar 2021 4 Jun 2024
4	Short/medium term plan for Groundwater management including aquifer recharge options in Punjab – Final Report	6	26 Mar 2021 4 Jun 2021 14 Nov 2021
5	Water budget at basin and sub basin level	10	22 Aug 2021 14 Nov 2021
6	Pilot project designed – Draft Report	13	14 Nov 2021
7	Indus River Basin Management Plan – Draft Report	14	8 Nov 2021
8	Training of at least 10 PID staff in Groundwater Management	12	2 Sep 2021
9	Training of at least 10 PID staff in IWRM	12	17 Nov 2021
10	Training of 10 PID staff in River Basin Management	13	17 Nov 2021
11	IWRM framework, including institutional structure and implementation plan	14	8 Oct 2021
12	Design and implementation of a Water Resources Information System (WRIS)	12	15 Oct 2021
13	Draft Final Report	15	30 Nov 2021
14	Water Vision 2050 and Investment Plan	15	22 Nov 2021

NO.	DELIVERABLES	SUBMISSION AFTER CONTRACT (MONTHS)	DATE SUBMITTED
15	Final Report – This Report	15	24 Dec 2021
16	Plan to restructure IRI to serve as the Research and Capacity Building Unit for the PID on a continuing basis, consistent with the Provincial water policy and Water Act 2019	16	15 Dec 2021
17	IWRM Framework: Governance - Elaboration of the minimal disruption option into optional variants	15	8 Nov 2021
18	Institutional Strengthening: Provide additional guidance on the requirements and design of Centers of Capacity for effective IWRM and DRM	15	22 Nov 2021
19	Holistic Transformation Plan: Preparation of an initial Discussion Paper and plan outline	15	30 Nov 2021

1.5 PURPOSE AND CONTENT OF THE FINAL REPORT

This report is intended to present a synthesis of the information contained in a number of other technical reports required under the TOR that deal with specific themes that were required for effective project implementation. Specifically, a major objective is to make a reasoned assessment of the available water resources of the Punjab Province river basins, at present and projected into the future (2050), and the water demanded by the various uses within the Basin.

This report provides a key source of information for developing the IWRM framework for the Punjab Province river basins. It also provides a review of the current institutional arrangement within the Government of Punjab, including the PID, and proposes a Governance structure which minimizes disruption to PIDs day-to-day functions, while meeting the requirements of the Water Act.

Finally, the report presents a preliminary process flow chart for Achieving the Objectives of the Punjab Water Policy and Water Act 2019. The flow chart and action plan are helpful in generating more insight in what constitutes the major steps in the process. A next and much more detailed version can only be prepared once the PID have identified more clearly the best organizational option for the 'Comprehensive management' of Punjab IWRM and designed the needed capacity centres.

2 WATER VISION 2050 AND INVESTMENT PROGRAM

2.1 GENERAL

This Section provides:

- Punjab's Water Vision 2050;
- An investment program to support the activities required to implement Water Vision 2050.

2.2 VISIONING WORKSHOP

It was originally planned to hold a Visioning Workshop with all relevant stakeholders to help explore, design and agree on solutions to the water resource management problems of the Province which will drive integrated management at all levels to serve the interests of people and the environment effectively, efficiently, and equitably.

The Visioning Workshop was intended to identify the key objectives in managing the Provinces water resources, which would then guide the development of an Action Plan and Investment Program. However, due to COVID 19 it proved difficult to consult and coordinate with the various stakeholders and the workshop did not proceed. In the absence of the Visioning Workshop the key objectives have been identified based on objectives in the Punjab Water Policy, the Pakistan Vision 2025 and the Strategic Directions for ADB Water 2030.

It is intended that the objectives, Action Plan and Investment Program be reviewed by relevant stakeholders (including PID and WASA) and amended/refined as appropriate.

2.3 WATER VISION 2050

Water Vision 2050 establishes what the stakeholders would like to achieve by the year 2050 in terms of managing the water resources of Punjab and provide a roadmap on how the vision can be achieved. It includes:

- A vision statement that summarizes the overall objective;
- A list of goals which if achieved will contribute to achieving the vision;
- Identification of key result areas (KRA's) and strategies which will provide the means to achieve the goals;
- Outline of actions to implement the strategies.

The hierarchical relationship between the vision, goals, KRAs, strategies and actions is shown in Figure 2-1, which will be reflected in the higher level Provincial Plans and budgets and in the business plans of the different departments.

The work plan is organized into strategically related KRA's, where specific actions for implementation are identified. The KRAs are the important issues which need to be addressed urgently in order to achieve the Plan's vision and goals.

Each KRA identifies important strategies and activities for the next 5-10 years and identifies the agency responsible for each strategy and action. The Actions identified in the Plan are included in the 5 yearly and annual work plans of the relevant government agencies. The Provincial Water Resources Department would be the lead agency for coordination and implementation of the Plan, under the auspices of the Provincial Water Resources Council in cooperation with various line agencies.

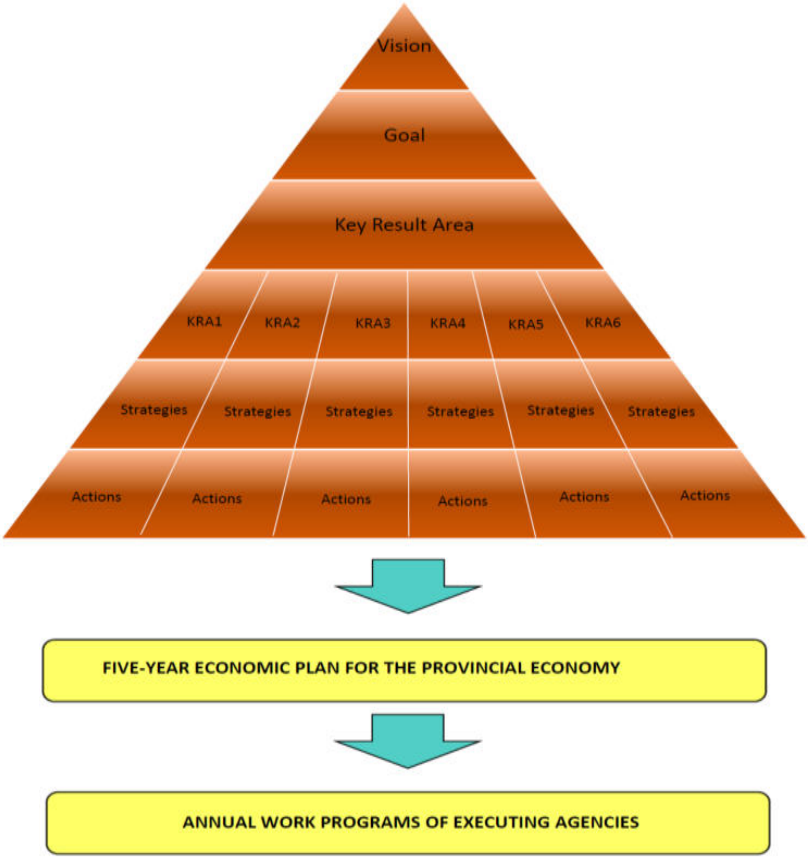


Figure 2-1: Hierarchy of Plan Vision Elements

2.4 CURRENT SITUATION AND CHALLENGERS

2.4.1 CURRENT CONDITIONS AND ISSUES

The current situation is characterized by the following:

- All available water is fully committed, and additional future water requirements will most likely need to be met by demand management, achieving water use efficiencies, reducing losses and investments to harvest flood waters.
- Current groundwater extraction exceeds the rate of recharge and will need to be reduced for long term sustainability.
- Water quality is declining.
- Much of the existing infrastructure is old and poorly maintained, with reducing efficiencies.
- The discharge of sewerage and industrial effluent and disposal of solid wastes to drains and waterways has negatively impacted surface water quality particularly near large urban areas.
- Seepage of contaminate surface water has contaminated groundwater, especially near large urban areas.
- Existing flow and water quality monitoring data collection and management systems are inadequate to allow for efficient operation of the system.
- The population is growing at a rate of 2.4% per year leading to increased urban demand for potable water and increased effluent discharge which threaten water supply security and water quality.
- Migration from rural areas to cities intensifies urban water demand.

- Some of the groundwater being extracted for irrigation has elevated salinity, which impacts the river water quality due to irrigation runoff.
- Farmers at the tails of systems do not have equitable access to water and typically receive 30-40% less water than those at the head of the system.
- Flood risks and flood damages are increasing despite significant investment in flood management, mainly due to uncontrolled development on the floodplains i.e. new development is occurring in flood liable floodplain areas increasing the number of people and property at risk.
- Uncontrolled or poorly planned development on the floodplain also increases flooding risk by impeding flows and removing flood storage.

2.4.2 CHALLENGES

Challenges include:

- Climate change will increase flows over the next 50 years due to glacial retreat, following which flows will decline.
- The growing population will increase the demand for potable water.
- The growing population will put more pressure on water quality, as a result of increased sewerage and industrial effluent production and generation of solid waste.
- There are likely to be no significant new sources of water other than new storages to harvest excess river flows and MAR schemes to harvest flood waters.

2.5 WHAT IS A VISION STATEMENT?

The Vision Statement is intended to describe the ambitions of the government and people of Punjab through improved management of the water resources of the province and represents a shared vision. The Vision Statement should provide inspiration by highlighting a desirable future that everyone would like to achieve. It is important that the people who manage, use or impact the water resources (surface and groundwater) of the Province embrace the Vision Statement as something they would like to achieve. The Vision Statement will guide the development of goals, strategies and actions required to achieve the ultimate objectives.

It is generally recommended that representatives of each stakeholder group be invited to participate in the development of the Vision Statement via one or more workshops.

Typically, a Vision statement for managing water resources attempts to capture the following key objectives, but in the words of the key stakeholders:

- Sustain human and economic development
- Maintain essential functions of our water ecosystems

The purpose of this document is to provide a provisional Vision Statement and to develop a corresponding set of goals, strategies and actions required to achieve the Vision. The Vision Statement, goals, strategies and actions can be subsequently refined in consultation with the stakeholder representatives.

The provisional Vision Statement and goals provided in this document have been developed taking into account the Punjab Water Policy (December 1918), Punjab Water Act (December 2019) and the Pakistan Vision 2025 (2014).

The Punjab water policy identified a requirement for strategy to focus on the need to balance productivity, development and supply against Conservation, environmental health and demand as illustrated in **Figure 2-2.**

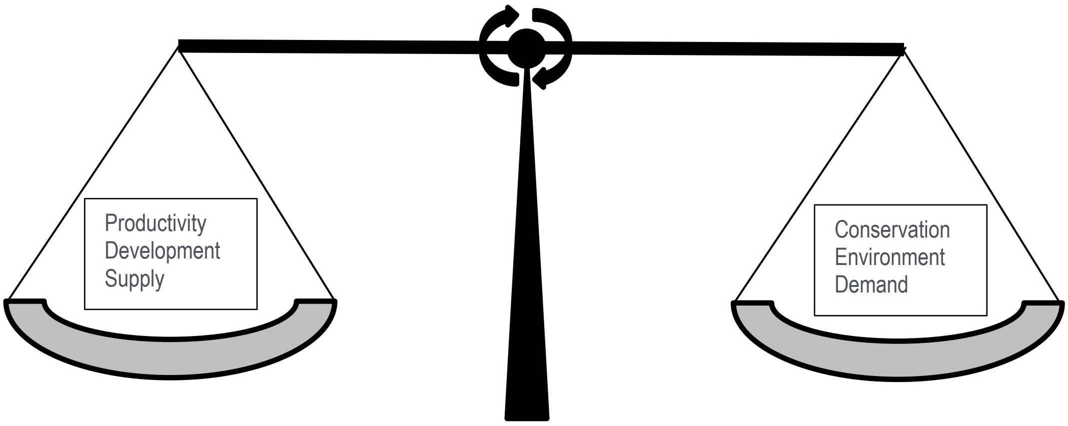


Figure 2-2: Balance Use vs Conservation

2.6 PROVISIONAL VISION STATEMENT

A number of potential or provisional Vision Statements are provided below.

Option 1

"The Vision is to provide adequate quantity and acceptable quality water for all uses and all users for current and future generations; protect riverine, floodplain and groundwater dependent ecosystems; manage water related risks associated with flooding, drought and disease to minimize the impact on welfare and to minimize economic impact."

Option 2

"The Vision is for an economically prosperous, socially developed, and environmentally sustainable Indus River Basin."

Option 3

"The Vision is to achieve sustainable use of water resources for the welfare and benefit of the Indus River Basin's people while protecting and where possible improving the environmental conditions of the basin and downstream communities."

Option 4

"The Vision is to ensure the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water related risks to people, environments and economies."

2.7 PROVISIONAL GOALS

Provisional goals and sub-goals are provided below. The goals are grouped into 5 categories.

1. Adequate Water Supply and Equitable Water Sharing (including resilience to drought and climate change)
   - Provide reliable irrigation supplies.
   - Provide water in an equitable manner (improve supply to tail-end irrigators).
   - Improve irrigation water use efficiency by 20%.
   - Improve Governance of water supply systems and improve trust amongst stakeholders.
   - Pursue opportunities for recycling/reuse of water.
   - Provide safe drinking water to urban communities.
   - Manage groundwater extractions to match recharge.
   - Introduce adaptation measures for agriculture and urban settings to cope with climate change.

- Improve community resilience to climate extremes

2. Sustainable Management of DOAB Irrigation Land and Water Systems
    - Develop and implement integrated land and water management plans for DOABS to use water more efficiently, balance groundwater usage to recharge, reduce export of agro-chemicals and improve agricultural productivity.
3. Improved Water Quality and Environmental Condition
    - Manage discharge of sewerage and industrial effluent and disposal of solid wastes to reduce impacts of water quality of surface and groundwater systems.
    - Establish environmental flow rules to protect riverine and floodplain environments.
    - Set water quality targets for rivers with different standard depending on environmental significance.
4. Improved Flood Risk Management and Drainage
    - Minimize impact of floods reducing risks to human life and reducing flood damages
    - Minimize annual monsoon flooding in urban areas to reduce health risks.
5. Sustainable Management of Water Shed, Hill Torrent and Desert Areas
    - Develop and implement Integrated Watershed Management Plans to better manage runoff and floods, to reduce erosion, and improve water availability.
6. Reduce Risks of Disease
    - Manage discharge of sewerage effluent to reduce risk of water borne disease
    - Provide suitable treatment to ensure safe drinking water
7. Improve Productivity
    - Improve agricultural productivity.
    - Improve infrastructure and operational efficiency.
    - Provide efficient drainage to reduce water logging.
8. Enabling Environment

The likelihood of developing and implementing a successful plan is enhanced by providing a suitable enabling environment which involves 5 key result areas as illustrated in ***Figure 2-3*.**

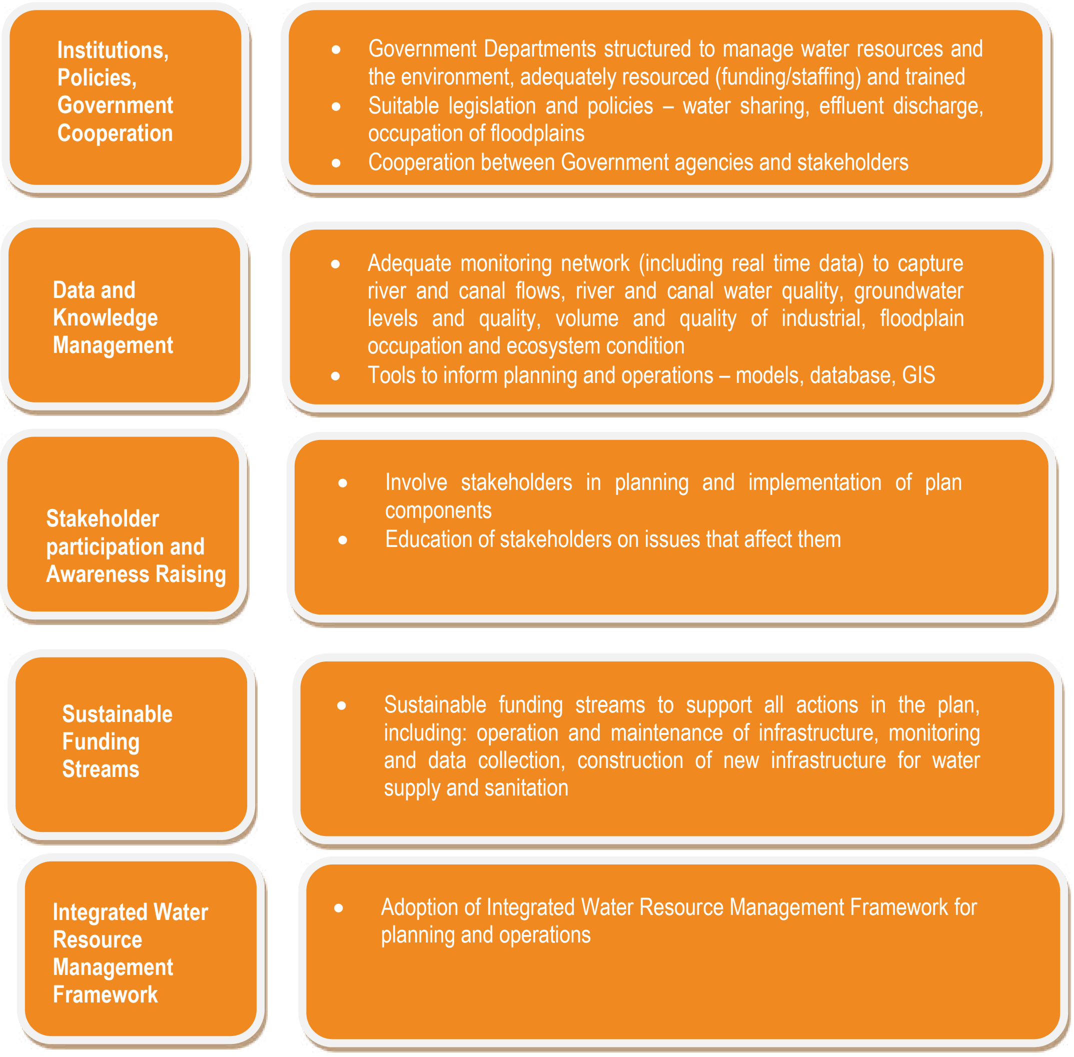


Figure 2-3: Enabling Environment

2.8 KEY RESULT AREAS

The Indus River Basin Plan Draft Report identified five key results areas (KRA) which are listed below, and which will be adopted for the Vision Statement for consistency:

- KRA 1: Equitable Water Sharing and Resilience to Climate Change
- KRA 2: Sustainable Management of Doab Irrigation Land and Water systems
- KRA 3: River and Environmental Health
- KRA 4: Reducing Risks and Impacts from Floods
- KRA 5: Sustainable Management of Watershed, Hill Torrent and Desert Areas

However, the above KRA's fail to address two other key result areas namely reducing the risk of disease and improving productivity. Therefore, two additional KRA's have been added as below:

- KRA 6: Reduce Risk of Water Borne Disease
- KRA 7: Improve Agricultural Productivity

A short comment on each KRA is provided in the following section.

2.9 ACTION PLANS

A series of Action Plans have been developed to address the issues associated with the KRA's. It is not feasible to implement these actions immediately or all at once, as government resources are limited. As a result, a measured approach is required. The actions have been selected based on an initial assessment of needs with some to be implemented immediately whilst others are to be implemented over the long-term.

2.10 INVESTMENT PLAN

2.10.1 GENERAL

This section on financial management is a key cornerstone of the Punjab Basin Action Plan. Having the necessary financial resources in place, together with the necessary systems, structures and processes, will enable the implementation and progress monitoring of the Action Plan. Financial management must thus provide for the financial resource needs identified in the other chapters.

2.10.2 CONTEXT AND CHALLENGES

2.10.2.1 PUNJAB RIVER BASIN WATER INVESTMENT FRAMEWORK

To facilitate effective and timely investment, the Punjab Government shall initiate development of a comprehensive investment framework that will inform budgeting and integrated planning based on a life-cycle approach, which includes planning and construction costs, operation and maintenance, financing costs and the costs of sustainable and integrated water resources management.

2.10.2.2 PRIVATE SECTOR PARTICIPATION

The private sector should be mobilized to finance the economically viable portion of water resource development; that is water supplies to users who can afford to repay loan finance, such as industries, mines and power generation and domestic users receiving high levels of water services. The private sector should be encouraged to contribute towards the social component of infrastructure investment where they use water from the same infrastructure. Irrespective of the funding model adopted, the ownership of major water resource infrastructure should always reside in an organ of State or Federal Government.

2.10.2.3 SUSTAINABLE FINANCIAL MANAGEMENT AND ADMINISTRATION

Ineffective financial management and poor cost recovery has impacted negatively on the financial viability of water infrastructure and water management and water services institutions in Punjab Province. The PID are at present, not recovering all their costs from water users and they are therefore not able to break even.

In order to address the above, the following measures should be undertaken:

i. The Punjab Province Water Resources Department will compile an accurate database of registered and licensed water users and install appropriate water meters for all consumers of supplied water;
ii. The Punjab Province Water Resources Department will correct and update all water billing information (where applicable) and adopt a clear debtor management strategy including enforcement of payment of all outstanding bills;
iii. Undertake a basin wide study on urban water tariff setting & structures and implement recommendations upon agreement with relevant stakeholders;

iv. Undertake a study on Operation & Maintenance (O&M) costs for public funded irrigation schemes and review all irrigation water tariffs to cover at the minimum the full O&M costs;

v. Lobby with Pakistan Central Government to include provisions in the Water Bill that enable financial assistance (in the form of grants, loans or subsidies) to the vulnerable and marginalized groups who may not afford the revised water tariffs; and

vi. Lobby the Pakistan Central Government to fast-track enactment of the new Water Bill.

2.10.3 INVESTMENT REQUIREMENTS

The Punjab Province overall investment plan to implement the Water Vision 2021-2050 are estimated at about US$ 25.44 Billion as shown in the ***Table 2-1***, that is equivalent to about US$ 848 Million of investment per year.

Table 2-1: Punjab Province Overall Investment Plan to Implement Water Vision 2021-2050

TASKS	MAIN COST ITEMS	TENTATIVE COST (US$)
Water availability ($3.0 billion @ $100 million/yr.) *All cost of infrastructure*	• Improve storages, wetlands and regulation • Improve surface water conveyance system and reduce unaccounted flows • Reduce unaccounted flow in WASH • Recharge groundwater and regulate • Reallocate and divert canal water for drinking water use	○ $2.0 billion ($66.0 million a year) ○ Covered under irrigation ○ Covered under WASH. ○ Covered under groundwater ○ $1.0 billion ($33.3 million a year)
Irrigation Water Management ($4.573 billion @ $152.4 million/yr.) *Cost of: Infrastructure = $4.5 billion* *Non-structural = $73 million*	• Improve/modernize irrigation network and reduce inefficiency linking it with water productivity • Expand irrigation when opportunities exist • Policy, institutions and capacity building • Develop Strategic Irrigation System Modernization Plan. • Enhance existing WRMIS including DSS for improved irrigation system operations • Identify and promote Innovativeness and knowledge solutions including rationalizing canal water allowance • Communication, knowledge sharing, advocacy and awareness raising	○ $3.5 billion ($116 million a year) ○ $1.0 billion ($33 million a year) ○ $50.0 million ($1.33 million a year) ○ $3.0 million ○ $10.0 million ○ $5.0 million ○ $5.0 million
Drainage and Protecting Land Degradation including Waterlogging and Salinity ($2.105 billion @ $70.2 million/yr.) *Cost of: Infrastructure = $2.0 billion* *Non-structural = $105 million*	• Develop Punjab's drainage plan • Improve productivity of saline land with communities • Infrastructure network and safe and effective disposal • Storm-water network and disposal • Safe use of marginal quality water/drainable surplus • Introduce communal management of waterlogging and salinity • Improve policy, planning and institution • Capacity building and upgrading of the institutions • Identify and promote Innovativeness and knowledge solutions including rationalizing canal water allowance • Communication, knowledge sharing, advocacy and awareness raising	○ $5.0 million ○ $20.0 million ○ $1.0 billion ○ $1.0 billion ○ $20.0 million ○ $50.0 million ○ $5.0 million ○ $5.0 million ○ $5.0 million ○ $5.0 million
Water Quality Management ($5.106 billion @ $170.2 million/yr.)	• Review, improve and develop water quality standards for all uses and type of waters • Enforce water quality regulations • Develop water quality management plan • Water quality monitoring and data management	○ $5.0 million ○ $10.0 million ○ $5.0 million ○ $10.0 million partly covered under groundwater

TASKS	MAIN COST ITEMS	TENTATIVE COST (US$)
Cost of: *Infrastructure = $5.0 billion* *Non-structural = $106 million*	• Laboratory upgradation • Conduct rivers health survey (ecological and morphological) and assess minimum flow requirement • Wetland development • Policy, institution and capacity building • Assess, aware, search funding source and manage wastewater from all sources and treat for minimum accepted standard before disposal in rivers • Create awareness and educate people on WQ	○ $10 million for EPD (partly covered under WASH & Irrigation/Agriculture ○ $3.0 million ○ $50 million ○ $3.0 million ○ $5.0 billion ($166.67 million a year) ○ $10 million
Hill Torrents, Pothohar and Dryland Management ($1.467 billion @ $48.8 million/yr.) *Cost of:* *Infrastructure = $1.4 billion* *Non-structural = $67 million*	• Communal management of watersheds including rainwater harvesting and livelihood opportunities • Water storage and regulation, if feasible • Improve spate irrigation including farmers support • Improve livelihood and reduce degradation in deserts • Establish Desert Research Centre and build capacity • Capacity building and upgrading the institution • Identify and promote Innovativeness and knowledge solutions • Communication, knowledge sharing, advocacy and awareness raising	○ $100 million ($3.3 million a year) ○ $1.0 billion ($33.3 million a year) ○ $200 million ($6.6 million a year) ○ $100 million ($3.3 million a year) ○ $50 million ○ $5.0 million ○ $5.0 million ○ $5.0 million
Groundwater Management ($239.5 million; @ $8.0 million/yr.) *Cost of:* *Infrastructure = $141.5 million* *Non-structural = $98 million*	• Resource Monitoring and Data Analytics including farmers organizations	○ $31.5 million ($1.05 million a year)
	• Resource Management - Priority canal command areas - Non CCA areas	○ $10.0 million ○ $10.0 million
	• Ecosystem Monitoring and Management - Survey of groundwater pollution - Monitoring bores in trace metals areas - Specialized monitoring and analysis	○ $5.0 million ○ $15.0 million ○ $15.0 million
	• Water Productivity and Conjunctive Management - Improved irrigation application efficiency and reduce unaccounted losses - Improve water productivity	○ Covered under Irrigation/ Agriculture ○ Covered under Irrigation/ Agriculture
	• Groundwater use management under WASH - Reduce unaccounted flow - Efficient operational management of abstraction - Introduce smart metering.	○ Covered under WASH ○ Covered under WASH ○ Covered under WASH
	• Artificial groundwater recharge (MAR) - Rainwater harvesting and recharge - Floodwater harvesting and recharge	○ $20.0 million ($0.65 million/year) ○ $90.0 million ($3.0 million/year)
	• Water quality management (urban) - Water quality monitoring - Laboratory upgradation - - Data management	○ $10 million ○ Covered under WASH, EPD and Irrigation/Agriculture ○ Covered under WASH, EPD and Irrigation/Agriculture
	• Groundwater Allocation, Licensing and Policy - Community engagement to set acceptable allocation limits for stressed groundwater zones - Capacity development in licensing and implementing regulation	$5.0 million $5.0 million

TASKS	MAIN COST ITEMS	TENTATIVE COST (US$)
	• Institution and capacity building - Establish groundwater institution, equipment and training - Establish, equip and train community-based organizations	○ $10.0 million ○ $10.0 million
	• Cross-sectoral coordination - IWRM: coordination with the main stakeholders (departments and agencies) - Dispute resolution - Evaluation, planning and implementation	○ Covered under IWRM ○ $1.0 million ○ $2.0 million
Flood Risk Management ($3.525 billion @ $117.5 million/yr.) *Cost of:* *Infrastructure = $3.5 billion* *Non-structural = $25 million*	• Develop basin-based plans, strategy and guiding principles for reduced flood risks • Improve flood related infrastructure, develop wetlands and clear flood channel ways • Introduce conducive land use planning and improve flood drainage including clear river ways • Improve storm-water management & innovativeness • Improve forecasting and early warning mechanisms • Improve institutions and introduce institutional coordination mechanism for FRM • Develop and manage flood emergency and recovery programs • Identify and promote Innovativeness and knowledge solutions • Communication, knowledge sharing, advocacy and awareness raising	○ $5.0 million ○ $1.5 billion ($50.0 million a year) ○ $1.0 billion ($33.3 million a year) ○ $500 million ($16.67 million a year) ○ $ 5.0 million ○ $ 5.0 million ○ $500 million as contingency plan ○ $ 5.0 million ○ $ 5.0 million
Water Supply, Sanitation and Hygiene ($5.195 billion @ $173.0 million/yr.) *Cost of:* *Infrastructure = $5.115 billion* *Non-structural = $80 million*	• Review and upgrade WASH plan • Enforce water conservation practices to all • Improve infrastructure and reduce water consumption • Manage water supply for all and reduce hazards • Introduce appropriate water pricing including metering • Monitoring, evaluation and coordination • Mainstream and implement the promised SDGs • Capacity building and upgrading three departments • Identify and promote Innovativeness and knowledge solutions • Communication, knowledge sharing, advocacy and awareness raising	○ $5.0 million ○ $10 million ○ $1.0 billion ($33.3 million a year) ○ $4.050 billion ($135.0 million a year) ○ $50.0 million ($1.6 million a year) ○ $10.0 million ○ $10.0 million (the cost of infrastructure already included as above) ○ $50.0 million ($1.67 million a year) ○ $5.0 million ○ $5.0 million
Agriculture Development ($47.1 million @ $1.6 million/yr.) *Cost of:* *Infrastructure = $25 million* *Non-structural = $22.1 million*	• Institutional support for development of high yielding staple food varieties and promoting production of fruits and vegetables, including value addition. • Support for development of technical bulletins, establishment and strengthening of Agricultural Training Centres. • Development of GW management plans for each sub basin. • Design and implement Managed Aquifer Recharge schemes (ponds, wells, abandoned land) • Capacity building and upgrading the institution	○ $5.8 million ○ $0.8 million ○ $0.5 million ○ $25.0 million ○ $5.0 million ○ $5.0 million

TASKS	MAIN COST ITEMS	TENTATIVE COST (US$)
	• Identify and promote Innovativeness and knowledge solutions • Communication, knowledge sharing, advocacy and awareness raising	○ $5.0 million
Implementation of IWRM Framework ($26.5 million @ $0.9 million/yr.) *All non-structural cost*	• Operationalize institutions, policies, and intergovernmental cooperation • Prepare water resource management plans • Introduce data, Information, and Knowledge Management • Involve stakeholders • Introduce Doab and Irrigation Management • Ensure rivers health and environmental protection • Watershed, hill torrent, and desert area management • Integrated flood risk management • Urban WSS and Environment	○ $20.0 million ○ $0.5 million ○ $0.5 million ○ $0.5 million ○ $0.5 million ○ $1.5 million ○ $1.0 million ○ $0.5 million ○ $1.5 million
Institution and Capacity Building ($41.0 million @ $1.4 million/yr.) *All non-structural cost*	• Implement the PID Transformation into WRD • Upgrade IRI to support modernization • Institutional support to EPD for monitoring and enforcing the water quality standards • Institutional development for decision support system: hydrological and meteorological monitoring updates and design. • Institutional Support for implementing Water policy and Water Act at basin and sub-basin levels • Institutional Support for stakeholder consultations, political dialogue and advocacy	○ $10.0 million ○ $15.0 million ○ $5.0 million ○ $10.0 million ○ $0.5 million ○ $0.5 million
Summary	• **Total estimated cost = $25.44 billion** • **Average annual cost = $848 million** • **Cost for infrastructure = $24.68 billion** • **Cost of non-structural measures = $758.5 million**	

3 INTEGRATED WATER RESOURCES MANAGEMENT (IWRM) FRAMEWORK AND IMPLEMENTATION ROAD MAP

3.1 INTRODUCTION

This Section describes the development of an IWRM framework consistent with the Water Act 2019 and the proposed restructuring of the institutional structure at PID for implementation of the Water Act 2019.

Deliverables are:

- An IWRM framework and Roadmap for implementation - The IWRM Framework is to provide direction for PID towards comprehensive management of water resources and to the Government of Punjab for the sustainable, efficient, and sound management of water resources. This was reported in the IWRM Framework and Implementation Roadmap prepared in Nov 2021 and is summarized in this section.
- An institutional structure for PID have been report several separate reports and submitted to ADB in Oct and Nov 2021.
- Training of 10 PID staff in IWRM - held on 17 November 2021.

3.2 OUTPUTS AND FINDINGS

The consultant review of international best practice in relation to IWRM Frameworks and Roadmaps and identified important conditions for implementing IWRM which are given in **Table 3-1**.

3.3 THE IWRM FRAMEWORK

The complete IWRM Framework and Roadmap is given in separate report submitted to ADB on 22nd November 2021. The architecture of the IWRM Framework is shown in Figure 3-1.

The Framework provides objectives tailored to Punjab for each of the IWRM Themes. These are presented as four Functional cross cutting themes and five Sectoral IWRM themes recognizing that each sector should incorporate an IWRM approach into its management.

Functional Themes:

- Institutions, policies, and intergovernmental cooperation
- Water resources planning and management
- Data, Information, and Knowledge Management
- Stakeholder involvement.

Sectoral IWRM Themes

- Doab and Irrigation Management
- Watershed, hill torrent, and desert area management
- River health and environmental protection
- Integrated flood risk management
- Urban WSS and environment.

It should be noted that groundwater management would be a component of each of the Sectorial Themes.

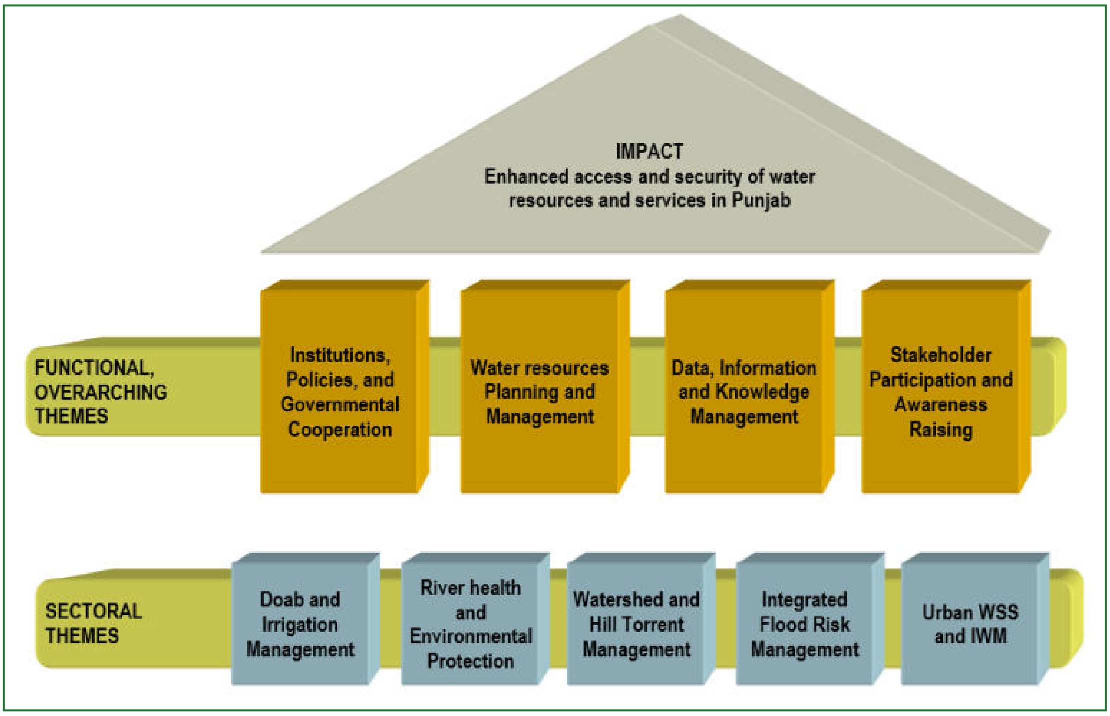


Figure 3-1: Punjab IWRM Framework Architecture

3.4 THE IWRM IMPLEMENTATION ROADMAP

For each of the above themes, the Roadmap provides timebound actions (years 1-2, 3-5, 6-15) for implementing priority activities. Actions identified in the Roadmap are based on studies conducted by the CDTA and the Punjab Indus River Basin Plan. An initial more detailed roadmap was prepared however this was deemed to be too complex and ambitious for GoP Departments at this stage and a more appropriate Roadmap developed.

The IWRM Roadmap which is provided in Table 3-1 presents a step wise progression of actions for implementing the Framework. The actions are broadly scheduled into initial (1-2 years), intermediate (3-5 years) and long term (6-15 years) actions.

3.4.1 IMPLEMENTATION

Due to the Covid 19 pandemic, it has been difficult to undertake consultations with the PID and other Departments to assess current work approaches, progress with the implementation of the Water Policy and Act their implementation, and the proposed roadmap.

The Roadmap should be reviewed in detail once the new WRD is established, in consultation with the PWRC. Once finalized, resource needs and budgets should be developed and finalized. This will be an important foundation for a conversation with the Government of Pakistan and with Development Partners.

The WRD should be responsible for implementing the Roadmap and this would be monitored by the PWRC There are two areas in the Roadmap that need to be addressed most urgently:

(i) Reliable data and contemporary computer modelling tools are essential for policy development, planning and management, and most critically reviewing surface and groundwater water entitlements and allocations. Lack of these tools is currently a significant hurdle for IWRM and planning at all levels in Punjab.

(ii) River health and its management are currently overlooked, which is a significant weakness when compared with approaches elsewhere particularly in developing countries. Rivers have many important and economically significant uses; not just environmental.

Table 3-1: Conditions for IWRM and Comment of the current situation in Punjab Province

IMPORTANT CONDITIONS	CONTENT	COMMENT ON SITUATION IN PUNJAB
Political will	Political will at all levels can enable and help unite stakeholders and move the process forward. It is especially needed if the resulting plan or arrangement would create or require changes in legal and institutional structures, or if controversies and conflicts among stakeholders exist. Involvement of actors outside the water sector is essential to move political will, gain sectoral support, and ease public pressure for IWRM.	This is unclear at the moment. The establishment of the WRC and WSRA is a signal of some interest however progress in implementing this is negligible it seems. There is interest in parts of PID about understanding what IWRM Is and how it might be.
Clearly designated institutional arrangements	Implementation of IWRM is only possible if there is a mandated and empowered water resources management department to provide the policy, planning and regulation functions for water resources management. Consideration should be given to the necessity for an interdepartmental Council and RBOs and lower-level sectoral planning and coordinating bodies. The transactional costs of coordination should also be considered. Further institutional refinements such as separation of policy and regulation from water resources managers (service providers) could be considered once basic water resources management has been successfully implemented.	Institutional arrangements are fragmented from an IWRM perspective. A major adjustment of institutional arrangements is required, and this is addressed in the accompanying TA reports.
A clear vision to guide development of a Basin water management plan	The various stakeholder needs to develop a clear shared vision for water resources management i.e. where society wants the water resource and its uses to be at some point in future. This is followed by an overarching jurisdictional water plan and then basin plans in priority basins that reflect individual sectoral plans for effective and efficient utilization of the resource.	The TA contributes to setting a clear vision however project constraints means that further stakeholder discussions are needed. The TA takes the first steps towards a jurisdictional 'river basin' plan
Recognition of all water resources management dimensions	Effective IWRM requires that all dimensions of water resources management are considered. This includes surface and groundwater; quantity, quality, and sustainability; the aquatic environment (rivers, wetlands, riverine vegetation, water dependent biota and environmental flows); the various water resource managers and their roles such as for policy, planning, management, infrastructure operation and maintenance; operation and maintenance of rivers (e.g. improving river health, control of riverbank erosion including gravel mining); flood management	The Punjab WR Policy recognizes most dimension of water management and is generally a good foundation for improving approaches. There are weaknesses, mostly recognized by the Policy, regarding groundwater management (refer to the accompanying reports), river health and river uses, water quality, climate change implications and adaptation.
Participation, coordination, and information-sharing	IWRM is enabled through the involvement of key stakeholders at the different levels of water management. This is facilitated by stakeholder analysis so that participation can be defined appropriately for the different levels and improved gradually. Initial sharing of general basin-wide data and information, and further sharing of more specific information, will assist facilitation.	The establishment of the WRC and WSRA is a step in the right direction here. However, this is yet to be implemented and there was not much evidence of interchange and information sharing between departments during the TA. Participation is not a feature of WRM in Punjab and mention was made that culturally this is difficult.

IMPORTANT CONDITIONS	CONTENT	COMMENT ON SITUATION IN PUNJAB
Capacity development	Capacity development should be based on capacity and knowledge needs and expressed at all levels, including that of decentralized local government as well as those of civil society and affected communities. Participation of those who may be adversely impacted and/or who are socially marginalized can be encouraged through information sharing, awareness raising and engagement.	A well-defined legal framework is absent with regulations and arrangements spread across many separate documents. These are also often more historic than contemporary. A comprehensive and modern, IWRM based, water law is needed.
Well-defined and enforceable legal frameworks and regulation	It is necessary to assemble and consider the full range of existing laws and regulations that apply to water-related activities and determine how existing legislation adapts or can be improved to accommodate sustainability, including the impacts of climate change, and integration for sound water resources management.	Water allocation plans for surface water are present under the WAA. Climate change, urban water supply deficits, increasing urban populations and increasing industrialization are all resulting in increased water insecurity and a worsening situation. Reviewing surface water and groundwater availability, (integrated) allocation plans and opportunities to manage these is needed.
Water sharing plans	As water is a shared resource, water rights should be flexible in terms of allocation in order to accommodate climate variability and change, as well as changing social and economic development. Surface and groundwater allocation plans should regulate the volume of water taken by different water users, provide for the needs of the environment and allow for the most beneficial uses of the basin's water resources.	There are difficulties with asset management and its financing although this was not a topic addressed in depth by the project.
Adequate investment, financial stability, O&M, and cost recovery	Coordination for IWRM implementation needs financial sustainability – such as the promotion of cost recovery and must consider long-term asset management, operation, and maintenance. Various funding options can be considered such as government grants and loans, public resources, user charges and taxes, donor funds, basin environmental trust funds.	The project contributed to improving the State WRIS. There are difficulties in sharing data between departments and with the availability of data such as for groundwater, water quality and river condition.
Good knowledge of the natural resources	Adequate knowledge of the inventory of water resources is required including availability, demands, potential development and climate change impacts. Involving scientists with management as well as in research capacities, can help maintain and accrue knowledge of the natural resources as well as build human resources for the future. Water information should be available to water users for planning their investments and management.	WRM monitoring needs strengthening. There are limited tools for analysis and evaluation conducted
Comprehensive monitoring and evaluation	Monitoring and evaluation are essential for ensuring that the current management of water resources is properly implemented, and to identify the needs for adjusting management strategies and plans. Upgrading new technologies is vital for effective performance both of local and central water management.	This is unclear at the moment. The establishment of the WRC and WSRA is a signal of some interest however progress in implementing this is negligible it seems. There is interest in parts of PID about understanding what IWRM Is and how it might be.

Table 3-2: IWRM Implementation Roadmap

KEY IWRM THEME	INITIAL (YEARS 0-2)	INTERMEDIATE (YEARS 3-5)	LONG TERM (YEARS 6-15)	RESPONSIBILITY
1. Institutions, policies, and intergovernmental cooperation	(i) Review WRD's capacity for policy development, provincial and intergovernmental engagement, support of WRC and establish its core mandate. (ii) Facilitate intergovernmental engagement and coordination and with evidence-based negotiations on matters affecting Punjab (iii) Support and coordination with of WRC, WSRA, the provincial agencies and promote IWRM (iv) Develop a comprehensive water law with a strong IWRM foundation, institutional and regulatory approach (v) Capacity building plan in IWRM and technical skills for WRD staff	(i) Continue core mandate (ii) Finalize the IWRM based law and implementation plan and arrange for enactment (iii) Develop and implement policies, regulations, decrees, guidance etc. for IWRM to implement the law (iv) Negotiate with other levels of government on matters such as revision of WAA and new water storages using results of studies (v) Implement capacity building plan for WRD staff	(i) Continue core mandate (ii) Implementation of the water law once enacted (iii) Continue providing direction and support for the WRC and WSRA (iv) Continue strengthening of WRD	(i) WRD works closely with WRC (ii) WRD leads and involves and coordinates with other agencies as relevant
2. Water resources planning and management	(i) Establish/strengthen a strong integrated water planning and management unit within WRD with required expertise for IWRM. (ii) Manage the annual water allocation process and commence review of the re-assignment of water entitlements and allocations between water users. Assess scope to move from Warabandi to water on demand system (iii) Build capacity and prepare guidelines for integrated planning at different scales (e.g. Provincial, Doab, watershed) with relevant sector	(i) Continue mandate for planning at different levels, management and regulation of provincial water entitlements and water allocations (ii) Prepare a rolling 5-year Provincial Water Plan in consultation with stakeholders (iii) Review WAA including arrangements if South Punjab becomes a party to the WAA. (iv) Build and implement a water accounting and reporting system (v) Arrange research to address important WRM needs	(i) Continue mandate for planning at different levels, management and regulation of provincial water entitlements and water allocations, and implementation of 5-year Provincial water plan (ii) Review and revise Provincial Water Plan on a 5-yearly cycle (iii) Monitor and assist the preparation of other integrated water resource management plans (e.g. Doabs, rivers, watersheds, etc.) by units within WRD	(i) WRD to support WRC (ii) WRD to establish/ strengthen unit and involve other sectors and agencies in preparing plans and management arrangements

KEY IWRM THEME	INITIAL (YEARS 0-2)	INTERMEDIATE (YEARS 3-5)	LONG TERM (YEARS 6-15)	RESPONSIBILITY
3. Data, Information, and Knowledge Management	(i) Ensure that there is a strong information and knowledge management capacity within WRD to support policy planning and management initiatives with capacity for: GIS, remote sensing, surface water and groundwater modelling, (ii) Continue to upgrade, maintain and use the Punjab WRIS, data and monitoring systems and remote sensing capacity particularly of land use, crop water consumption and productivity (iii) Adapt, downscale and build capacity to apply the Indus River System Model IRSM to beyond the canal command level for within provincial WR assessments, planning, and management. (iv) Adapt and downscale Indus Basin Irrigation System GW Modflow model for Punjab Doab resource assessments, planning, allocation, option study and management decisions. (v) Adopt and apply models (e.g. HEC-RAS) to flood planning, forecasting and management	(i) Continue mandate for IWRM data and information to support planning, policy and management (ii) Review and upgrade water discharge, quality and river health monitoring networks and data management systems (iii) Downscale climate change models for Punjab for inclusion in water resources planning and management. (iv) Couple the surface water and groundwater modelling for application to water resource assessment, water allocation, river and Doab level planning and management	(i) Continue mandate for IWRM data and information (ii) Continue capacity building and technical strengthening (iii) Continue to apply resources to priority projects (iv) Continue to strengthen monitoring networks and data management procedures (v) Encourage and facilitate research into water resources data, information and knowledge management	(i) WRD to support WRC (ii) WRD to establish strong units to undertake technical studies (iii) WRD to facilitate capacity of universities, institutes and consultants to undertake technical studies (iv) WRD to seek support from develop partners to build capacity
4. Stakeholder involvement	(i) Establish capacity within WRD to assist with community participation, awareness raising and schools' education programs (ii) Identify important issues that are to be addressed by awareness raising command participation, prepare plan and commence implementation	(i) Continue mandate for participation and awareness raising programs, to support priority government activities and to encourage participation. (ii) Plan and commence implementation of schools' education program (iii) Implement agreed water user participation	(i) Continue implementation (ii) Review progress and adapt approach at years 6 and 11.	(i) WRD with WRC

KEY IWRM THEME	INITIAL (YEARS 0-2)	INTERMEDIATE (YEARS 3-5)	LONG TERM (YEARS 6-15)	RESPONSIBILITY
		programs, such as Land care, watertable watch, river watch.		
5. Doab and Irrigation Management	(i) Establish arrangements in WRD to lead sustainable management of Doabs and irrigation systems (ii) Develop pilot participatory, Land and Water Management Plan (LWMP) for Bari Doab with integrated and sustainable management of surface and groundwater, and water productivity (iii) Assess priority for comprehensive modernization of command area based on needs, costs and benefits (iv) Develop and introduce a trial plan for the successful operation of Khal Panchayat	(i) Prepare participative and integrated Bari Doab LWMP (ii) Plan and commence the comprehensive modernization of priority command areas (iii) Strengthen MOM to asset management and level of water supply service (iv) Monitor water use and water productivity (v) Monitor and strengthen Khal Panchayats	(i) Continue mandate for Doab and command area management (ii) Commence implementation of Bari LWMP and commence the planning and implementation of other Doab LWMPs (iii) Continue the modernization of priority command areas (iv) Introduce volumetric water service fees O&M recovery	(i) WRD zones facilitated and supported by technical and planning units (ii) PAD involved regarding on-farm practices and improving on-farm water management and productivity
6. River health and environmental protection	(i) Review in detail and strengthen current river management capacity in PID/WRD so that it includes capacity for river health and environmental protection (ii) Undertake training and review of international approaches to river health and environmental protection and design approach suitable to Punjab (iii) Review river water quality monitoring network, including that of other agencies, and data management system and prepare implementation plan including data sharing between agencies (iv) Continue established riverbank protection activities	(i) Establish river water quality monitoring network and commence monitoring and planning (ii) Undertake study of river health and environmental flow requirements in Punjab rivers and establish river health monitoring system (iii) Prepare Punjab river health strategy and work plan, identifying critical river stretches, and commence implementation (iv) Commence triennial reporting of Punjab river health (v) Implement priority projects	(i) Review progress, strengthen and continue water quality monitoring (ii) Monitor river health and continue triennial reporting (iii) Review and report on implementation of river health strategy (year 10) (iv) Implement priority projects	(i) The WRD River Health Unit will implement this theme with WRD/PID zone units and involve other agencies that undertake related activity, such as: (ii) WRD/PID zone units (iii) Forest, Wildlife and Fisheries Department (iv) Environment Protection Department, (v) IRSA (vi) WWF-Pakistan

KEY IWRM THEME	INITIAL (YEARS 0-2)	INTERMEDIATE (YEARS 3-5)	LONG TERM (YEARS 6-15)	RESPONSIBILITY
7. Watershed, hill torrent, and desert area management.	(i) Strengthen WRD capacity and establish coordination and working arrangements with relevant agencies in the 3 separate areas. (ii) Establish cooperative arrangements with specialist national and international agencies. (iii) Prepare approach for participatory integrated management plans including guidelines for the plans and priority locations. (iv) Undertake emergency, no -regrets, repair and rehabilitation of infrastructure	i) Prepare plans involving farmers and other natural resource managers. ii) Provide training and capacity building for WRD staff in watershed and Hill torrent areas iii) Identify research needs and initiate a cooperative research program with relevant institutes iv) Undertake asset condition inventory of relevant infrastructure.	(i) Commence implementation of plans for prioritized areas with farmer-based committees and prepare plans for remaining prioritized areas (ii) Continue capacity building	(i) Responsibilities for leading the effort in the 3 areas differ. (ii) Hill torrent area, Project Circle D.G. Khan; Pothohar plateau, the Barani Area Development Authority of the PDD; Cholistan desert, the Cholistan Development Authority at Bahawalpur (iii) Other agencies such as PAD, EPA, Local Govts
8. Integrated flood risk management	(i) Work with Punjab Disaster Management Authority and other agencies to strengthen capacity and identify priority needs. (ii) Undertake training in international approaches to IFRM and review FRAU and Zone staffing and resourcing needs (iii) In collaboration with relevant WRD units update discharge monitoring network, data management, and flood modelling and planning (iv) Prepare annual flood management reports based on the international best practice (e.g. EU)	(i) Provincial flood management plan is prepared that incorporates IFRM. Implementation of Plan commences (ii) Rural and urban drainage plans prepared and implemented with local government and communities for priority floodplains which will include land use zoning plans and building regulations to ensure appropriate development on floodplains. (iii) Flood preparedness, forecasting and warning systems are upgraded	(i) Continue mandate for flood management with other agencies, local government, and communities (ii) Damaged infrastructure repaired/rehabilitated after events (iii) Annual flood reporting and flood event reporting commenced following updated approach	(i) WRD and FRAU will work with the Punjab Disaster Risk Management Authority and other responsible agencies
9. Urban WSS and Integrated Water Management	(i) Department of Public Health Engineering (PPHED) establishes interdepartmental working group and role of WRD reviewed	(i) Implement pilot project and review its performance. (ii) Select another 3-5 priority projects for	(i) Continue mandate	(i) Responsibilities to be determined: e.g. PPHED lead, with other

KEY IWRM THEME	INITIAL (YEARS 0-2)	INTERMEDIATE (YEARS 3-5)	LONG TERM (YEARS 6-15)	RESPONSIBILITY
	and agreed (ii) Capacity building on urban IWM using international best practice with practical guidelines (iii) prioritize city for pilot project and prepare project	implementation (iii) Develop guidelines to improve water supply, wastewater disposal, and environmental conditions for small habitations		departments and WSAs. (ii) WRD water allocation and supply for rivers and link canals, groundwater, and non-conventional sources.

4 SUPPORT IMPLEMENTATION OF PUNJAB WATER POLICY (PWP) AND PUNJAB WATER ACT 2019 (PWA)

4.1 GENERAL

The Punjab Water Policy (December 2018) responds to an important challenge, namely the threat of insufficiency in availability of water for to meet demand for consumption, such as by irrigated agriculture, drinking water and sanitation, and mines and industry. The policy calls for adoption of IWRM and River Basin Management. The Province has started the process of designing and establishing its IWRM Governance Structure. The Province passed in December 2019 the Punjab Water Act which requires establishment of a Punjab Water Resources Commission (PWRC) and a Punjab Water Services Regulatory Authority (PWSRA), and introduces a licensing system for regulating the abstraction of water, the supply of (drinking) water, and the disposal of sewage (At the time of writing this report, November 2021, the establishment processes have not yet been completed.). The Legal-Institutional Sub-Team was charged with preparing these deliverables.

IWRM has to be a joint effort involving all water-related agencies, businesses, and citizens. The Provincial Government will establish and implement its IWRM through its agencies. This will require an understanding of how the various IWRM-themes need to be managed, followed by allocation of responsibilities (mandates) to provincial agencies and development of agency capacity.

The PWP 2018 calls for the Punjab Irrigation Department (PID) to transform into a Water Resources Department (WRD). The CDTA assists PID to enhance its capacity for this transformation and provides recommendations for the Provincial IWRM Governance Structure.

The core of the CDTA work allocated to the Consultant's Legal/Institutional Sub-team was/is the preparation of the recommendations for the Provincial IWRM Governance Structure. The sub-team completed these recommendations and presented them in the following reports:

1) Deliverable 3: 'Action Plan to achieve the objectives of the Punjab Water Policy and Water Act'
2) The report titled 'River Basin Plans and IWRM Framework: Governance considerations and Institutional Structure, being the Legal/Institutional Sub-team's contribution to two deliverables:
    a) Deliverable 7: 'River Basin Management Plan'
    b) Deliverable 13: IWRM framework, including institutional structure and implementation plan
3) Three additional deliverables as per the revised ToR (August 2021):
    a) 17: Governance - Elaboration of the minimal disruption option into optional variants
    b) 18: Institutional Strengthening: Provide additional guidance on the requirements and design of Centres of Capacity for effective IWRM and DRM
    c) 19: Holistic Transformation Plan: Preparation of an initial Discussion Paper and plan outline

The principal recommendations are summarized in the sub-sections below.

4.2 ACTION PLAN TO ACHIEVE THE OBJECTIVES OF THE PUNJAB WATER POLICY AND WATER ACT

The Action Plan serves to operationalize the Punjab's Water Policy and Water Act and focuses on the establishment of the legal, institutional, and organizational elements that are needed to make implementation of the policy possible, while meeting the requirements of the Water Act. The Action Plan starts with a review of the relevant national and provincial institutional framework, as a basis for developing the recommendations. The most important framework elements are the following:

- Federal and Provincial Powers in respect to Water and Water Resources Legislation
- The National Water Policy (2018)
- Punjab Province Government's Organizational Set-up
- The Punjab Water Policy (2018)
- The Punjab Water Act (2019)

4.2.1 FEDERAL AND PROVINCIAL POWERS IN RESPECT TO WATER AND WATER RESOURCES LEGISLATION

The State of Pakistan was created under the Indian Independence Act of the Parliament of the United Kingdom, which received Royal Assent on 18th July 1947. The Act made provision for the setting up in India of two independent new Dominions, India and Pakistan (which at the time had a West and an East region). The establishment day of the dominions is 15th of August 1947. The Act converted the existing 'Constituent Assemblies' into the Dominion Legislatures. Initially, the territories of former British India were to be governed in accordance with the Government of India Act, 1935, and the Assemblies were to exercise all the powers which were formerly exercised by the Central Legislature. They were expected to subsequently establish their own constitutions.

From 1947 to 1973, Pakistan adopted and abolished a number of constitutions. The current constitution is the Constitution of the Islamic Republic of Pakistan 1973, promulgated on 14th August 1973. The Constitution defines Pakistan as a 'constitutional federal parliamentary republic' with a bicameral national parliament, constituted by a National Assembly and a Senate (the 'Upper House'). It defines the division of power between the local and national governments. The federal-level powers are divided between the President, the Prime Minister, the Legislature, and the Courts. The executive authority of the state vests with the Prime Minister. The Prime Minister is elected by the National Assembly, appoints the cabinet, oversees the execution of the laws and ensures a smooth functioning of the State.

The President, according to the Constitution, is at the apex, representing the unity of the Republic. Originally, the President appointed ministers, provincial governors, and the chiefs of the army, and could veto legislature (but can be overridden by a Parliamentary majority). The 18th Amendment (2010) has reduced the powers of the President.

The Cabinet is appointed by the President and the Prime Minister and makes recommendations to the executives. The Legislature has a Senate with members elected by Provincial assemblies and introduces and passes legislation, with the exception of finance bills. The National Assembly is formed by direct elections and passes legislation.

The Judiciary comprises a Supreme Court with a Chief Justice appointed by the President and Justices appointed by the President at recommendation by the Chief Justice.

There are four provincial governments in Pakistan, namely respectively the governments of Punjab, Sindh, of Khyber Pakhtunkhwa, and Baluchistan. The provincial government operates under local law. Each is headed by a non-executive governor appointed by the President and has a directly elected unicameral legislature with members elected for five-year terms. Each province has a High Court, which forms a part of the higher judiciary.

The division of powers between Federal and Provincial level governments is defined in the 'Legislative Lists', contained as Schedule 4 in the Constitution. Originally, the schedule contained two lists, the first being the 'Federal Legislative List', and the second being the 'Concurrent Legislative List'. Regarding the subjects in the 'Concurrent Legislative List', the Federal and Provincial Government both have powers to legislate. The Provincial Legislative List is not explicit, but implicit: residuary powers, thus all subjects not included in the 'Federal Legislative List', are subject to Provincial Legislation, with the understanding that there is a possibility for a Provincial Assembly to pass a resolution requesting National Parliament to make a law on a provincial subject.

The 'Federal Legislative List' does not contain any direct references to water and water resources management. There are a number of entrees in the 'Federal Legislative List', though, that in a less direct manner relate to water and water resources management, and these are:

- Part I/Entry 37: Works, lands and buildings vested in, or in the possession of Government for the purposes of the Federation (not being military, naval or air force works), but, as regards property situate in a Province, subject always to Provincial Legislation, save in so far as Federal law otherwise provides.
- Part II/Entry 3. Development of industries, where development under Federal control is declared by Federal law to be expedient in the public interest; institutions, establishments, bodies and corporations administered or managed by the Federal Government immediately before the commencing day, including the [Pakistan Water and Power Development Authority and the Pakistan Industrial Development Corporation]; all undertakings, projects and schemes of such institutions, establishments, bodies and corporations, industries, projects and undertakings owned wholly or partially by the Federation or by a corporation set up by the Federation.
- Part II/Entry 6. All regulatory authorities established under a Federal law.

Amendment 18 (19th April 2010) to the Constitution introduced a substantial shift in powers. It strengthened the power of the Prime Minister relative to the President and of the Provincial Governments relative to the Federal Government. Among others, it required the Concurrent Legislative List (subjects for which the responsibility/powers are shared by the Federal and the Provincial level) to be omitted and the related powers to be (mostly) devolved to the Provinces within a year.

There has always been Federal management of water resources, first through a Ministry of Water and Power, and subsequently through the Ministry of Water Resources (MoWR). The MoWR was created on 4 August 2017 out of the Ministry of Water and Power, by depreciating the power division from the ministry, which was merged into the Ministry of Petroleum and Natural Resources and converted into the Ministry of Energy. The ministry is headed by the Pakistan Secretary of Water Resources.

The Ministry has been tasked with the mission of developing the country's water resources to meet future challenges of water shortage, providing visionary leadership in National Water Policy formulation & implementation, taking all stakeholders on board, by consistently embracing creativity, initiative, innovation and technology.

The Federal Rules of Business 1973 (as amended up to 19th August 2019) divide the Government business into 'divisions', with each Government Ministry given charge over one or more of these, lists in Schedule I, 'List of Ministries and Divisions' (with Ministries in alphabetical sequence), at No. 34. the Ministry of Water Resources in charge of the 'Water Resources Division'. This division includes the following (see Section 40. 1):

1) Matters relating to development of water resources of the country.
2) Indus Waters Treaty, 1960, and Indus Basin Works.
3) Water and Power Development Authority.
4) Liaison with international engineering organizations in water sector, such as International Commission on Large Dams, International Commission on Irrigation and Drainage and International Commission on Large Power Systems (CIGRE).
5) Federal agencies and institutions for promotion of special studies in water sector.
6) Institute of Engineers, Pakistan.
7) Administrative control of Tube-well Construction Company.
8) Indus River System Authority (IRSA).
9) Pakistan Trans-border Water Organization.

The following departments and authorities function under the Ministry as defined under the Schedule-iii of the Rules of Business 1973:

1) Federal Flood Commission
2) Indus River System Authority
3) Office of Pakistan Commissioner for Indus Waters
4) Water and Power Development Authority (WAPDA)

The National Water Policy of 2018 (discussed below), further clarifies the Federal level view on where the responsibility is placed, where it states on page 2 the following:

> "The water resource is a national responsibility but irrigation and agriculture, as well as rural and urban water supply, environment and other water related sub-sectors are provincial subjects."

Apparently, this division between Federal and Provincial Government is not yet fully clear and/or satisfactory. Perhaps because of this, the National Policy also states (page 4, point xi) that the mandate and roles of the federal and provincial water related agencies need to be reviewed in view of the 18th Amendment to the Constitution.

In practice, the Federal involvement focuses on water and water resources management aspects that transcend/exceed the provincial capacity, such as the implementation and monitoring of the Indus Waters Treaty (IWT) signed on 19 September 1960 between Pakistan and India; the inter-provincial sharing arrangement of available water; the hydro-power generation for national benefit; the construction and management of large water infrastructure works.

The regulatory and legal aspects of pollution control are being implemented by the EPAs. Environment institutions have been established within most of the organizations besides the federal and provincial Environmental Protection Agencies (EPAs) to address issues related to field level activities.

As was mentioned above, it is important to distinguish between 'irrigation and drainage' and 'water resources management'. Irrigation and drainage is basically a local agricultural service and has always been and still is handled fully by the provincial government. The Provincial Irrigation Departments (PIDs) have the responsibility for and authority in this area. A number of water resources management aspects relate to/impact on irrigation and drainage, mainly being the following:

- The principal water sharing arrangements: i) with neighboring countries; ii) between provinces; and iii) between water use sectors within the province;
- The major water resource exploitation works and their management; and
- The protection of the water resources.

Not all agree with the Federal Government's involvement in Water Resources, arguing that the Constitution's Federal Legislative List (FLL) does not include 'water', and, hence, Provincial Governments are the ones responsible for the water resources within their territory. Accordingly, the National Water Policy 2018 is viewed by some as an overreach. The Constitutional position is that neither the Federation nor the Province can "force" the other's hand. (See also: Ahmad Rafay Alam (2019) 'A Constitutional History of Water in Pakistan' in Jinnah Institute 'Policy Brief' of 7 Jan 2019'.)

4.2.2 THE INDUS WATERS TREATY (IWT) OF 1960 BETWEEN PAKISTAN AND INDIA AND THE INTER-PROVINCIAL WATER APPORTIONMENT ACCORD (WAA) OF 1990

Pakistan's water resources management is governed by (i) the Indus Waters Treaty (IWT) of 1960 between Pakistan and India and (ii) the Water Apportionment Accord (WAA) of 1990. The IWT rules that India can make full use of the flows through the Eastern Rivers, being the Ravi, Beas and Sutlej. Hence, the flows in these rivers are more or less depleted (by the uses in upstream India) where they cross the border into Pakistan. Pakistan thus depends for its water on the Western rivers, such as the Indus, Kabul, Jehlum, and Chenab. The Permanent Indus Commission (PIC) monitors and supports the implementation of the IWT 1960.

The WWA sets volumetric water rights for each province. The water available to Pakistan is distributed among the provinces in compliance with the WWA, as per schedule periodically set by the Indus River System Authority (IRSA). IRSA serves as a forum for inter-provincial co-operative decision-making between the four provinces on water distribution. Each province has freedom to decide on the further distribution of the water it receives as per IRSA-allocation.

4.2.3 THE IMPORTANT ROLE OF WAPDA

Within the Indus River Basin, Punjab Province occupies the Indus River section where the large tributaries meet up. The land area of Punjab Province is composed of downstream parts of the 'Five major Punjab Rivers' basins: no complete river basin can be found in the province. The various downstream parts are, with respect to bulk water distribution, managed 'as one integrated unit', by operating barrages and interconnecting link canals. The Water and Power Development Authority (WAPDA) operates the two large reservoirs (Tarbela and Mangla), Chasma Barrage, and one strategic link canal (Chashma-Jhelum), through which Punjab Province receives most of its water. The Punjab Irrigation Department operates the other barrages and link canals, as well as the irrigation infrastructure within the Irrigation Canal Command Areas. It is also responsible for the flood management infrastructure. The Punjab Irrigation Department is a very large bureaucracy with a very long history. Such organizations often have great difficulty to adapt to different work processes and to transform. However, their strong point is their great stability, long experience, and strong organizational capacity for doing what they have always done.

4.2.4 PUNJAB PROVINCE'S LOCATION AND SCOPE FOR RIVER BASIN MANAGEMENT

Punjab Province's territory is fully situated within the Indus River Basin and does not coincide with a natural sub-basin. Rather, it covers an area 'carved out of the larger Indus basin' by (national and provincial) administrative boundaries and comprising downstream 'pieces' of a number of major Indus-tributary basins. Across the province, large link canals inter-connect the various tributary river basin 'pieces' and transport water from the western rivers (Indus, Jhelum, and Chenab) to the Eastern rivers (Ravi and Sutlej). This configuration warrants the question whether it would make any sense to divide Punjab Province's Indus River Basin area into river basins. After having considered various options, a useful division appears to be into the seven 'Irrigation Sub-basins' (the five doabs + 2 non-doab areas), which then would need to be expanded to include also any provincial area that is outside but drains into it. This subdivision might be helpful, particularly for some management of some the IWRM themes, such as groundwater, water logging, and salinity management. It is not meaningful for bulk water allocation and distribution management, because it must regard the whole Province as one-integrated water management area.

Applying this subdivision does not necessarily imply that the envisaged Provincial Water Resources Department should have its own organizational sub-units in each of these Irrigation Sub-basins. PID and other water-services related agencies or environmental management-related agencies have their own monitoring systems already in place, and WRD will receive the data through a sharing arrangement.

Stakeholder participation and consultation should be adequate. WRD will be required to organize periodical stakeholder meetings, probably best via local government administrations. Each service provider should be required to have its own customer relations arrangement. For PID, the Punjab Khal Panchayat would perhaps offer a good mechanism for stakeholder participation.

4.2.5 PUNJAB PROVINCE ORGANIZATIONAL SET-UP

The organizational arrangements of the government respond to the various Acts pertaining to water which make an administrative distinction between 'types of water', with each regulated/managed by a different entity, as regulated in the Punjab Rules of Business 2011 (discussed below).

The most relevant Acts for the water-related sectors are the following:

1) Irrigation and Drainage Act, 1873 (National)
2) Lahore Development Authority Act, 1975
3) Punjab Development of Cities Act, 1976
4) Punjab Irrigation and Drainage Authority Act, 1997
5) Punjab Environmental Protection Act, 1997
6) Punjab Flood-Plain Regulation Act, 2016
7) The Punjab Local Government Act, 2019
8) The Punjab Water Act, 2019

The Punjab Water Act is discussed below.

4.2.5.1 PUNJAB RULES OF BUSINESS

The Constitution expects the Federal and Provincial Governments to make their own rules for the discharge of their responsibilities (their 'business'). Typically, Schedule 1 of a set of Rules of Business specifies the set-up of the organization, thus the ministries, divisions, etc. of the government. Schedule 2 lists the specific responsibilities of each of these units of government organization, and these can be regarded as mandates. Thus, provincial department mandates do not come from the Federal level, but are internal arrangements made by a Province.

The current Punjab Rules of Business dates originally from 2011. They set out the procedure for the operation of the Government of Punjab, the functions of a minister, Chief Secretary, Department Secretaries, matters to the referred to the Governor, specific Departments or Cabinet as well as preparation of legislation to present to the Punjab Assembly.

The legal mandate of the PID originates in the Punjab Rules of Business and from any responsibilities assigned to the Department by any legislation. The Irrigation Department responsibilities in the Rules of Business also list the legislation the responsible Department. Based on this legislation, a large volume of subsidiary legislation elaborates on the practices and procedures to be applied by the PID.

The Punjab Government Rules of Business prescribe and allot the roles and responsibilities of its various Departments. From a quick review of the Punjab Rules of Business, 2011, follows that water-related governance issues are assigned to seven departments. Among the Public Sector Organizations with roles and responsibilities directly related to water and water resources management, the following are the most important:

1) The Irrigation Department is responsible for legislation and policy formulation for irrigation and drainage. The department is also the irrigation service provider. It abstracts, conveys and delivers water to mainly Irrigated Agriculture and therefore it is responsible for establishing, operating and maintaining the irrigation and drainage infrastructure. Flood management and protection is also a part of its duties.
2) Irrigated agriculture is by far the largest water consumer. The Agriculture Department is responsible for the legislation, policy formulation and sectoral planning regarding, the improvement of agricultural and water management methods and use of tube-wells and installation, as well as for the Water Management Training and Research Institute, Lahore. It also provides agricultural Information and publications/training. Furthermore, it is responsible for the preparation and review of agricultural production strategy, in coordination with district agriculture extension.
3) The Housing, Urban Development and Public Health Engineering Department ("HUD&PHE") is responsible for overseeing municipal/urban as well as rural drinking water schemes. Local governments are empowered by law to charge rates and fees with respect to drinking water and sanitation as may reasonably cover their operation and maintenance charges. However, it has been difficult to set charges high enough and therefore the various Water and Sanitation Agencies are forced to meet their deficits with Provincial Government grants.

4) The Environmental Protection Agency, Punjab ("EPA, Punjab") has the responsibility to ensure the protection of water resources and is mandated to apply the ambient water quality standards prescribed in the Provincial Environmental Quality Standards ("PEQS"). With urbanization and industrialization (most industries are located in urban areas) water pollution has increased seriously. So far, their efforts have been confined largely to urban settings and the capacity to extend its role into rural districts has not been developed. A province-wide assessment of water quality throughout the province is currently lacking.

Table 4-1 lists these and other departments and their roles and responsibilities with relevance to Water Resources and Water Services Management.

Table 4-1: Punjab Departments responsible for water management.

NO.	PUBLIC SECTOR ORGANIZATION (DEPARTMENT)	ROLES AND RESPONSIBILITIES, AS PER PUNJAB BUSINESS RULES 2011 (AS UPDATED SUBSEQUENTLY)
1	Irrigation	- Legislation and policy formulation for irrigation and drainage; - Construction and maintenance of barrages, rivers, canals, tube-wells, drainage schemes, storage of water and construction of reservoirs, food control and flood protection schemes; - Research in irrigation hydraulics, ground water and land reclamation - Survey of water bodies for data collection and analysis for future planning; - Distribution of canal water and assessment of water rates - Training; - Human Resource Development including Engineering Training Academy; - Tolls on barrages and waterways; - Strategic Planning Units; - Planning, designing, construction, maintenance and repair of all building and related infrastructure under the control of the Department; - Administration of: a. Canal and Drainage Act, 1873 b. Soil Reclamation Act, 1962 c. Land Improvement Tax Act, 1975 d. On Farm Water Management Ordinance, 1981 e. Punjab Irrigation and Drainage Authority Act, 1997 f. Punjab Minor Canal Act
2	Agriculture	- Legislation, policy formulation and sectoral planning regarding: a. Improvement of agricultural and water management methods. b. Mechanization, reclamation of land, use of agriculture machinery, ploughing, tube-wells and installation and research Agricultural Engineering (Agricultural Machinery and Implements), Water Management Training and Research Institute, Lahore. c. Agricultural Information and publications / training. d. Preparation and review of agricultural production strategy in coordination with district agriculture extension. - Monitoring of Agriculture inputs like fertilizer, pesticides, irrigation through field extension staff.

NO.	PUBLIC SECTOR ORGANIZATION (DEPARTMENT)	ROLES AND RESPONSIBILITIES, AS PER PUNJAB BUSINESS RULES 2011 (AS UPDATED SUBSEQUENTLY)
		- Promotion of modern agriculture technologies and other extension activities through method / result demonstration, farmer gatherings, print and electronic media, etc. - Market Information & Intelligence System and matters common to all Market Committees - Water Management Operations, Planning, Research and Coordination. - Coordination and Strengthening of Research activities in Agriculture, Livestock, Irrigation, Water Management, Forest and Fisheries Sector through Punjab Agricultural Research Board. - Administration of the following laws and the rules framed there-under: a. The Punjab Soil Reclamation Act, 1952 b. Water Users Association Ordinance Act, 1981.
3	Housing, Urban Development and Public Health Engineering	- Matters relating to development authorities / agency / company as reflected in Schedule-I. - Provision of drinking water, drainage & sanitation facilities and legislation/policy matters related thereto. - Matters relating to public health engineering including its establishment. - Maintenance and development of parks, green belts, other open spaces and to regulate outdoor advertisement sector wherever assigned. - Administration of the following laws and the rules framed there-under: a. The Town Improvement Act 1922 b. The Lahore Development Authority Act 1975 c. The Punjab Development of Cities Act 1976 d. The Disposal of Land by Development Authorities (Regulation) Act 1998 e. The Punjab Housing and Town Planning Agency Ordinance 2002
4	Environment Protection	- Planning and policy making in the disciplines of environment and ecology. - Administration of Environmental Protection Agency Punjab. - Administration of the following laws and the rules framed there-under: a. Pakistan Environmental Protection Act, 1997.
5	Industries, Commerce and Investment	- Legislation, policy formulation, and sectoral planning in respect of: a. Industries including Industrial estates, small industries and handicrafts enterprises. - Administration of the following laws and the rules framed there-under: a. The Punjab Industries (Control on Establishment and Enlargement) Act, 1963 b. The Punjab Small Industries Corporation Act, 1973 c. Punjab Industrial Development Board Act, 1973 d. The Punjab Small Industries Corporation (Works) Rules, 1984
6	Local Government and Community Development	- All matters relating to the local council services & supervision of local governments - Framing of rules, regulations and policies under the Punjab Local Govt. Laws - Matters relating to: a. Local Governments / Local Councils. b. Local taxation and local rates.

NO.	PUBLIC SECTOR ORGANIZATION (DEPARTMENT)	ROLES AND RESPONSIBILITIES, AS PER PUNJAB BUSINESS RULES 2011 (AS UPDATED SUBSEQUENTLY)
		- Matters relating to urban improvement, renewable and re-development. - Rural / community development.
7	Forestry, Wildlife and Fisheries	- Legislation, policy formulation and planning regarding Forestry, Wildlife and Fisheries. - Management of forests, including watershed lands; of fisheries including natural fisheries resources, including sanctuaries. - Extension services: publicity; public awareness through mass media; holding of exhibitions, seminars, workshops, symposia, etc. - Protection, promotion and conservation of forestry; wildlife; fisheries - Acquisition of land for forestry; wildlife; fisheries. - Survey, data collection, mapping for analysis and future planning. - Planning, monitoring and evaluation - Conservation, promotion and management of biodiversity. - Administration of the following laws and the rules framed there-under: a. Punjab Forest Act, 1927 (Amended 2010) b. Fisheries Act, 1927 c. Punjab Fisheries Ordinance, 1960
8	Transport	- Legislation, transport policy and planning. - Shipping and Navigation on inland water ways as regards mechanically propelled vessels, and the rules of the road on such waterways; carriage of passengers and goods on inland waterways. - Administration of the following laws and the rules framed there-under:
9	Health	- Health management, planning and policy - Policy matters relating to guidelines regarding prevention and control of infectious and contagious diseases; eradication / control of malaria; nutrition surveys; nutrition and publicity in regard to food.
10	Revenue	- Minor canals, hill torrents, alienation of rights in water - Suspension and remission of land revenue and water rates - Waterlogging and salinity other than schemes relating thereto
11	Finance	- Budgets, audits, staff positions

With an eye on the changes described in the Punjab Water Policy, several other parts of the Punjab Rules of Business are relevant:

- The Chief Minister is responsible for constituting new Departments (Rule 3(2)) or assigning and transferring any subject from any Department to another (Rule 3(5), and as such will be the official responsible for ordering the amendment to the Punjab Rules of Business to reorganize the Punjab Irrigation Department as a Water Resources Department. The Supreme Court decided in 2018, that the CM will have to place any such proposed changes before the Provincial Cabinet for their approval.
- The Secretary of a Department has the power to distribute the work of the Department by Standing Order (Rule 4(2))
- Some relevant rules in respect of Policy are:

- 10(c): The Secretary assists the Minister in the formulation of Policy, etc.
- 6(a): The Minister is responsible for the Policy matters.
- 10(d): The Secretary executes the sanctioned Policy.
- (N.B. It used to be that the Minister could approve or change Policy, but a 2018 Supreme Court decision put an end to this practice and directed that all provincial policies must be placed before, considered and approved by the Provincial Cabinet. Thus, in case of the Water Policy, the Secretary PID needs to submit the Policy to the Minister, and the Minister would then present the Policy, as a "summary", to the Chief Minister, for discussion in the Cabinet and for Provincial approval.)
- When a legislative subject concerns more than one Department, the proposing department is responsible for consulting the other departments. Importantly, no case may be submitted to the Chief Minister or Cabinet unless such consultation has taken place (Rule 15). Water and water resources management is typically a multi-department legislative subject.
- Consultation with the Finance Department is mandatory in a matter that directly or indirectly involves a change in the number or basic scale of posts or the terms and conditions of government servants (Rule 19(1)), and to the extent the transformation of PID to WRD involves these elements, such consultation will be mandatory.
- Consultation with the Law and Parliamentary Affairs Department is mandatory for any proposed legislation, substantive or delegated (Rules 20(2)) as to the extent the "operationalizing" the Water Act certain rules and regulations are required, such consultation will be mandatory.

4.2.5.2 PUNJAB SERVICE RULES

The Punjab Civil Services Act, 1974 (Act VIII of 1974; 4 June 1974) regulates the appointment to, and the terms of conditions of service in respect of services of the Province of Punjab. The Act allows the Government of Punjab to make rules regarding the staffing, their experience and qualifications, in service at the various departments, autonomous bodies and other public sector institutions and organizations.

Where the organization envisaged under the Punjab Water Policy requires other positions than those allowed by the current service rules for the concerned department, recruitment of the new staff will require new sets or modifications to the relevant existing sets of service rules.

Several sets of rules made under the Act relate to the staffing at the Punjab Irrigation Department. These include the following:

Set 1: Punjab Irrigation Department (Engineering Posts) Rules, 2013

Set 2: Punjab Irrigation and Power Department (Land Reclamation) Service Rules, 1989

Set 3: Programme, Monitoring and Implementation Unit, Irrigation Department (Service) Rules, 2017

Set 4: Punjab Irrigation Department Ministerial (Zonal, Circle and Divisional Office) Service Rules, 2017

Set 5: Punjab Irrigation Department Supervisory Control and Data Acquisition System Employees Service Rules, 2017.

4.2.6 PUNJAB WATER POLICY (2018) AND PUNJAB WATER ACT (2019)

The review found that the Punjab Water Policy and Act have only a few similarities. Perhaps the clearest of these similarities are the stated overall objectives. The Act's formulation is simplest and at the same time comprehensive in coverage: to achieve "comprehensive management and regulation of water resources in Punjab Province in the interest of (i) the users, and (ii) the conservation and sustainability of the resources". Also, quite similar are the platforms for inter-sectoral consultation and coordination: The Policy's Punjab Water Council (PWC) and the Act's Punjab Water Resources Commission (PWRC). The Act's Commission, though, with nine different departments

represented on it, has a wider stakeholder participation than the Policy's Council with its four. Figure 4-1 is a diagram of the Governance Structure according to the Policy. Figure 4-2 is a diagram of the Governance Structure according to the Act.

The Punjab Water Policy (2018) identifies ten important challenges in the water sector, among which the most serious is the high-water stress. Among the other challenges are depletion of groundwater; irrigation with groundwater with a high TDS; increasing occurrence of flood damage; low water productivity; transboundary disputes (incl. about construction of new dams); poor governance and trust; insufficient funds for maintenance and repair; inadequate knowledge database and water informatics; and degradation of land and water resources due to use of fertilizers and pesticides, and sewage disposal. The Punjab Water Policy (2018) lists twelve 'specific objectives'. The objective at the top of the list is to Increase water availability through advocacy of construction of large dams at Federal level, construction of small and medium dams, beneficial use of flood waters, reallocation between sectors and recycle and reuse of wastewater.

The Policy calls for the adoption of IWRM and RBM and provides a sketch of what is needed for implementation. The Policy's twelve 'specific objectives' can be seen as a first step in the direction of development of a provincial strategy. The Policy envisages a Water Resources Department (WRD) as the guiding and driving force for the process. The Policy recognizes the need for strengthening capacity; to identify what is needed and determine future implementation actions. Providing advice on this has become the principal task of the CDTA.

The Policy pays attention to establishing a mechanism for inter-sectoral consultation and coordination, but not for the strengthening of control. The policy places much emphasis on action and investment. It lists 116 water resources management actions which the Provincial Government would need to undertake. The Policy's attention for investment action is reflected by the important role it envisages for the Provincial Planning and Development Board. Board Chairman is a member of the Punjab Water Council and the chairperson of an envisaged Water Policy Implementation Committee (WPIC).

The Act requires establishment of a number of the elements needed for an improved framework for water and water resources governance. These elements serve inter-sectoral consultation and coordination, and effective control over water abstraction and disposal. A Punjab Water Resources Commission (PWRC) will be responsible for holistically managing and developing water resources in the province. The powers and duties of the Commission are to conserve, redistribute and augment water resources, allocate water resources for domestic, agricultural, ecological and industrial purposes and to secure the proper use of water resources. The Commission is also to maintain, improve and develop wildlife and fisheries in bodies of water from which water is to be withdrawn or discharged under the Act. The PWRC is supported by its own Director-General, responsible for the discharge of the functions of the Commission. The Chief Minister is the Chairperson, PID is Co-chairperson, and Chief Secretary is Vice-Chairperson. Membership includes the seven Ministers of (i) Irrigation (as Co-chair), (ii) Environment Protection, (iii) Housing, Urban Development & Public Health Engineering, (iv) Agriculture, (v) Industries, Commerce & Investment, (vi) Local Government and Community Development, and (vii) Forestry, Wildlife & Fisheries. The Secretaries of the seven represented departments are also members. Furthermore, the membership includes the Finance Secretary, the Commission's Director General (in the position of PWRC secretary), and four private experts.

The Punjab Water Services Regulatory Authority (PWSRA) is to regulate the supply of drinking water and disposal of sewage through a system of licenses to water undertakers and sewerage undertakers and is, similar to the PWRC, supported by its own Director-General who is responsible for the discharge of the work of the Authority. The Chief Secretary is the Chairperson, there is no Co-chairperson or Vice-Chairperson. The PID Secretary is PWSRA Secretary. Membership includes the secretaries of six departments (i) Housing, Urban Development & Public Health Engineering; (ii) Local Government and Community Development; (iii) Irrigation; (iv) Environment Protection; (v) Industries, Commerce & Investment; and (vi) Primary and Secondary Healthcare. Furthermore, the membership

includes a water quality expert, a public health expert, and the Authority's Director General (in the position of PWSRA secretary).

The duties and powers of the Authority are (1) to oversee the performance of water and sewerage undertakers; and (2) revise tariffs for water and sewerage undertakers. The PWSRA is to ensure that activities under licenses for the abstraction from or disposal of water into (State-) 'controlled waters' are properly carried out. Licenses shall be subject to terms and conditions imposed by the PWRC. For example, for licenses for water disposal, the PWRC will stipulate environmental standards and regular tests and standards. The licensing arrangement will cover abstraction of water, quality of drinking water, the effectiveness of sewage and wastewater treatment facilities, and the level of fees and charges to be levied on the end-users. Four 'schedules' (matrices) specify which authority issues the licenses for what water use. In all cases of disposal, the PWSRA grants the licenses. The third schedule lists for each of the types of offences mentioned in the act, which entity can file a complaint of an offence having occurred.

Licenses for five of the eight specified water abstraction purposes are to be issues by the Authority self. The three exceptions are: (i) where it concerns abstraction within an area managed by an appointed water undertaker, the undertaker will grant the license; (ii) where it concerns abstraction of water for agriculture, the Canal Officer in consultation with the Dep Dir of Agriculture Department will grant the license; and (iii) where it concerns water for ecological purposes, the Authority in consultation with the Forest Department will grant the license.

The Act does not provide much direction and does not mention the need for IWRM and RBM, nor the need for a WRD. Implicitly, the Act's view is that the PID can largely remain as it is, or if change is required, then that should be arranged separately. Hereby, the Act avoids the need for a large-scale reorganization of the Punjab Government and a possibly difficult redistribution of departmental powers and resources. It also avoids the discussions which tend to arise about what IWRM is and how to apply it in the local context.

How to finance the water resources actions is perhaps the point weakest developed in the Policy and in the Act. The Policy is repeatedly explicit on the need to ensure Financial Sustainability but refers only to better water pricing and agriculture income taxes. Both are low and raising them is a highly sensitive matter. Is it realistic to expect that the cost of the desired comprehensive management can be financed from these? Or are other more adequate financing sources available?

This report finds that generally the legal/regulatory requirements for implementing the policy are met, but that in a number of places there is little or no legal authority and thus supplementary legislation may be warranted.

***Note 1*:** The proposed 'minimum disruption option' has the PWRC and PWSRA report directly to the Chief Minister and Chief Secretary. Because their decisions are binding for departments, including for the WRD, PWRC and PWSRA cannot and should not be placed under the WRD. However, it would be practical for their Director General offices (functioning as their secretariats) to be hosted by the WRD. In this manner, the two DGs will have better access to the WRD and its various units and vice versa, than when they would be positioned fully separate.

***Note 2*:** In the current situation, all regulatory decisions need to be presented for discussion and approval to the Cabinet. What is the advantage of having water resources management-related regulatory decisions take place in a Punjab Water Resources Commission? How can this arrangement be made to have added value? It is important to contemplate this question. If there is no serious added value, intended participants will choose to attend to more important matters and the idea will not work. The answer is perhaps that when all regulatory proposals that are concerned with water-related topics are processed and presented by the Director General of the Commission after consultation/cooperation/exchange of ideas with the WRD, the combined package of regulations will become more and more consistent and supportive of achieving the overall objective of "comprehensive management and regulation of water resources (all sources of water)".

***Note 3**: The Punjab Water Policy 2018 envisages a Water Policy Implementation Committee (WPIC). The above framework assumes that such a body is not needed, because standing government procedures and coordination by the PWRC will suffice. The WRD will provide recommendations for priority actions and inter-sectoral coordination.

Note 4: The National Water Policy 2018 states that each province should establish a Groundwater Authority. The above discussed framework does not yet include a Groundwater Authority. Related to this is the question what technically will be done to manage groundwater: will there be any groundwater services? What about Vertical Drainage Wells for keeping groundwater levels low? What about recharging aquifers?

Note 5: It is perhaps best to not provide WRD with any direct infrastructure construction and management responsibility, as this may become a focus of WRD attention to the cost of its IWRM-supporting role.

Note 6: The concept of water undertakers and of sewerage undertakers could have been extended to not only cover drinking water supply and related sewerage services but also the irrigation water supply and drainage. For example, the Canal Officers could be regarded as irrigation and drainage undertakers. If the idea is to have irrigation water supply and drainage undertakers as customer-oriented service providers, then some of the options are to tender/appoint for each command area a private sector or State-owned enterprise as undertaker. The PID field-based, direct irrigation services delivery activities would then become the work of the undertaker. PID could split itself up into (i) an irrigation & drainage services regulator; and (ii) a number of irrigation water supply and drainage undertakers, being enterprises with an existence outside PID. The PID as regulator would remain responsible for reviewing seasonal irrigation water demand requests received from the undertakers and oversee the performance of them. The WRC would determine the finally allowed seasonal water allocations for each command area.

Note 7: The WSRA operates/utilizes/applies the licensing system that the Act introduces. There are licenses for water abstraction from and (other) licenses for water disposal into ‘controlled waters’. Irrigated agriculture is by far the largest water consumer. How will the irrigation licenses be arranged? Will each intake on a river need a license? Who will hold the license: (i) the PID, or (ii) an association/cooperative of irrigation water users, or (iii) an irrigation water supply and drainage undertaker (e.g. having a service contract with the local irrigators associations and users-right for the irrigation and drainage infrastructure)?

Note 8: One of the Act’s arrangements drawing the attention of the reader is that for abstraction of water for agriculture, the Canal Officer in consultation with the Deputy Director of the Agriculture Department will grant the license. If the requirement will be (see discussion above at Note 6) that each irrigation water main intake will need to have a license, then it is not a wise arrangement having PID granting the license to itself.

Note 9: Not mentioned in the Act’s list of PWSRA members is Secretary PAD. Possibly this is an oversight: The Act allocates to PAD a role in licensing for water abstraction for agriculture. Furthermore, agriculture is the largest surface water and groundwater consumer and causes considerable pollution.

Note 10: The Act is not clear on a number of points, such as the composition of the Advisory Committee to the Commission (s 4(4)(b)); the manner of appointment of the two DGs (s. 6(1), s. 9(1)); the maintenance of the Register of Undertakers (s. 11); and the format of the abstraction and disposal licenses (s. 45(1)).

Note 11: It needs to be realized that available water is used and re-used by different stakeholder departments. A data base on water availability and consumption/use by all stakeholders will need to be maintained and plans for best use/sharing of available water will need to be prepared, for decision-taking.

Note 12: It is reasoned that wastewater from cities should be passed on to Agriculture, in order to make best use of it. Such re-use will be possible on condition that a strict water quality control system is in place. How best to arrange this will be discussed and agreed in the PWRC.

4.2.7 THE PUNJAB IRRIGATION DEPARTMENT (PID)

The PID's main role is to provide provincial irrigation and drainage services. The Rules of Business list its formal mandate. The PID is responsible for legislation and policy formulation for irrigation and drainage. PID administrates the Canal and Drainage Act 1873 and a range of other acts related to its main role. Furthermore, PID is responsible for the construction and maintenance of irrigation, drainage, flood management, and storage infrastructure.

Figure 4-3 provides the organization structure of PID. PID is a large organization with more than 43,000 sanctioned staff positions (2009 data). The Secretary is the administrative head of the Department and is assisted by three additional secretaries (Administration; Technical matters; and Budget/Operation). Eight Zonal Chief Engineers manage irrigation services delivery. Each of them oversees a number of Superintending Engineers in charge of one or two main canals and these, in turn, supervise a number of Executive Engineers and Sub-Divisional Officers. At the head office, Chief Engineers are each in charge of a Department Section. In addition, PID has several other organizational units at its Head Office, among which is importantly the Strategic Planning and Reform Unit (SPRU). The SPRU role is strategic planning, monitoring and evaluation, and facilitation in implementation of a range of ongoing performance improvement activities. It manages the transformation of PID into a WRD. Anticipating the transformation, a new unit, headed by a Chief Water Resources, was recently added.

4.2.8 IWRM GOVERNANCE STRUCTURE FOR MINIMUM DISRUPTION

This project is required to propose a Governance Structure that minimizes disruption to (the Government of Punjab, including the PID's) day-to-day functions, while meeting the requirements of the Water Act. The Action Plan proposes the structure in Figure 4-4. Disruption of the government's day-to-day functions leads to a loss in organizational capacity and performance (work quality and quantity). The disruption referred to concerns the government's work process. Two categories of this disruption can be distinguished (i) disruption caused by/accompanying the organizational change process of moving from the current government-work process to the desired IWRM-based/inspired process, which will affect the legal/regulatory framework, agency mandates, reporting lines, organization structures, staff positions, and resources allocations; and (ii) the 'disruption' experienced from the 'added' activities, newly generated under the new IWRM-based/inspired process, such as more coordination meetings, more discussions, more reporting, more monitoring, more data sharing, more transparency, and more stakeholder participation. Disruption cannot be avoided, but an effort can be made to minimize disruption.

The approach below minimizes disruption:

- minimize the need for change to existing structures, to organizational mandates, and to resources allocation.
- make the structure fit into the established administrative hierarchy and principles.
- make maximum use of available organizational expertise and capacity in all agencies.
- ensure that PWRC coordination meeting agendas are carefully prepared; that information needed for understanding the topics on the agenda is shared in advance; those objective recommendations are made available to the participants.

Figure 4-1 shows that at the governance structure's top-level are concentrated the powers of regulation, and of coordination of sectoral IWRM programs (PWRC). The PWSRA implements the licensing regulation specified and decided in the PWRC. The Act rules that the PWRC will be chaired by the Chief Minister and the PWRSA by the Chief Secretary. PWRC and PWRSA will each be supported by a Director General. The Act does not specify where in the provincial governance structure these DGs should be positioned. Below this top-level the structure shows the departments providing water supply services for irrigated agriculture; for water supply and wastewater disposal; and others. These services require operation of infrastructure and equipment for water abstraction/diversion, storage, conveyance, and disposal.

The diagram shows a (to be established) Ministry of WRD which advises and supports the PWCR in matters of IWRM. In order to carry out its role as adviser effectively, the WRD needs to be sector-neutral, have its own Minister and senior leadership and should therefore be separate from any provincial line-agency with IWRM responsibilities, including from PID. Changes to the current governance structure are mainly the establishment of the WRD and the introduction of a Provincial IWRM Work Process (this process is clarified below). Changes to line agency roles and responsibilities (mandates) need to be determined, but few are likely to be required. The PID would continue as an individual department, keeping its responsibilities for irrigation, drainage, and flood management services and likely receive additional powers, responsibilities, and resources, as necessary for its future contribution to Provincial IWRM.

The WRD would provide technical advice to the PWRC and be the driving force behind the province's progress towards achieving the Policy's and Act's objectives. It will monitor and report on process progress; and provide policy, strategy, legal, water allocation, investment coordination and planning support via the two Director Generals to the WRC and the WSRA, who it will host. The Director Generals will report to the WRC and WRSA. The WRD will have several supportive organizational units, among which sections/cells for policy and strategy, legal matters, water demand and allocation balancing, planning & investment regulation & coordination monitoring, and data base/information system.

4.2.9 PROCESS FOR ACHIEVING THE OBJECTIVES

The Action Plan presents a process flow chart for Achieving the Objectives (Figure 4-5) and a Gantt chart (Figure 4-6). The plan assumes three subsequent years of action implementation will be needed to put in place most of the elements for comprehensive management. Based on rough estimates for the timing of the various process activities, the action plan achieves the objectives by early 2025.

The flow chart and action plan are helpful in providing a bit more insight into what the major steps in the process are and stimulate discussions on this.).

4.3 ELABORATION OF THE MINIMAL DISRUPTION OPTION INTO OPTIONAL VARIANTS

The proposed minimum disruption structure was provided as a starting point for consultations with PID. On 14/06/21, the Consultant met (online) with representatives of the Punjab Irrigation Department (PID) and the Asian Development Bank (ADB) to discuss the 'Action Plan'. Among others, PID commented that it would like to see more variants presented for the governance structure and the strengths and weaknesses of each discussed. The meeting concluded that additional items of work were needed. The following three deliverables were added to the CDTA ToR:

- Item No 17: Governance - Elaboration of the minimal disruption option into optional variants
- Item No 18: Institutional Strengthening: Provide additional guidance on the requirements and design of Centres of Capacity for effective IWRM and DRM
- Item No 19: Holistic Transformation Plan: Preparation of an initial Discussion Paper and plan outline

The Legal-Institutional Sub-Team was charged with preparing these deliverables.

As detailed below, the development of variants took some of its inspiration from a study of governance structures elsewhere. Subsequently, four more variants were developed and discussed.

4.3.1 GOVERNANCE STRUCTURES ELSEWHERE

The countries and states reviewed were India, with the states Maharashtra and Punjab; and Thailand. In South Asia, transforming an irrigation department into a water resources department was before the emergence of IWRM a standard step for improving the coordination of initiatives for water resources development within river basins. The

WRD's role remained focused on water resources infrastructure development and management, typically widened from irrigation to also include the monitoring of rivers, flood protection, and construction of storage reservoirs. It was found further that for supporting better inter-sectoral coordination in water resources management and development, governments may or may not establish a commission or council under chairmanship of the prime/chief minister and with a membership representing the water-related ministries/departments. In more recent developments, a better separation of roles and responsibilities was observed: establishment of an office or authority with roles as advisor and/or executor of water resources management. Typically, these authorities support/advise the government decision-maker with regards to inter-sectoral water allocation and water resources regulation/coordination/licensing and also receive delegated powers for public management of water resources. These authorities are separate from the Water Resources or Irrigation Department, which keeps as its principal task the management, development, and operation of water resources/irrigation infrastructure.

4.3.2 OPTIONAL VARIANTS REVIEWED

The optional governance structure variants reviewed meet the requirements of the PWA 2019 and could therefore be considered for application in Punjab Province. The following variants, which differ in regards to the relative positions of PID, WRD, PWRC, and the wider Punjab Government, have been reviewed (see the diagrams in Figure 4-7):

A. Combined

Variant A1	The PWRC/IWRM Coordination Support Unit accommodated as three Directorate Generals in WRD, alongside the current PID units
Variant A2	PID accommodated in WRD as a 4th Directorate General (Irrigation, Drainage, and Flood Management Services), alongside the PWRC/IWRM Coordination Support Unit
Variant A3	HUDPHE accommodated as 5th Directorate General in Variant 2

B. Separate

Variant B1	PID and PWRC/IWRM Coordination Support Unit (WRD) as separate ministries/departments (this is the original minimum disruption option))
Variant B2	PID as ministry/department and department and the PWRC/IWRM Coordination Support Unit as a unit in the Chief Minister Office

The strengths and weaknesses of each option are as follows:

Comparing Variants A and B

Variants B are preferred over Variants A. The principal argument is that for providing effective inter-agency coordination support to the PWRC, the WRD (envisaged in these diagrams as a PWRC/IWRM Coordination Support Unit) needs to be a neutral, non-biased entity, clearly acting professionally and on behalf of public interest. A separate WRD and PID means that each will be represented on the PWRC by its own minister. These two ministers can speak with a clear voice for their own ministry. If WRD and PID would be combined in one ministry, it would not be clear to other parties whether the minister is speaking on behalf of PID interests, or on behalf of WRD interests. This could lead to the WRD/PID leadership finding itself in conflict of interest situations. This would undermine the credibility of the WRD voice. Just a suspicion among IWRM stakeholders that WRD is perhaps serving the interests of its ex-PID-part, could already seriously undermine the inter-agency process of reaching consensus on the correctness of status reports and recommended program priorities.

One of the most sensitive roles of the WRD as a PWRC/IWRM Coordination Support Unit will be to provide recommendations to PWRC with regards to (i) how available water would best be distributed among the various

users/demands, and (ii) which sector program actions qualify for priority implementation. In order for the WRD to be objective (neutral) and non-biased, it should not also be a water services provider and/or infrastructure developer.

The arguments indicate that it would be better if PID and the PWRC/IWRM coordination support unit (the envisaged WRD) were separate organizational units (Variants B1 and B2). The PID would continue to focus on its role as water-related services provider and infrastructure developer and manager. The WRD would focus on supporting PWRC in respect of deciding IWRM priority actions and sectoral coordination of programs and water distribution.

Variants B1 and B2

Comparing Variant B1 (the original minimum disruption option) and B2, consideration should be given to establishing the PWRC/IWRM coordination support unit (the envisaged WRD) under/in the office of the Chief Minister of Punjab Province. This looks to be the most promising in terms of effectiveness among the governance structure optional variants.

Variants A1, A2, and A3

If, notwithstanding the above logic, the PWRC/IWRM coordination support unit needs to be positioned alongside PID in the same ministry/department, three variants could be considered. Variant A1 sees the three Directorate Generals of the PWRC/IWRM coordination support unit (DG IWRM, DG PWRC Secretariat, and DG PWSRA Secretariat) added to the PID. The current organization structure of PID shows that the Secretary oversees a large number of units already and adding three newly established and highly important directorate generals will dilute the attention that the secretary can pay to each unit. Variant A2 shows a possible solution to this problem, by placing all current PID units in one Directorate General ‘Irrigation, Drainage, and Flood Protection’. The Secretary (of the new WRD) would then oversee just four Directorate Generals, and this should make it possible to pay adequate attention to the three Directorate Generals of the new PWRC/IWRM coordination support unit.

In Variant A3, the ministry/department of HUDPHE is accommodated as a fifth Directorate General into Variant A2. However, because this will bring substantial change to the existing governance structure, Variant A3 does not qualify as a ‘minimum disruption option’.

Conclusion

Disruption can be minimized by minimizing change to the existing institutional structure, to organizational mandates, and to resources allocation. This will make it easier for the change process to proceed as this also avoids triggering resistance and the associated loss in organizational capacity and performance. Furthermore, the new governance structure should make maximum use of current organizational expertise and capacity through inter-agency Consultation, Communication, Co-ordination, and Co-operation, rather than restructuring of government agencies, for example with the objective of improving coordination by concentrating as many as possible of the water resources management powers and responsibilities in one agency.

A Governance Structure with a PWRC/IWRM Coordination Support Unit that is separate and independent from any water service provider, including from PID, can be expected to perform much more effectively in helping the province achieve the desired water resources management and development, than if the PWRC/IWRM-support unit would be part of and dependent on a water service provider.

Strong leadership is essential for making a successful shift to IWRM and the Chief Minister will need to provide this. The Governance Structure Variant B2, with the PWRC/IWRM-support unit placed in the Office of the Chief Minister, looks to be the most promising among the reviewed variants in terms of effectiveness and is perhaps also the one that is easiest to organize. From this position, the PWRC/IWRM-support unit will have good access to the Chief Minister as well as to the various water-related departments.

4.3.3 THREE, TWO, OR JUST ONE DIRECTOR GENERAL?

The Punjab Water Act 2019 specifies the need for two Director Generals, one to support the PWRC and one to support the WSRRA. The diagrams of the five variants discussed below, depict a third Director General, heading a (technical) Directorate-General 'ÍWRM'. Figure 4-7 presents an optional organizational structure for this Directorate-General 'ÍWRM'. Among others, this unit will host and maintain the central portal to the provincial Water Resources Information System.

Figure 4-8 show a diagram of options for three, two, or just one Director-General. The idea behind the arrangement with three Directorates-General is that the Directorate-General 'ÍWRM' will support the technical needs of both the PWRC and the PWSRA. Concentrating the technical capacity needed in one neutral technical IWRM-focused organizational unit will contribute to the effectiveness and efficiency of not only this unit's own performance, but also of the whole provincial water resources governance arrangement, particularly in respect of achieving coordinated IWRM action. In the second place, this arrangement with a third Directorate-General better ensures the technical support unit's all-important independence. The alternatives of (i) placing this unit in one of the two secretariats; or (ii) dividing the technical capacity of the technical support unit over the PWRC secretariat and the PWSRA secretariat will make provincial level collaboration and coordination much more difficult. In case the preference is for not exceeding the Act's specification, it would be better to place the whole support unit in the PWRC secretariat than to break it up and divide it over the two secretariats. For sake of keeping the discussion simple, these sub-variants with two instead of three DGs are not indicated in the diagrams.

It is also possible to consider deviating somewhat from the Act, by having just one Director General, who will then head the IWRM Directorates (Figure 4-10), as well as two additional Directorates, respectively being the secretariats for the PWRC and the PWSRA. This makes sense if the secretariats' roles and responsibilities are confined to preparing and reporting the PWRC and the PWSRA agenda's and meetings and keeping their archives.

4.3.4 A ROLE FOR IRI OR ANOTHER WATER RESOURCES-RELATED INSTITUTE?

The Indian State Tamil Nadu transformed its Institute of Water Studies into the State's Water Planning Organization to serve this purpose. The Institute had its responsibilities redefined accordingly through Government Order. This WPO is the technical support unit for the State's Water Resources Control and Review Council (WRCRC), chaired by the Chief Minister, for making decisions on water planning and allocation. The WPO was charged, among others, with the preparation of the overall State Water Plan.

One option for Punjab Province to consider is to transform (parts of) one of its institutions into the needed independent technical coordination support unit, referred to in the diagrams as the Directorate-General 'IWRM'.

4.4 PWP 2018'S LIST OF DETAIL-POLICIES: LINE AGENCIES AND PWRC/IWRM-SUPPORT UNIT

The design of a structure for the proposed PWRC/IWRM-support unit is the main subject of the Legal/Institutional sub-team's report titled 'River Basin Plans and IWRM Framework: Governance considerations and Institutional Structure'. This report is their contribution to two deliverables: Deliverable 7- 'River Basin Management Plan' and Deliverable 13- 'IWRM framework'. The design is based on a thorough analysis of the 116 detail-policies in the PWP 2018.

4.4.1 DESIGN RATIONALE

The rationale adopted for designing a suitable organizational structure for the water-related agencies comprises four elements:

1. The design should consider the specific context of Punjab Province and should be directed to effectively support the implementation of the Punjab Water Policy 2018 and it's twelve specific objectives, by implementing the policy's 116 interventions.
2. A tentative allocation of principal roles and responsibilities to the key-actors within the Provincial IWRM Framework.
3. A Provincial IWRM Work Process.
4. An analysis of the PWP 2018 policies ('interventions') that identifies the following:
   (a) the provincial line-agency which has a mandate and capacity needed for the intervention's implementation;
   (b) the capacity centre which this agency will need for implementing the intervention; and
   (c) the capacity centre which the PWRC/IWRM-support unit (WRD) will need to provide useful coordination-support in respect of the programming of the intervention

Note: Provincial line agencies will need to have one or more basic units for carrying out the responsibilities they will be allocated. In this report, such a centre can be any type of organizational entity and can be of large, medium, or small size, or just one part-time working individual.

Elaborating the above recommendations, the following sub-sections present the elements of the rationale for designing the needed institutional structure, including proposed structure for the future PID and the Water Resources Department/Office. The rationale is in the form of (i) a set of design principles, distilled from the context study; (ii) a basic allocation of roles and responsibilities to agencies; (iii) a concept for a work process, that fits the national budgeting cycle; and (iv) an analysis of the PWP 2018's interventions and how these can possibly be linked to agencies and identify needed capacity centres which each agency may need to have in order to fulfil its role in the provincial IWRM. This rationale is an important contribution to the thought-processes for deciding the IWRM governance and institutional structures and is therefore presented in this final report.

4.4.2 DESIGN PRINCIPLES

It is recommended that Punjab Province's institutional structure ('the structure') for its water resources management will be based on the following key principles:

1) The arrangement complies with the Punjab Water Act 2019.
2) The arrangement is directed to effectively support the implementation of the Punjab Water Policy 2018, with a focus on achieving the set of twelve specific objectives (relating to twelve 'IWRM themes') and implementing the detailed policies and their interventions.
3) Under the prevailing and still worsening water scarcity, the primary challenge to the province's IWRM structure will be to determine how much water is available and what the optimal distribution (in terms of allocations) is among the various water use sectors. The main idea is that in case of no increase in overall water availability, the allocation to irrigated agriculture needs to shrink in order for the allocation to urban and industry use to rise.
4) It is important to minimize change to the existing institutional structure, to organizational mandates, and to resources allocation because this will make it easier for the transformation process to proceed and thereby avoid disruptions and loss in organizational capacity and performance (work quality and quantity). The institutional structure
   a. should comply with the established hierarchy and function well under the envisaged water resources governance arrangement;
   b. should make maximum use of current organizational expertise and capacity through inter-agency Consultation, Communication, Co-ordination, and Co-operation, rather than concentrating as many as possible of the water resources management powers and responsibilities in one agency, because

that would require a large and therefore likely disruptive re-organization of the provincial government;

Where large changes to the existing situation are unavoidable, a stepwise introduction should be considered.

5) The governance structure should allow for/support a clear and welcome voice speaking on behalf of the province and pointing out the direction in which water resources management should proceed. In order for this voice to be clear and welcome, it should come from a 'sector-neutral entity', which has an IWRM-dedicated leadership;
6) The governance structure should allow for/support a clear and welcome voice speaking on behalf of the province and pointing out the direction in which water resources management should proceed. In order for this voice to be clear and welcome, it should come from a 'sector-neutral entity', which
   a. has an IWRM-dedicated leadership;
   b. has a wide view and understanding of water resources management and how its actions impact the socio-economy;
   c. is free from sector-specific responsibilities and associated potential conflict of interest situations;
   d. is not burdened by responsibility for actions in the past;
   e. is well-informed by independent inspections, real-time monitoring, and generous data sharing.
7) The institutional structure should have an adequate set of capacity centres to carry out all required water resources management tasks, including (i) the interventions in detailed in the PWP 2018 and (ii) the tasks proposed by the CDTA consultant in the management plans for the various IWRM-themes, such as water allocation, and river basin management, groundwater management, flood management, drought management, etc.
8) Within some of the capacity centres a sub-division into geographical attention fields might be useful, such as a sub-division according to irrigation sub-basins for groundwater, water logging, and salinity management and a sub-division into rivers for surface water quality management.
9) The institutional structure should clearly recognize the different scales of IWRM:
   a. Water source and storage management (rivers, lakes, reservoirs, aquifers)
   b. Bulk water diversion, conveyance, and delivery (via operation of barrages and link canals) to Irrigation services providers, to DMI service providers, and to any other bulk water user.
   c. Conveyance and distribution to customers (via irrigation canal systems and water supply systems) to farmer water user groups, households, and offices/businesses, by Irrigation services, DMI service providers, and other water services providers (to be identified).

4.4.3 ROLES AND RESPONSIBILITIES

1) The PWRC is the lead agency in the province's IWRM decision-making process (as per Punjab Water Act 2019).
2) Once an IWRM decision is taken in/by the PWRC, it will be issued, implemented, and financed through the standard provincial administrative processes.
3) The PWRC's secretariat will prepare the PWRC meetings and agenda, assist the PWRC with communications with member agencies, other agencies, and other stakeholders, and keep records of all communications and meetings
4) The PWRC will allocate to the various provincial government agencies their roles, responsibilities, and targets for implementing the Punjab Water Policy and achieving the objectives, in accordance with their current principal mandates. The PWRC will monitor progress and evaluate the result. Where a needed mandate does not exist yet, such mandate will be provided to the agency best equipped and situated for carrying it out.
5) The existing government agencies will carry out the decisions issued by the PWRC, and it will be they who will do the actual integrated water resources management work.

6) Standard roles of the various provincial government agencies in contributing to the provincial water resources management will be the following:
    a. Preparation of work programmes and budget proposals for achieving received targets.
    b. Implement approved work programmes and budgets and report on progress.
    c. Record and make available IWRM-relevant data: routine monitoring and data collection, processing, and entering into the provincial water resources data base.
    d. Preparation of periodical monitoring and evaluation reports, including analysis and evaluation of the relevant data and description of the current status and achieved progress/change relative to previous report and relative to the target.
7) The roles of the WRD will be to support the PWRC and its secretariat, by:
    a. Advising on the status of implementation of the Punjab Water Policy 2018 (and any updates) and achievement of (each of) the objectives. WRD will have access to line-agency monitoring data, will analyze this data, will make verifications as necessary, and write status reports.
    b. Advising on additional legislation/regulation, policy, and strategy development or amendments.
    c. Advising on bulk water allocation and any needed adjustments to schedules.
    d. Preparing the periodical Punjab Water Resources Status Report.
    e. Preparing discussion papers on key issues in preparation of PWRC decision-taking.
    f. Keeping in touch with the various government agencies and with other actors and stakeholders in provincial water resources management, processing the communications, reports and questions/requests addressed by them to the PWRC, and advising on PWRC actions to be taken, as well as facilitating inter-agency consultation, cooperation, including data exchange.
    g. Hosting (is this the best place?) the provincial central water resources data base and ensuring/overseeing its further development, updating, and maintenance.
8) WRD will have a capacity centre dedicated to bulk water allocation scheduling and services. WRD will inventories/predict bulk water demand and set bulk water delivery. PID will implement the allocations. WRD and PID will consult each other, co-ordinate their work, and co-operate. Perhaps, the arrangement could be somewhat similar to how IRSA operates. Instead of setting water allocations to provinces (as IRSA does), WRD's water allocation centre will set allocation of water to sectors (Irrigation, DMI water supply, groundwater recharging, environmental flows), in consultation with sector representatives. This will need a monitoring system that meets Briscoe and Qamar's requirements for successful implementation of the WAA 1960, as follows:
    a. a rigorous, calibrated system for measuring water inflows, storages, and outflows be put in place
    b. the measurement system be audited by a party which is not only scrupulously independent and impartial but is seen to be so by all parties
    c. reporting must be totally transparent and available in real time for all parties to scrutinize
9) Ideally there should be an inter-sectoral 'Water Apportionment Accord', which gets periodically updated to reflect the growing water need of the urban sector with its higher water consumption priority.
10) In respect of the preparation of the annual and multi-year Provincial IWRM Programs, the work process can best resemble that which the Federal Flood Commission practices. Punjab Province agencies with IWRM responsibilities, will prepare their IWRM plans. WRD will (i) provide coordination, based on PWRC decisions and directions regarding priorities, and (ii) compile the Agency IWRM Programs into a comprehensive well-coordinated Provincial IWRM Program.
11) Punjab Province will make maximum use of the capacity available at its line agencies. Because these agencies already have branch/field offices outside Lahore there will (most likely) not be a need for WRD to have its own 'branch/field offices' outside Lahore for the purpose of management and data acquisition.

Table 4-2: Federal Budget Calendar 2021-2022

S#	ACTIVITIES	RESPONSIBLE	TIMELING (LAST DATE)
1.	Submission of Current & Development Expenditure Budget Estimates (Form-II and (Form-III)	PAOs	15th March, 2021
2.	Development of Budget Strategy Paper	Finance Division	2nd week of March, 2021
3.	Demand Review Committee's Meetings (if required)	Finance Division	1st week of April, 2021
4.	Submission of Budget Strategy Paper to the Cabinet	Finance Division	1st week of April, 2021
5.	Issuance of IBCs for current and development budget	Finance Division	3rd week of April, 2021
6.	APCC & NEC meetings	Planning Division & Finance Division	April, 2021
7.	Submission of BO/NIS Forms for current budget	PAOs	26th April to 14th May, 2021
8.	Submission of BO/NIS Forms by Ministries / Divisions for development budget	PAOs	10th to 21st May 2021
9.	Completion of all Budget Documents, Schedules and Summaries for the Cabinet etc.	Finance Division	End of May, 2021
10.	Presentation of Budget to the Cabinet and the Parliament	Finance Division	1st week of June, 2021

4.4.4 PROVINCIAL IWRM WORK PROCESS

The above roles and responsibilities play out in the administrative work process for IWRM. The principal purpose of the work process is to support/realize integrated and effective water resources management. This can be achieved through a multi-agency joint formulation of a Provincial IWRM Program and budget with best prioritization of activities and high degree of inter-agency program coordination. This report suggests that there is no necessity to bring together all IWRM actions into an IWRM project and request a project budget to finance it. Instead, the Provincial IWRM Plan Program can be a coordinated compilation of IWRM activities which will be implemented by the various IWRM-related provincial agencies, through their 'normal' budget procedure. For this, the IWRM work process will have to step in pace with the federal budgeting process, of which a typical timing of its milestones is indicated in Table 4-2. A suggested provincial IWRM work process is presented Figure 4-9. Three, two or just one Director General (Figure 4-10). The diagram shows that the process is a cycle, turning in pace with the federal budgeting process. Each budget cycle starts with the identification of water resources condition and water use issues that need to be addressed and ends with the WRD submitting progress reports and an update of its assessment of the water resources condition and water use as basis for the start of the next cycle. For each step are indicated the activities expected from the main actors in the process: (1) the Provincial Line-agencies; (2) the Water Resources Department; and (3) the Punjab Water Resources Commission.

Note:

1) For the process to function effectively, it is important that the provincial government leadership and the agency leaders have adopted the IWRM-way of thinking, so that the recommendations provided by the WRD can be properly valued and the work process does not fall back into the old moult of sector-led water resources projects. One of the most urgent activities therefore is to assist the provincial government leadership and the agency leaders in adopting the IWRM-way of thinking.

4.4.5 LINE-AGENCIES AND CAPACITY CENTRES

For details of the analysis, see the abovementioned report. The analysis identified a total of 32 capacity centres that would be needed for the implementation of the interventions, located in nine IWRM-related agencies with a fitting mandate and capacity. In addition, the analysis found that each IWRM-related agency may need to have a standard set of four capacity centres (in order of alphabet), namely for respectively:

a) Awareness, Education, Research, and Capacity Strengthening
b) Data and knowledge management
c) Development and implementation of policies for adaptation to Climate Change, in particular for Drought management and Flood management, and
d) Legislation

A fifth standard capacity centre would be needed in agencies with infrastructure operation and maintenance responsibility, such as PID, namely for 'asset management'.

4.4.5.1 PID CAPACITY CENTRES

The analysis identified PID as the suggested implementation agency for 55 out of the 116 interventions listed in the PWP 2018. It identified the following capacity centres which PID would need to have for implementing the interventions, as follows:

CAPACITY CENTRE	NR OF RELATED PWP 2018 INTERVENTIONS
Standard:	
Adapt to Climate Change:	
Awareness, Education, Research, and Capacity Strengthening	
Data centre	
Legislation	
Specific:	
Bulk water service	8
Drought management	3
Flood management	13
Irrigation & drainage service	14
PID Leadership	3
Project management	1
Storage management (gw)	5
Storage management (sw)	4
Transboundary Consultations and Negotiations	4

PID is a large organization and has been managing water resources for quite some time, it is probable that a verification finds that all these capacity centres already exist in one form or another. Perhaps, with only few and minor changes/modifications the capacity needs can be met.

4.4.5.2 CONCEPT FOR A FUTURE ORGANISATION STRUCTURE FOR PID

Figure 4-10 presents an idea for a future PID reorganization. The future structure presented is not intended as a recommended best structure but rather as a 'try-out' with the purpose of providing a reference and orientation point for consultations between PID, ADB, and CDTA Consultant. Through such consultations a better/more fitting version will form.

To move from the current to the future structure, a number of changes would need to be made.

A first change would concern the PID unit 'Chief Water Resources'. It would be logic to transfer this unit, fully or partly, to the WRD.

The biggest change - which is to be contemplated for the longer term - is the splitting up of the 'the irrigation process' into three parts and providing each part with its own dedicated management organization. The first part is the management of water storage (surface water and groundwater storage) and thus focuses on keeping/making water available in storage and releasing water from storage to meet (part of the) water demand. The second part is the management of bulk water services. This connects water availability to (sectoral) water demand. Through water allocation scheduling and operation of barrages and link canals water will be supplied to Irrigation Canal Command Areas, DMI services, groundwater recharging, and river environmental flows, etc. The third part is irrigation services management, which takes place within Irrigation Canal Command Areas. Each Irrigation Canal Command Area would have an irrigation services provider and these can be regarded as 'irrigation services undertakers', similar in concept to and to be licensed by the Punjab Water Service Authority in a similar way as the water supply and sanitation undertakers mentioned in the Punjab Water Act 2019.

The rationale for a separation of the bulk water services management and the irrigation service management is easy to understand. Bulk water management needs to ensure water supply to all types/sectors of water use. It should not be perceived as being an integral part of the irrigation service. Therefore, it would be better to have bulk water services managed by personnel who have an open eye for the needs of other sectors, in addition to irrigation services.

The rationale for establishing a unit for water storage management separately is less strong. This is in the first place so because the large reservoirs, serving more than one province, are managed by the national agency WAPDA, with water allocation scheduled via IRSA. It is these IRSA water allocations which determine largely water availability to Punjab Province. On the other hand, the PWP 2018 mentions in its interventions the need to allocate canal flow and diverting flood flows for charging groundwater storage. So, perhaps, if there is not much surface water storage to be managed, then this unit's focus will be heavier on groundwater storage.

Smaller changes to the current organization structure would be

1) Conversion of the Chief Engineer division 'Drainage and Flood' into a Climate change, flood, and drought management unit
2) Expanding of the Chief Engineer division 'Development' into 'Development and transboundary consultations'
3) Establishment of a unit 'Awareness, Education, Research, and Capacity Strengthening', which will work organisation-wide.
4) Establishment of a unit 'Data Centre', for storing and making accessible all PID data.

4.4.6 A PROPOSED WATER RESOURCES DEPARTMENT/OFFICE

This report envisages the PWRC/IWRM-support unit to be a part of a Water Resources Department/Office, together with the two Directorate-Generals that support the PWRC and the PWSRA. The support unit's principal role will be to support the PWRC in decision-making and IWRM program coordination. The support will be in the form of (i) 'water resources status reviews', (ii) monitoring of program progress and impact achieved, (iii) maintaining a water resources

information center, and (iv) providing recommendations for prioritization and coordination of actions to be decided by the PWRC and implemented as part of a Provincial IWRM Program.

The analysis of the PWP's 116 detail-polices identified the capacity centres which the support unit will need. These were used to sketch a first prototype of the WRD's institutional/organization structure, as presented in ***Figure 4-12***. The unit would have three Directorate Generals (DG): namely for (A) 'Punjab IWRM' (this is the support unit proper), (B) 'PWRC secretariat', and (C) 'PWSRA secretariat'. This report is concerned with DG 'Punjab IWRM'. As can be seen in the diagram, it would have four directorates, each with a secretariat-type of section to ensure internal coordination, and a number of capacity centres (here referred to as sections). The organizational units are numbered for ease of reference. For each unit a simple role description is provided. In the lower part of the figure are indicated for each 'Punjab IWRM' capacity centre, the interventions which it will provide support for. The interventions are arranged by line-agency capacity centre. Thus, a relation is established between the 'Punjab IWRM' capacity centres and the Line agency capacity centres. From the figure it can be easily seen that some of the 'Punjab IWRM' capacity centres can be expected to need to work with a large number of line-agency capacity centres.

The 'Punjab IWRM''s Directorate 'Water Allocation and IWRM Programs Co-ordination' is the largest number of interventions to which it is linked: 93. Within this Directorate, the Sections with most links to interventions are: 'Rivers, lakes & reservoirs, aquifers' (30 interventions); 'DMI water use and disposal' (18 interventions), and 'Agriculture and rural water use & disposal and land use change' (30 interventions). 'Punjab IWRM' units working with multiple line-agencies and their capacity centres is exactly what is needed for moving from what historically was a sector-led and 'divided' water resources 'exploitation' to integrated water resources management. The proposed IWRM Work Process and the above set-up of the DG 'Punjab IWRM' have been designed to make integration possible, if not to 'forge integration', through coordination by PWRC, considering the recommendations made by the WRD.

Further detailing of the 'Punjab IWRM' design can be expected to find that the Sections need to have sub-sections or desks for various themes. For example, 'Rivers, lakes & reservoirs, aquifers' may need technical knowledge/capacity needed for (coordination of) river ecology, water storage management (reservoirs and groundwater), flood management, drought management, water quality management. It has to be kept in mind that these sections are not taking over the responsibilities and associated capacity from line agencies and implement IWRM Program activities/interventions but are to provide recommendations for IWRM Program coordination for these IWRM themes.

Notes:

1) Re units 2.1 to 2.4 in the diagram: These combine water scheduling tasks with IWRM programming. The advantage of combining these is that these capacity centres will be confronted with the challenges encountered by line-agencies in the practice of managing water storage, bulk water distribution, irrigation, and DMI water supply. This will help them to recognize and understand the challenges and support their addressing in the Provincial IWRM Program.
2) Is there sufficient justification to separate 'Water allocation and IWRM Program co-ordination' from 'IWRM Program Monitoring & Evaluation'? This report argues that monitoring and evaluation should be 'independent'. Full independency is in practice not achievable. However, separating the unit responsible for monitoring and evaluation from the unit responsible for program coordination adds some measure to independency.
3) The WRD units 2.3 and 2.4 deal both with water use. Does it make sense to combine 2.3 and 2.4? If combined into one unit 2.3 'Water Use', then there could be a further subdivision of the unit according to types of water use, thus agriculture (irrigation) and rural water use, urban water use, and others (e.g. groundwater recharging and environmental flows) water uses.

4.4.7 COMPLIANCE WITH THE OECD'S 'PRINCIPLES ON WATER GOVERNANCE'

The Organization for Economic Co-operation and Development's (OECD) lists in its publication 'Principles on Water Governance', twelve principles, each with a set of recommended concrete arrangements or activities. For the complete

list of principles, see the Legal/Institutional sub-team's report titled 'River Basin Plans and IWRM Framework: Governance considerations and Institutional Structure (its contribution to Deliverable 7: 'River Basin Management Plan' and 13: 'IWRM framework'. The sub-team verified to what extend and in which manner the rationale and the proposed institutional structures comply (or not) with these principles. It concludes that the proposed IWRM Governance and Institutional Structure for Punjab Province provide a rigid structure for formulation and implementation of a well-coordinated provincial IWRM program. The rationale and structures generally comply with the OECD principles where these principles are concerned with structure. However, most of the OECD principles are not directly concerned with structure but are activities to be undertaken. These activities will need to be accommodated in the Provincial IWRM Program and perhaps also in a future update of the Punjab Water Policy.

4.5 DESIGNING CAPACITY CENTRES

This section summarized the contents Deliverable 18: 'Provide additional guidance on the requirements and design of Capacity Centres for effective IWRM and DRM'. The deliverable was prepared by the CDTA Consultant's Legal/Institutional Sub-team.

Under the future Provincial IWRM Governance Structure, the responsibilities for managing the various IWRM-themes (see ToR Para 6 for a list of themes) will be defined and allocated by the Provincial Government to its line agencies. As explained in the section above, the provincial line agencies will need to have one or more basic units for carrying out the responsibilities they have been allocated. With a focus on the IWRM capacity aspect these basic units are referred to as 'Capacity Centres'. Such a centre can be any type of organizational entity and can be of large, medium, or small size, or even just one part-time working individual. Having a clear list of needed capacity centres, each with a description of its management work and needed capacity, will facilitate provincial decision making on the allocation of IWRM responsibilities to its line agencies.

ToR Para 20, 21, and 22 ask the CDTA Consultant to recommend the capacity which the province will need for its IWRM. These Para require among others the CDTA Consultant to:

- Develop a proposal for capacity development of PID to execute the functions as required by the Water Act 2019 and the Punjab Water Policy
- Identify new positions to complement existing positions, job descriptions; and person specifications of the positions to transform the PID into a water resources department
- Review current institutional arrangement within the Government of Punjab including the PID, and propose a Governance structure which minimizes disruption to its day- to-day functions, while meeting the requirements of the Water Act
- Develop a proposal for necessary institutional strengthening of the PID
- Develop duty statements and selection criteria for positions for personnel within the proposed governance structure
- Identify technical, institutional, and policy interventions for IWRM of the river basins;
- Conduct sector analysis working with the Team Leader and other relevant team members;

Particularly the identification of new positions, job descriptions/duty statements, person specifications, selection criteria, will require work highly detailed work. This report argues that Capacity Centres need to be designed with a systematic description of the IWRM-theme management work that will need to be undertaken, which is needed as a basis for the identification of new positions, job descriptions, etc. Such a description would need to be qualitative (types of activities) as well as quantitative (the amount of work) and adequately comprehensive. The detailed work of identifying needed staff positions and preparing job descriptions, etc., will need to be based on the local understanding and in accordance with local traditions, and therefore be done locally. This report regards the CDTA Consultant's technical sub-teams as being in the best position to prepare the capacity centre designs.

In the meeting on 14/06/21 (see Section 10.4.4), ADB consented with the understanding that descriptions of the management work should constitute the basis for identifying the capacity requirements, including staff positions and job descriptions, and that the Consultant's technical sub-teams are in the best position to provide this. guidance does not consider any limitations imposed by available input time and resources to what the Consultancy Team can reasonably produce.

4.5.1 TECHNICAL MANAGEMENT AND REQUIRED CAPACITY

In this report, a 'capacity centre' is an agency unit that manages (part of) an IWRM-theme. From the discussion in Section 10.3 follows that for the design of a capacity centre to serve as an element in the 'holistic plan', it needs to be comprehensive. This is interpreted as meaning that the design needs to describe (i) how the centre needs to technically manage the IWRM-theme, and (ii) the centre's capacity requirement for this management. The capacity centre designs would form a basis for development of other components of the holistic transformation plan, such a Capacity Building Plan and a Road Map.

A capacity centre's 'IWRM-theme management' is its 'daily work', which it will carry out throughout the budget year. Important daily activities of line agencies are monitoring and data collection and processing, planning (among which project-type interventions), annual budgeting, procurement of services, and reporting. This management work is not to be confused with 'project execution': a capacity centre in a line agency is not a project.

Defining the needed technical management for an IWRM-theme requires a good understanding of the theme-related physical phenomena and challenges. Once defined, the management and capacity requirement would be compared with the current management and available capacity. The design would describe the capacity in terms of (i) organization structure, (ii) staffing numbers, qualifications, job descriptions, (iii) annual budget, and other resources). A design of a capacity centre needs to address the gap between the current actual capacity of the organization and the required capacity, by recommending what needs to be improved.

4.5.2 PREPARING A CAPACITY CENTRE DESIGN

For illustration this case for the IWRM-theme of groundwater management. This management will likely require periodical checking of groundwater levels and quality. The following questions reflect the way of thinking when preparing a design of a capacity centre:

- What is the purpose of the required groundwater level and quality checking/monitoring?
- How many monitoring points are needed for this purpose, and where should they be?
- Is the existing grid of monitoring points adequate and, if not, what needs to be improved?
- Will the monitoring be done in-house (thus by own staff) or be contracted out?
- For the relevant case (in-house or contracted out: what is the work process and what are the detailed the activities?
- What is the capacity requirement (think of staffing positions, skills, numbers, etc.)?
- Is the current capacity adequate?
- If not, how can the additionally required capacity be acquired?

In summary, a systematic way of developing a design would be as follows:

1) Describe the (a) current IWRM-theme management and (b) the current capacity of the capacity centre(-s) which have duties in managing the IWRM-theme (distinguish between the capacity 'on paper' and actual capacity
2) Describe the (a) required IWRM-theme management and (b) the required capacity of the capacity centre(-s) which have (should have) duties in managing the IWRM-theme, based on:
    a) the objectives which the IWRM-theme management is required to achieve (refer to the Punjab Water Policy)

b) the size of the management workload in terms of number of monitoring points, length of canals, surface area, volume of water, number of households, etc.)

3) Describe what needs to be done to upgrade the organization's capacity from the current to the required level

In capacity development, the possibility of moving currently available capacity in one organization to another organization should be considered.

4.5.3 A GENERIC TABLE OF CONTENTS FOR A CAPACITY CENTRE DESIGN

The following is a simple Table of Contents for a recommendation:

Title: IWRM Theme

1) Description of the IWRM Theme to be managed and challenges faced by Punjab Province Government
2) Punjab Water Policy 2018's specific objectives and detail-policies relevant for this IWRM Theme
3) Volumes of work involved in this IWRM Theme
4) Currently available capacity, on paper and actual (organization structure; staffing numbers, qualifications, job descriptions; annual budget; and other resources)
5) Recommended management activities and detailed tasks
6) Recommended capacity (detailed as mentioned above)
7) Recommended changes to establish the required capacity
8) Recommended training

4.6 CONCLUDING REMARKS

Punjab Province is on its way to change from a historically developed sector-driven and exploitation-oriented water resources management to one based on IWRM principles. This report assists PID with the transition process by presenting proposals for (i) an overall provincial IWRM Governance Structure; (ii) a provincial IWRM Work Process; (iii) a future Organization Structure for the Punjab Irrigation Department (PID); and (iv) an Organization Structure for the Water Resources Department (WRD). These are key elements of the needed IWRM Framework. They are rigid and suggest that, once adopted and applied, nothing can go wrong anymore on Punjab's path.

However, there are two critical points. The first point is that this governance and institutional structures part of the IWRM Framework has an Achilles heel. For the process to function effectively, it is important that the provincial government leadership and the agency leaders have actually internalized/ adopted/ absorbed the IWRM-way of thinking. If this is not the case yet, chances are that in the work process the recommendations which the WRD is expected to provide will not be valued. This would then result in the wrong decisions being taken. One can expect decisions that reflect the 'old style' of sector-led water resources exploitation. One of the most urgent activities therefore is to assist the provincial government leadership and the agency leaders in adopting the 'IWRM-way of thinking'.

The second point concerns the further detailing of the above IWRM Framework elements. PID has expressed that it needs a holistic (comprehensive) plan for the introduction of IWRM and its transformation process to a WRD. The CDTA ToR reflects this need in its detailed requirements. Illustrative is ToR Para 20, which requires a proposal for capacity development of PID; identification of new PID positions; job descriptions; and person specifications. Para 21 asks for duty statements and selection criteria for positions for personnel within the governance structure. Before these details can be produced, clarity is needed about the larger elements in the IWRM Framework, such as the provincial IWRM governance structure; the envisaged provincial IWRM work process/mechanism; and the principal roles and responsibilities of the IWRM-related provincial agencies. For the Government of Punjab Province to decide and reach consensus on these important large elements will require deliberations and thus time.

Figure 4-1 : Punjab Water Policy (2018) – Water Governance Structure

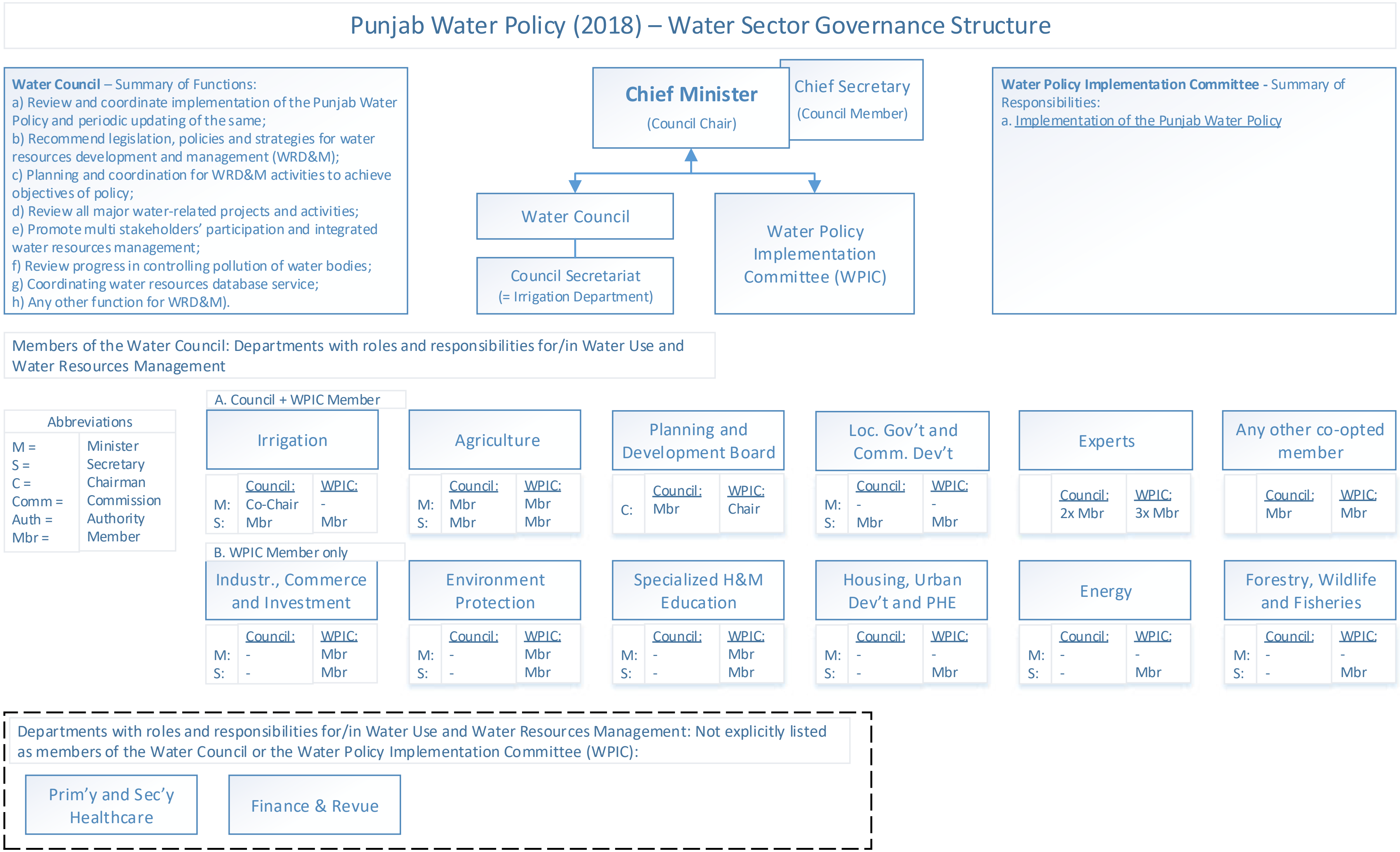


Figure 4-2: Punjab Water Act (2019) – Water Governance Structure

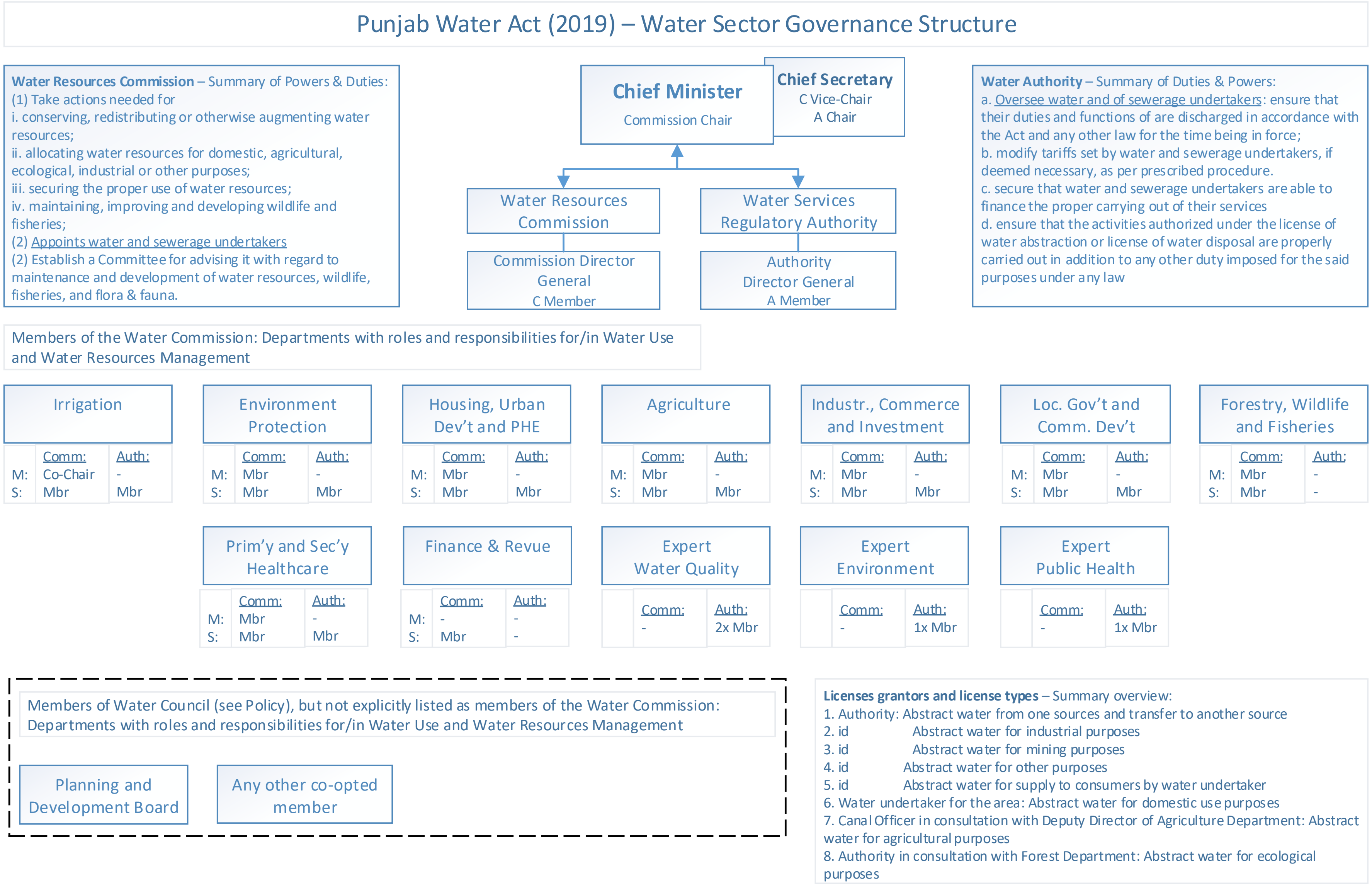


Figure 4-3: Punjab Irrigation Department - Current Organization Structure (January 2021)

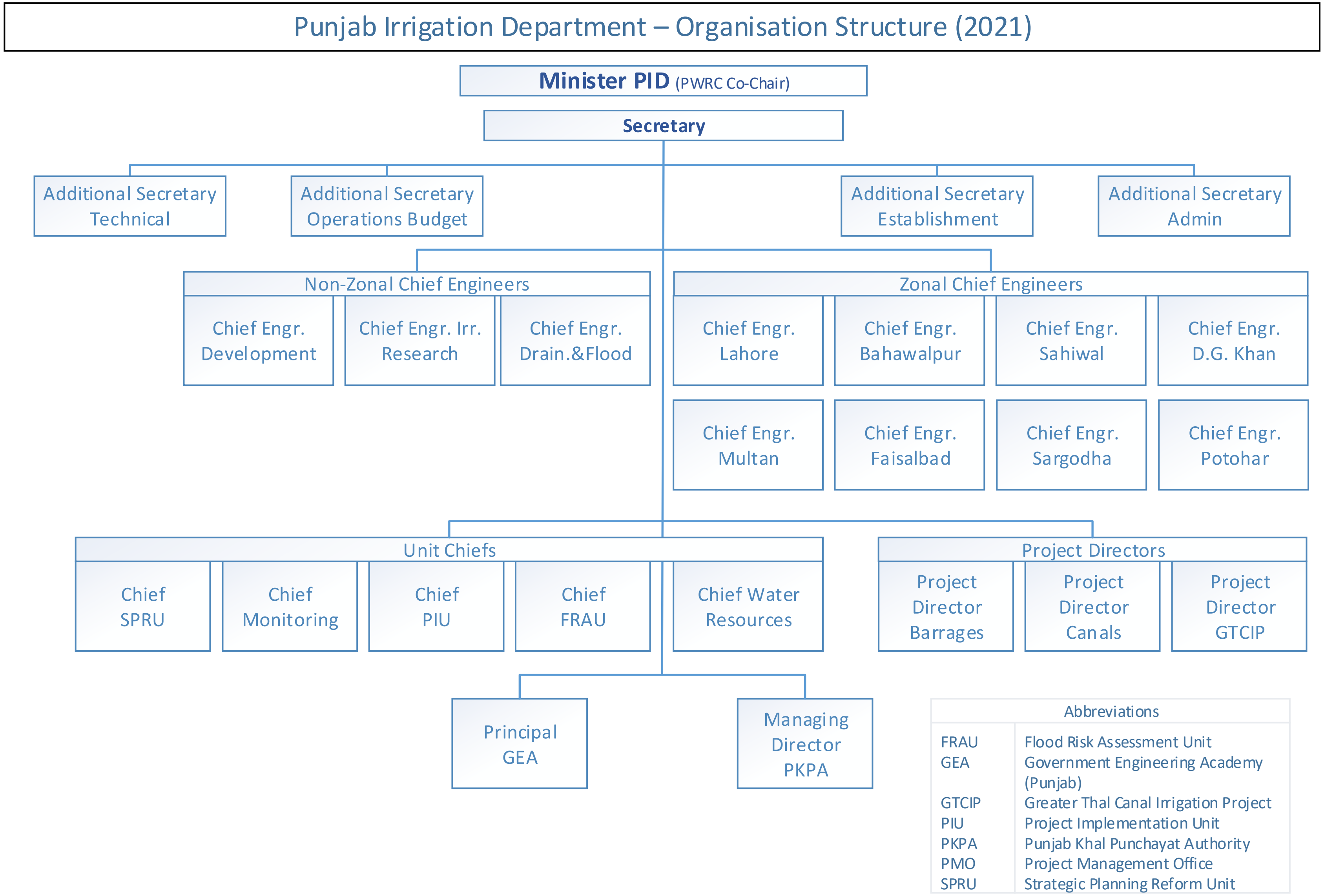


Figure 4-4: Alternative Water Resources and Water Services Governance Structure – A Minimum Disruption Option

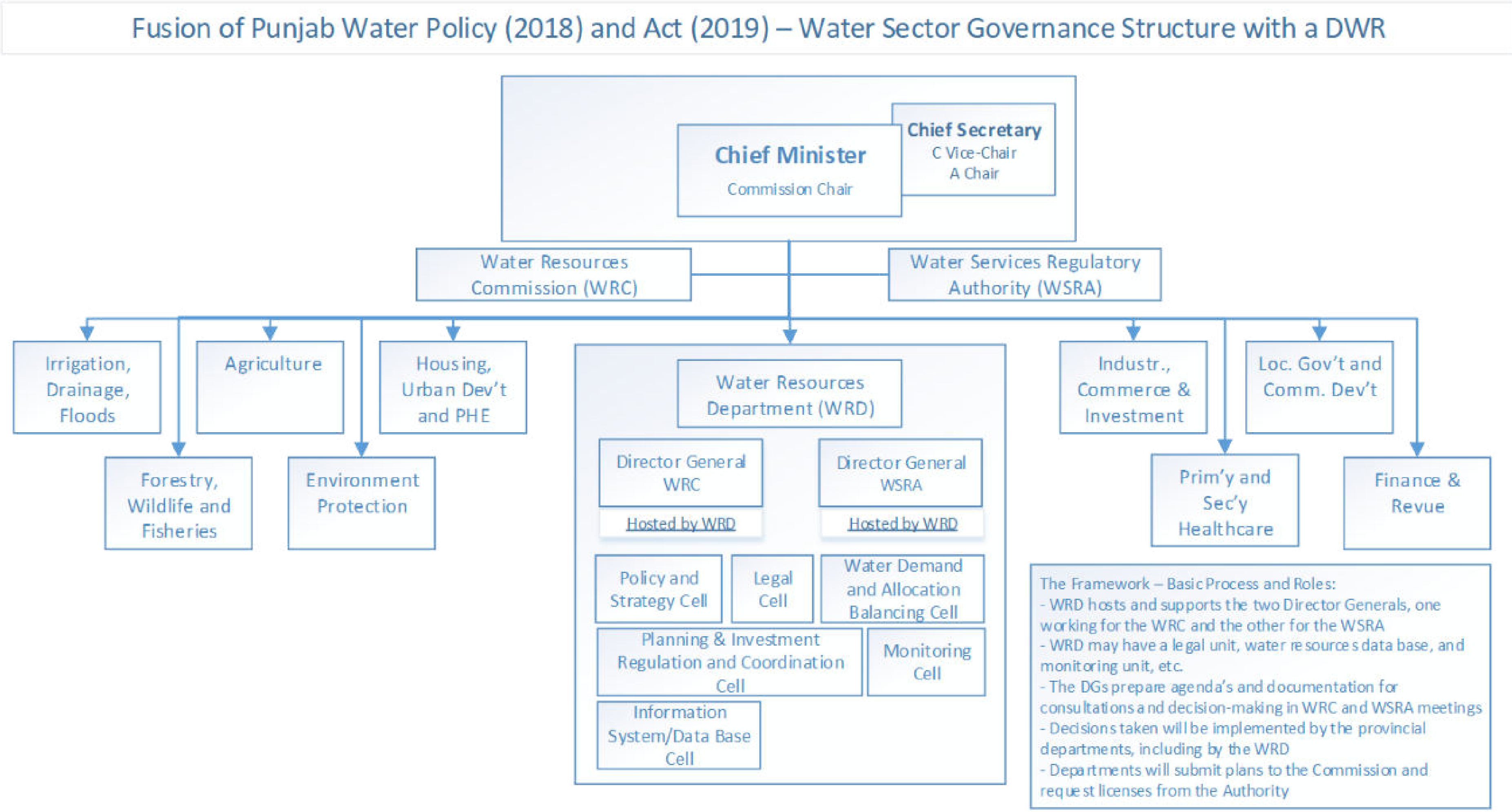


Figure 4-5: Process for Achieving Comprehensive Management of Water Resources

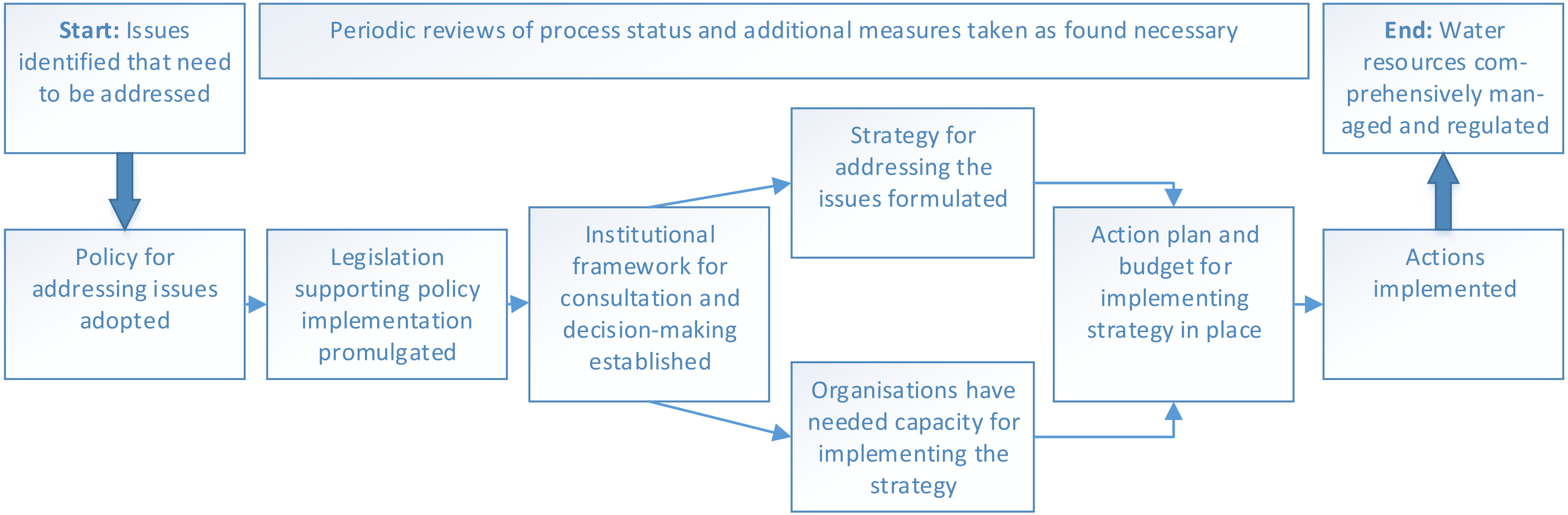
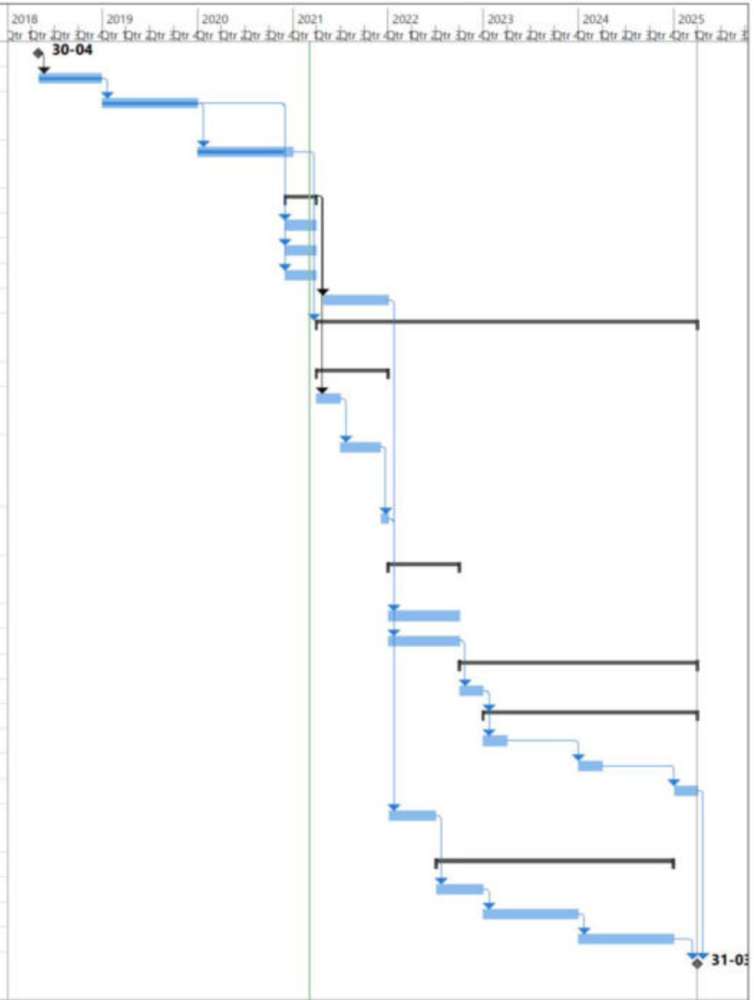


Figure 4-6 : Action Plan Gantt chart for Achieving Comprehensive Management of Water Resources

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Start: Issues identified that need to be addressed	0 days	Mon 30-04-18	Mon 30-04-18	
2		Policy for addressing issues adopted	174 days?	Tue 01-05-18	Fri 28-12-18	1
3		Legislation supporting policy implementation promulgated	261 days?	Tue 01-01-19	Tue 31-12-19	2
4		Institutional framework for consultation and decision-making established	262 days?	Wed 01-01-20	Thu 31-12-20	3
5		**CDTA Review of Status and Consultations**	**87 days?**	**Tue 01-12-20**	**Wed 31-03-21**	
6		Identified most suitable institutional framework	87 days?	Tue 01-12-20	Wed 31-03-21	3
7		Identified need for additional legislation, regulations	87 days?	Tue 01-12-20	Wed 31-03-21	3
8		Identified need for strategy elaboration	87 days?	Tue 01-12-20	Wed 31-03-21	3
9		Strategy for addressing the issues formulated	180 days?	Mon 26-04-21	Fri 31-12-21	5
10		**Organisations have needed capacity for implementing the strategy**	**1048 days?**	**Thu 01-04-21**	**Mon 31-03-25**	**4**
11		**Work procedures and capacity requirement**	**197 days?**	**Thu 01-04-21**	**Fri 31-12-21**	
12		Overall work procedure and requirement for capacity centres identified	65 days?	Thu 01-04-21	Wed 30-06-21	5
13		Detailed work procedures for each capacity centre and required staffing, offices, etc. identified	109 days?	Thu 01-07-21	Tue 30-11-21	12
14		Budget requirement estimated and budget requested	20 days	Mon 06-12-21	Fri 31-12-21	13
15		**Establishment of organisational units (capacity centres)**	**196 days?**	**Sat 01-01-22**	**Fri 30-09-22**	
16		Provision of offices and facilities	196 days?	Sat 01-01-22	Fri 30-09-22	14
17		Staff recruitment and assignment	196 days?	Sat 01-01-22	Fri 30-09-22	14
18		**Staff training**	**655 days?**	**Sat 01-10-22**	**Mon 31-03-25**	
19		Initial training	67 days?	Sat 01-10-22	Sat 31-12-22	17
20		**Periodical reviews and follow-up training**	**588 days?**	**Sun 01-01-23**	**Mon 31-03-25**	**19**
21		Annual review 1	66 days?	Sun 01-01-23	Fri 31-03-23	19
22		Annual review 2	66 days?	Mon 01-01-24	Sun 31-03-24	21
23		Annual review 3	64 days?	Wed 01-01-25	Mon 31-03-25	22
24		Action plan and budget for implementing the strategy are in place (includes technical work to be identified)	129 days?	Mon 03-01-22	Thu 30-06-22	9
25		**Actions implemented**	**654 days?**	**Tue 05-07-22**	**Mon 30-12-24**	
26		Year 1	131 days?	Tue 05-07-22	Sat 31-12-22	24
27		Year 2	261 days?	Sun 01-01-23	Sun 31-12-23	26
28		Year 3	262 days?	Mon 01-01-24	Mon 30-12-24	27
29		Water resources comprehensively managed and regulated	0 days	Mon 31-03-25	Mon 31-03-25	28,23



Project: 210306 - Flow chart an
Date: Sat 06-03-21

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Figure 4-7: Water Sector Governance Structure - Optional Variants (October 2021)

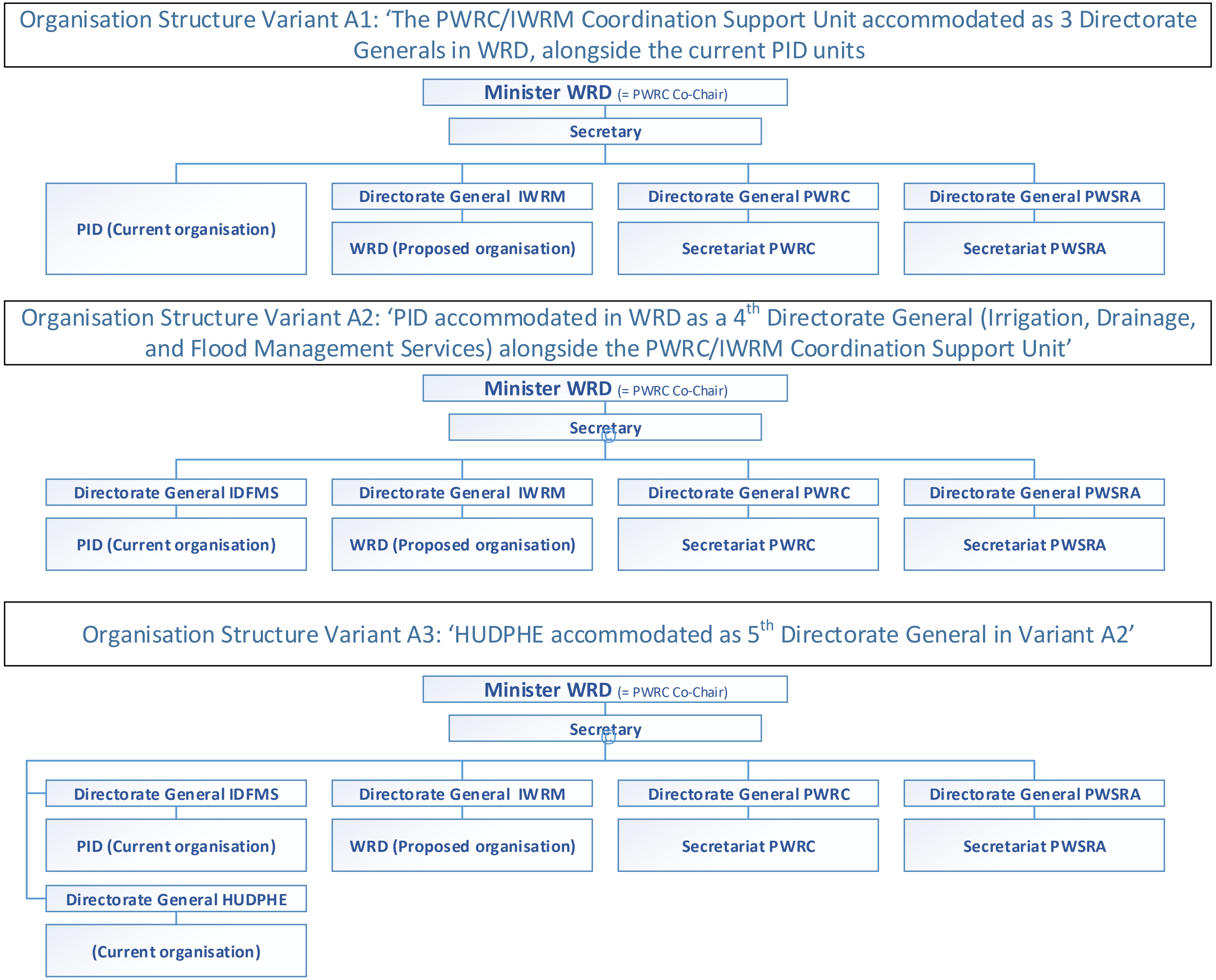


Figure 4-8 : Water Sector Governance Structure - Optional Variants

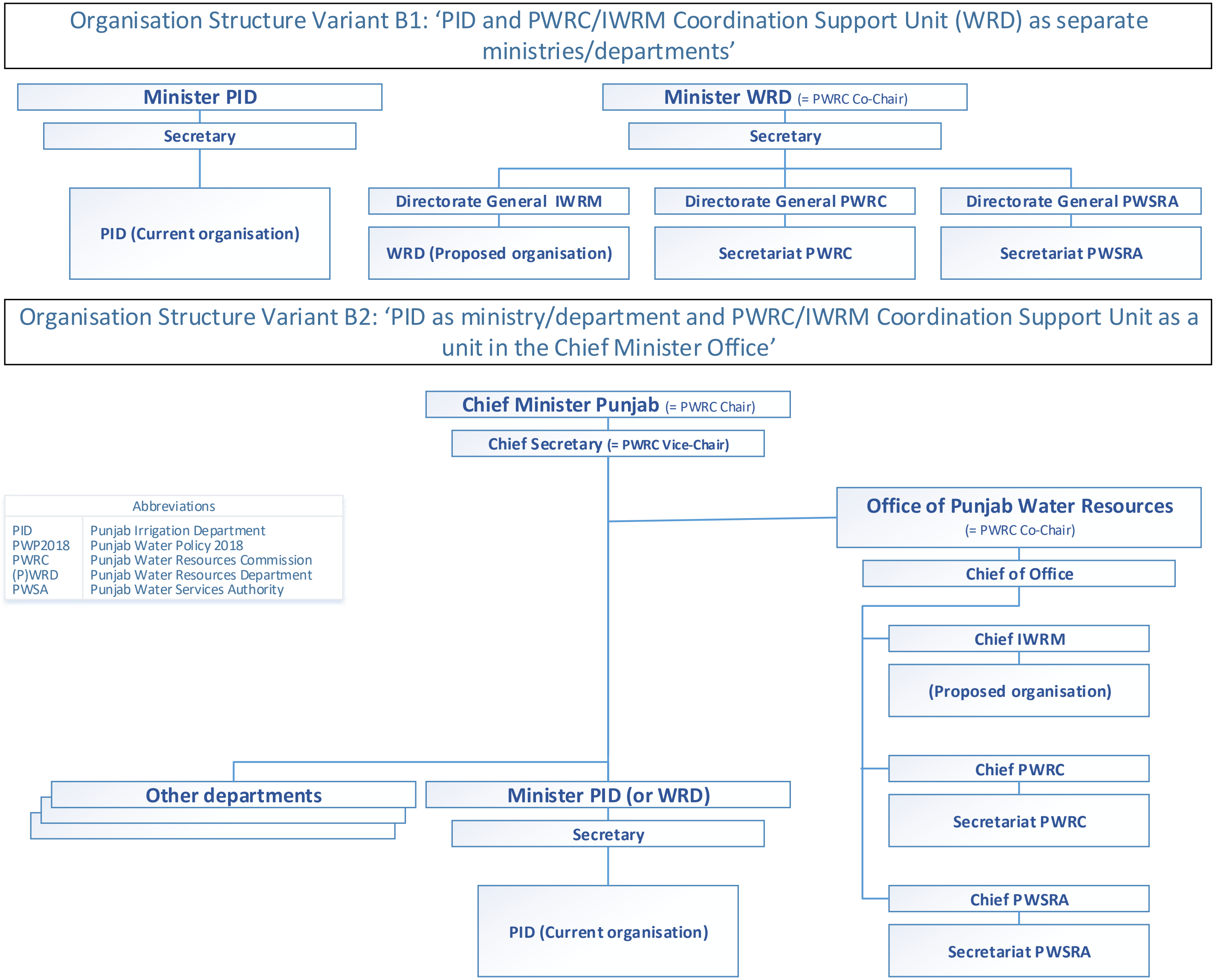


Figure 4-9 : Three, two or just one Director General

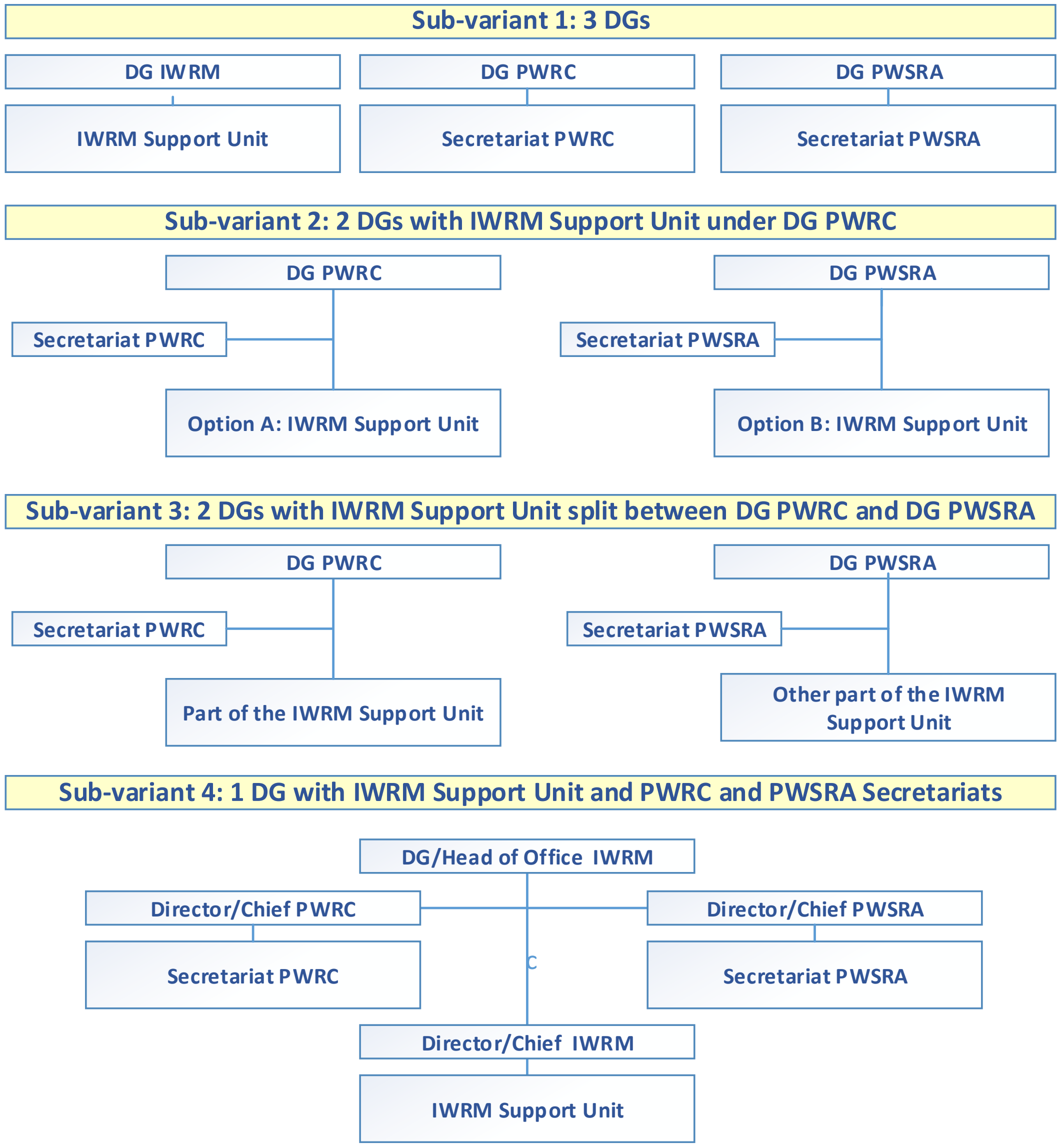
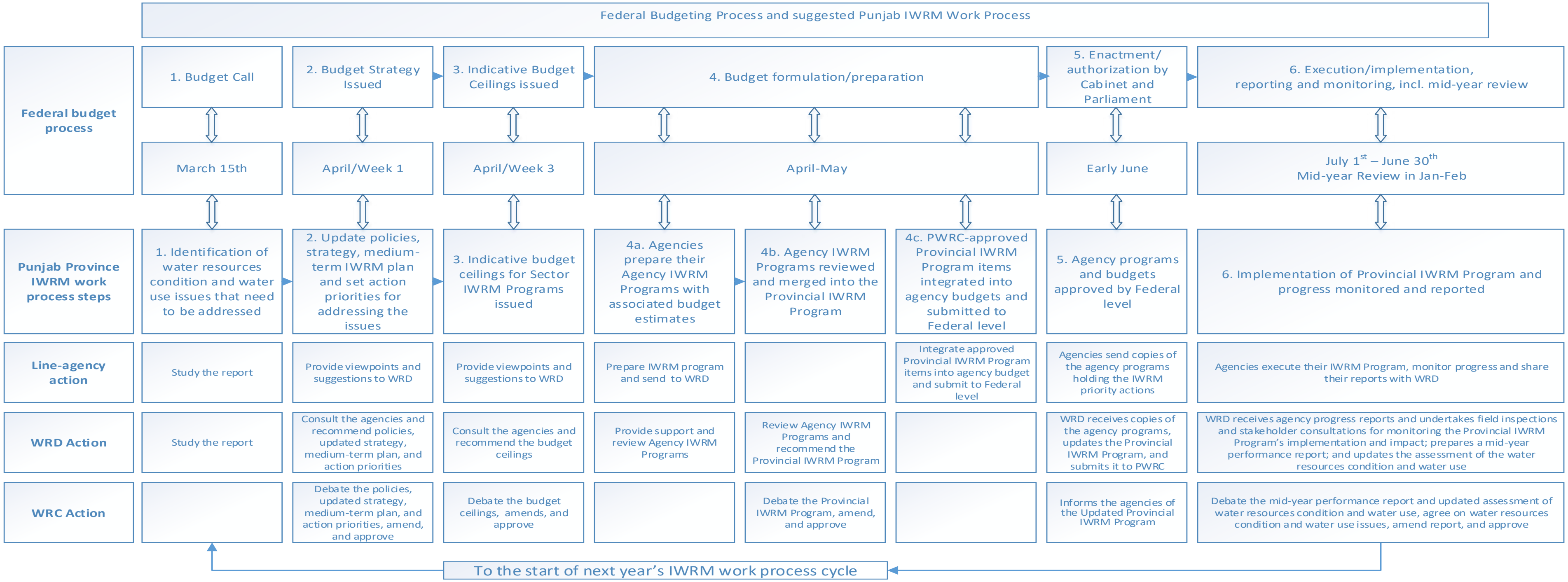


Figure 4-10: IWRM Work Process



Notes:
1) **Punjab Province IWRM work process,** Step 1: The PWP 2018 includes an initial Identification of water resources condition and water use issues that need to be addressed.

Federal Budget Calendar 2021-2022

S #	Activities	Responsible	Timeline (Last date)
1.	Submission of Current & Development Expenditure Budget Estimates (Form-II and Form-III)	PAOs	15th March, 2021
2.	Development of Budget Strategy Paper	Finance Division	2nd week of March, 2021
3.	Demand Review Committee's meetings (if required)	Finance Division	1st week of April, 2021
4.	Submission of Budget Strategy Paper to the Cabinet	Finance Division	1st week of April, 2021
5.	Issuance of IBCs for current and development budget	Finance Division	3rd week of April, 2021
6.	APCC & NEC meetings	Planning Division & Finance Division	April, 2021
7.	Submission of BO/NIS Forms for current budget	PAOs	26th April to 14th May, 2021
8.	Submission of BO/NIS Forms by Ministries / Divisions for development budget	PAOs	10th to 21st May, 2021
9.	Completion of all Budget Documents, Schedules and Summaries for the Cabinet etc.	Finance Division	End of May, 2021
10.	Presentation of Budget to the Cabinet and the Parliament	Finance Division	1st Week of June, 2021

Source: Government of Pakistan, Finance Division: Budget Call Circular 2021-2022 (available at https://www.finance.gov.pk/budget/Budget_Call_Circular_2021_22.pdf)

Figure 4-11: Punjab Irrigation Department - Optional Future Organization Structure (January 2021)

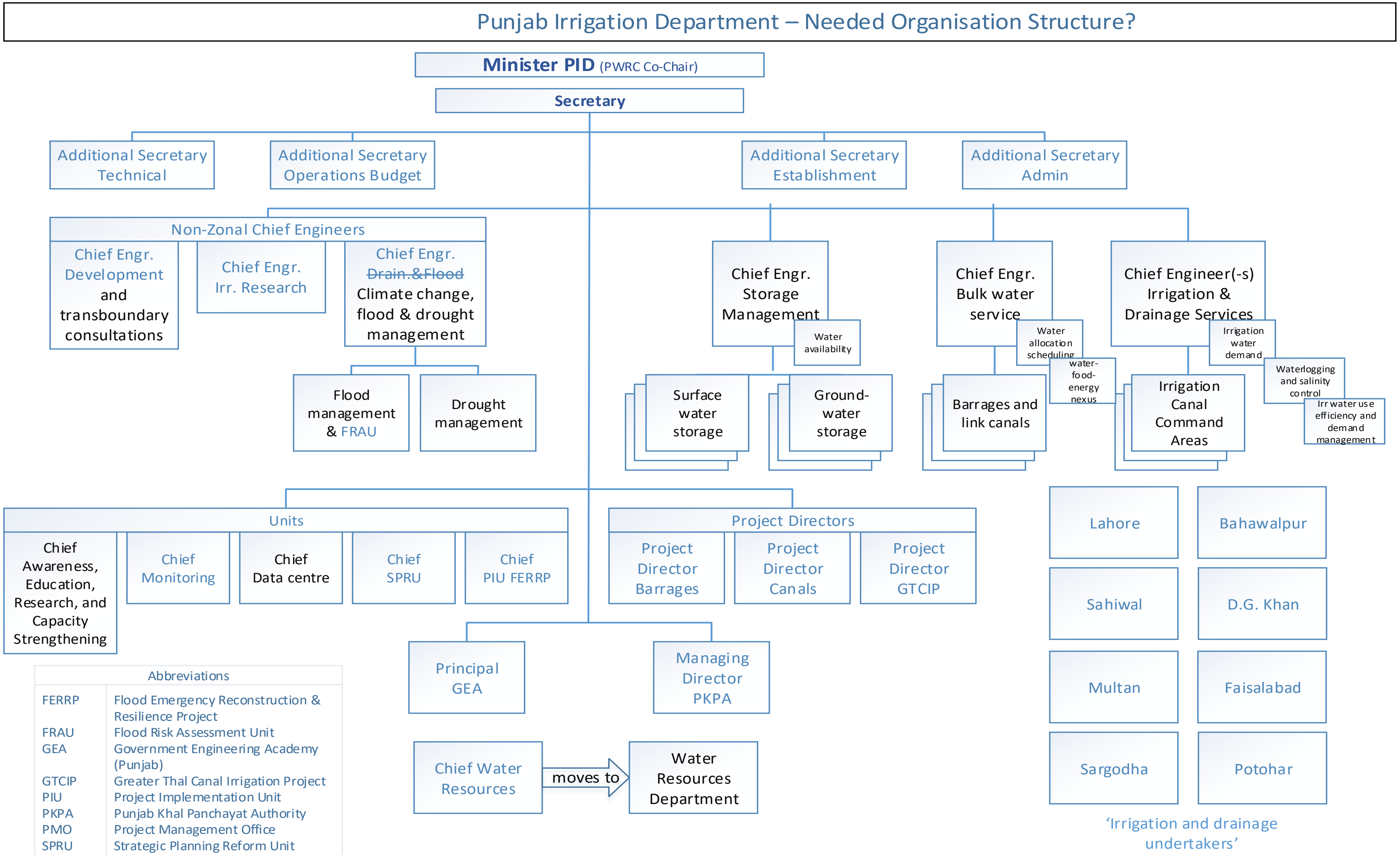
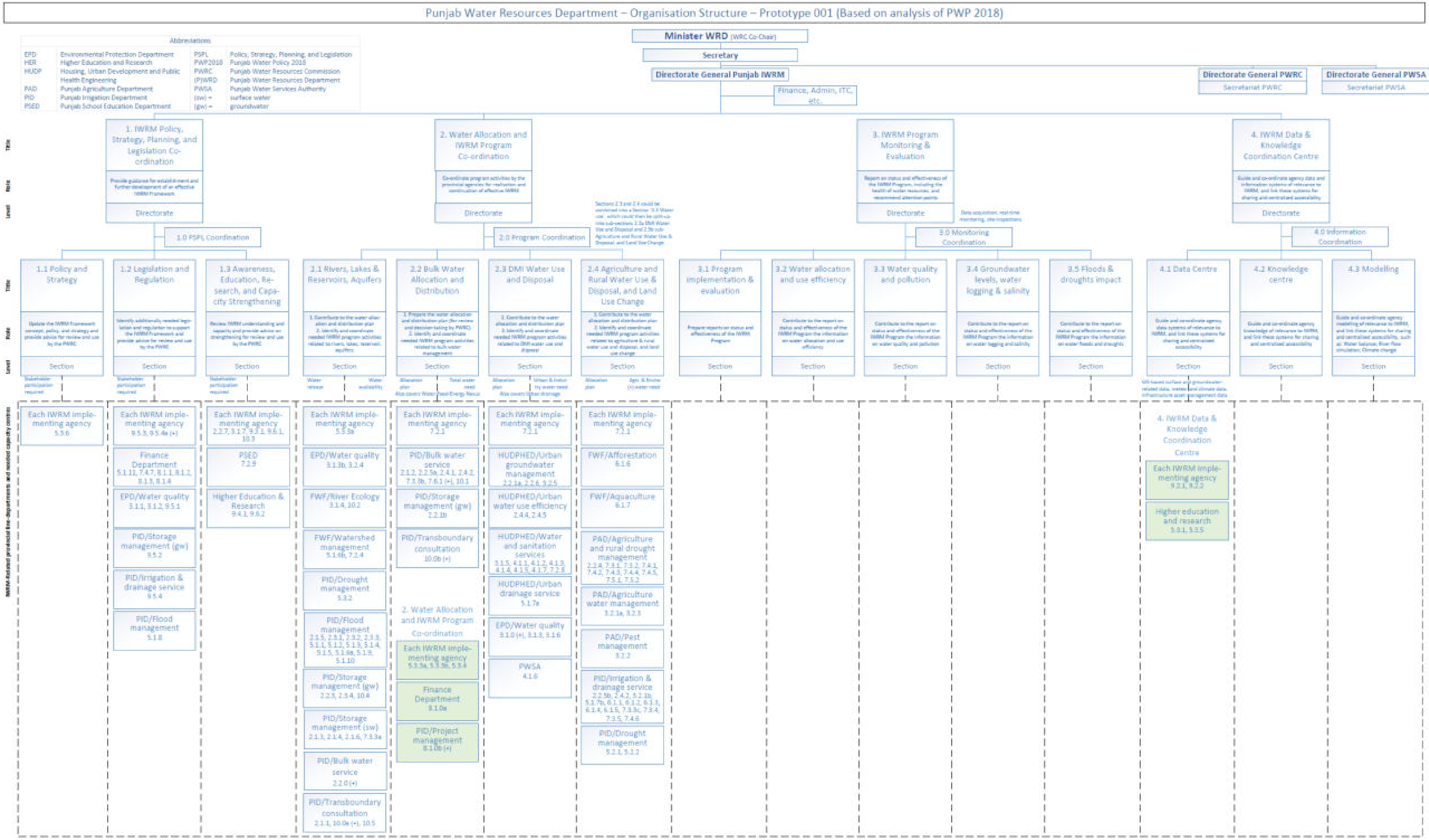


Figure 4-12: Proposed Water Resources Department/Office with PWRC/IWRM Coordination Support Unit - Prototype 001



5 GROUNDWATER MANAGEMENT

5.1 INTRODUCTION

Pakistan's Punjab is the heartland of irrigated agricultural production in Pakistan and is a major user of surface water and groundwater. About 90 percent of water use is for irrigated agriculture. However, irrigation efficiency and water productivity are lower than most countries in Asia (see Punjab surface and groundwater facts, Box 3.1). The fresh groundwater reservoir underlying the alluvial basin in Punjab has largely developed as a result of seepage losses from the extensive irrigation network. The Punjab Irrigation Department (PID) has recognized the need for improving the use and management of groundwater resources to meet growing demand for water for domestic, industrial use and urban growth centres, and for irrigated agriculture.

Box 3.1 Punjab Surface and Groundwater Facts

- 90% of all water used in Punjab is for irrigated agriculture, and 70% of drinking water is supplied from groundwater.
- Annual groundwater abstractions in the canal command areas of Punjab are about 55.5 BCM (45 MAF) which means the present share of groundwater supply for irrigation is approximately equal to canal supplies (Punjab Water Policy 2020).
- All water resources in Punjab are already committed. No additional surface water sources are foreseen.
- Groundwater abstractions and groundwater recharge almost balances (Young et al 2019). However critical areas in various sub-basins (e.g. Lower Bari Doab) are water stressed with groundwater levels and quality declining.
- Groundwater mining of some of the critical aquifers (such as Lahore) has already triggered reallocation from surface water for Lahore city.
- Groundwater mining in critical urban areas (Lahore and Multan) results in declining groundwater levels and water quality which has serious implications for human health and wellbeing and increases the cost of abstraction for water suppliers.
- Prolonged drought in the future will stress the dwindling groundwater resource and should be addressed under long-term planning.
- Inter-river water transfer from the Indus and Jhelum rivers to the drying river basins of Ravi, Beas and Sutlej has exhausted this source left little opportunity for further exploitation.
- Groundwater is dependent of surface water recharge (rivers, canals and irrigation fields) and rainfall. Therefore, surface water and groundwater operate as connected systems and actions that affect one can affect the other.
- Options for additional water are limited. Hence, management of all available water resources is critical for all uses and users.
- Water quality has declined reducing the availability of good quality water in future.
- Recycling used water and its safe uses has not been explored.
- Reallocation from agricultural water use appears to inevitable in future (in fact it has already started in some areas).

5.1.1 IMPORTANCE OF GROUNDWATER IN PUNJAB

Groundwater contributes over 50% of irrigation water supplies to 16 million ha of cropped land (8.4 million ha) and 70% of domestic water supplies to a population of 110 million in Punjab (2017 census). The contribution of groundwater to irrigation has increased steadily from about 10% in the 1960's to more than 50% in 2018. Groundwater pumping by over one million farmer owned tubewells has been the driving factor for increasing the cropping intensity from 67% to around 131%. Agriculture in Punjab contributes 20% of Punjab's GDP and provides 40% of jobs for skilled and unskilled labour. The dependence of agriculture on different sources of water in Punjab is provided in **Figure 5-1**.

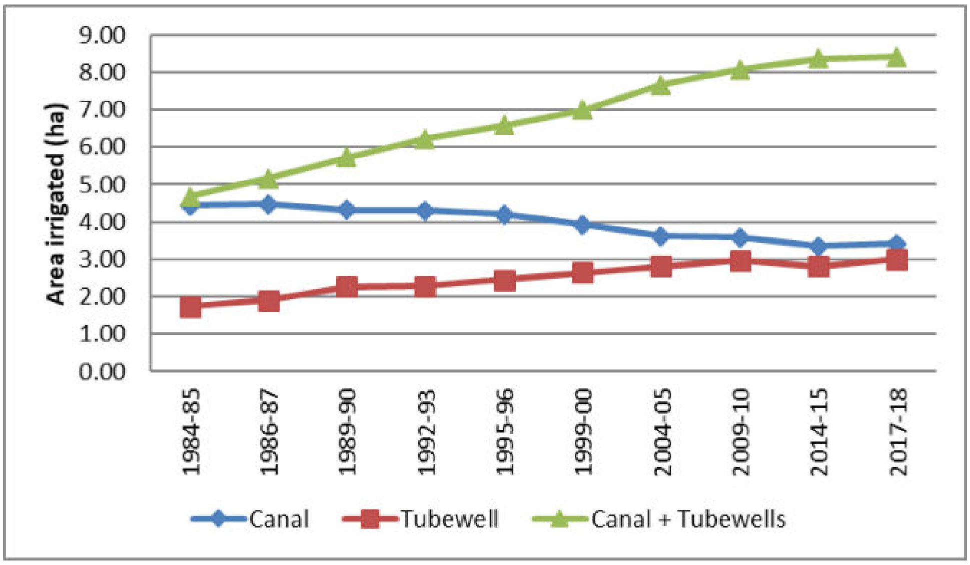


Figure 5-1 : Sources of Irrigation Water in Punjab (Source: Agri. Statistics of Pakistan 2017-18)

5.1.2 POLICY PROVISION

5.1.2.1 GROUNDWATER ABSTRACTION

The PWP (2018) has indicated that the sustainable groundwater abstraction in the province is around 53 BCM (43 MAF), with 60% in the fresh groundwater zone and the rest in the marginal to brackish zones. Close to 50% of irrigation water requirements in Punjab are now being met by groundwater. This means that about 21 BCM (17 MAF) abstractions are from marginal to brackish groundwater. In these areas, improved distribution of surface water supplies, coupled with improved conjunctive use practices, are essential to maintain agricultural productivity. The PWP also states that around 55.5 BCM (45 MAF) of groundwater is being abstracted annually in the province indicating net over abstraction of 2.5 BCM (2 MAF). The resultant lowering of the water table is severest in large urban centres (e.g., Lahore, Rawalpindi, and Multan).

To ensure sustainable groundwater abstraction, monitoring measures need to be strategic and the approach to monitoring should be linked to defined objectives. This will ensure that monitoring data serves to support the PWP. Spatial and temporal monitoring data will also provide the means to develop basin scale and sub-basin scale maps for groundwater status reporting and groundwater planning. Monitoring is also essential to enable the WRD to develop a suite of groundwater models which can provide a basis for developing groundwater budgets at the sub-basin (doab) scale which will give a much-improved assessment of recharge and discharge for each sub-basin. Monitoring of depth to water (DTW) and electrical conductivity (EC) of the groundwater is required for assessing the lateral and vertical movement of saline zones into freshwater zones, and to ensure the long-term sustainable management of freshwater zones. The PWP also calls for appropriate technologies to ensure skimming of fresh groundwater layers overlaying saline zones. The PWP further advocates the promotion of groundwater recharge measures, as 40% of recharge comes from seepage from the irrigation system. The PWP recommends that the lining of canals and distributaries should not be undertaken without proper feasibility studies.

In addition, the PWP indicates that regulatory mechanisms are required to be put in place and enforced, to control over-abstraction in critical zones. It recommends a Water Resources Commission be established, which will be responsible for allocation and management of water resources for different purposes.

To develop sustainable groundwater abstraction, following policy should be adopted

- Groundwater abstraction should be optimized at balance recharge
- Water Resources Commission should be created to manage groundwater extractions
- Artificial Recharge of groundwater through flood channels, rubber dams, detention ponds, rainwater harvesting, etc.
- Incentives should be given to households, communities for rainwater harvesting and artificial recharge
- Seepage through canal system in saline zones should be restricted through lining
- Urban groundwater pumpage in major cities e.g. Lahore, Gujranwala, etc. should be managed and supplemented by surface water
- Awareness raising and capacity building of the stakeholders must be ensured

5.1.2.2 GROUND WATER QUALITY

It is estimated that 5.6 million tons of fertilizer and 70 tons of pesticides are used annually in agriculture in Pakistan (Brisco and Qamar, 2005). A major portion is consumed in Punjab. The use of pesticides is increasing by 6% annually. A study by EPA Punjab [2005] collected 280 samples from all over the province and found that 25% of samples contained concentrations of heavy metals that exceeded WHO limits. The quality of water in shallow wells and tubewells around cities is affected by domestic and industrial effluents. The majority of samples analyzed for large cities and peri-urban areas are polluted with bacteria, heavy metals and chemicals.

A major source of pollution in Punjab is industrial and municipal effluents, resulting in accumulation of heavy metals and trace elements in groundwater aquifers and surface water bodies. Over-abstraction of groundwater leads to progressive deterioration of fresh groundwater sources, from lateral and vertical movement of deeper saline groundwater. Other pollution sources include drainage effluents and disposal of saline water into canals, which disproportionately affects downstream users. Salinity of groundwater varies widely, ranging from less than 1,000 ppm to greater than 3,000 ppm. Some 5.75 million ha are underlain with groundwater having salinity less than 1000 ppm, 1.84 million ha with salinity ranging from 1,000 to 3,000 ppm; and 4.28 million ha with salinity greater than 3,000 ppm. Improved monitoring systems will allow identification of salinity hotspots and will allow improved management of saline groundwater areas.

For groundwater quality, following policy should be adopted

- Maximum efforts to be undertaken to prevent saltwater intrusion into fresh groundwater zones
- Introduce biological control methods for Pest Management instead of use of pesticides for crops
- Control and monitor use of brackish water for agriculture
- Ensure effective enforcement of regulations for managing the heath of aquifers in collaboration with EPA
- Integrated Solid Water Management Plan and siting of Landfill sites to prevent seepage into groundwater

5.1.2.3 WATER RESOURCES COMMISSION

The Punjab Water Policy (PWP; 2018) provides policy direction for sustainable management of water resources for all type of water uses. It covers water availability, water quality, groundwater abstractions, water and sanitation standards, climate change, land resources, water demand management, governance, knowledge and database and capacity building. Punjab Water Act (2019) requires the formation of a provincial Punjab Water Resource Commission (PWRC) and a provincial Punjab Water Services Regulatory Authority (PWSRA) and water and sewerage undertakers.

To sustainably manage groundwater resources the Punjab Water Policy recommends that a Water Resources Commission be set up. The functions will include manage groundwater abstraction to balance groundwater abstraction and recharge, artificial recharge of groundwater; incentives to households and communities to encourage rainfall harvesting; lining canals in saline zones to control seepage; urban groundwater abstraction (e.g. Lahore, Gujranwala) should be managed and supplemented by surface water; and awareness and capacity building of stakeholders.

The Punjab Water Policy highlights the importance of groundwater resources in Punjab and provides directives for managing groundwater abstraction for agricultural production, minimizing the impact of soil salinization and to prevent water quality deterioration to minimize health impacts. The central theme is to balance recharge and groundwater abstractions through monitoring and regulation, reallocation of canal allowances, and by promoting artificial recharge in communities. The policy focus on enhancing water availability and improving water quality is to ensure improved potable water for communities, use of groundwater as a buffer during droughts, water conservation, and managing waterlogging and salinity.

It is imperative that the development of plans over the next 3-5 years is undertaken on an informed basis. And that means a step change in monitoring groundwater resources, data analysis, development of appropriate scale models, and forecasting by way of scenario analysis so that information provided to management in WRD and the Water Resources Commission is accurate and can provide a suitable basis for decision making and planning.

5.1.2.4 PUNJAB WATER ACT

The Punjab Water Act 2019 has been passed by the provincial assembly of Punjab on November 20, 2019. Under this Act it was directed to establish Punjab Water Commission within six months. However, the commission has not yet been established. The Commission will be headed by the Chief Minister and ministers and secretaries will be members of the commission. The Commission shall determine on water allocations for domestic, agriculture, industrial, ecological and other purposes a yearly basis.

The Punjab Water Services Regulatory Authority was to be established within 6 months, which is yet to be established. Chief Secretary Punjab will be the chairperson of the authority. The authority will have powers to revise tariffs set by water supply and sewerage undertakers, if deemed necessary as per prescribed procedures.

5.1.3 ISSUES RELATED TO GROUNDWATER QUANTITY, QUALITY, AND USE

Based on past studies, the following issues have been identified (Bhutta 2015):

- Groundwater needs to be managed conjunctively with surface water supplies.
- Over exploitation results in: saltwater intrusion; increased pumping costs due to deeper water levels and small farmers in some canal commands have been deprived of access to groundwater.
- Insufficient surface water supplies at the tail-end of canal commands are resulting in farmers using marginal quality groundwater, which results in land degradation and reduced productivity of agriculture.

- Progressive depletion of groundwater is occurring, particularly near urban centres and in canal commands with lower water allowance.
- Control on pumping is difficult to implement as there are over 1 million tubewells in Punjab.
- Uncontrolled groundwater use can result in land subsidence.
- Recharge augmentation using managed aquifer recharge has not been extensively adopted.
- Evidence of deterioration of groundwater quality from pollution.
- Salt accumulation in the root zone due to dependence on groundwater.
- The importance of monitoring and research in groundwater is not realized and is not adequately financed or staffed.

5.1.4 GROUND WATER USE

The number of tubewells by type of prime movers and annual groundwater pumpage in Punjab are given in **Figure 5-1,** including utilization factors and discharges. The estimated total pumping in Punjab is 54.04 MAF (66.66 BCM), which includes both CCA and non-CCA areas.

Table 5-1: Tubewell Number, Prime Mover type and Estimated Annual Pumpage in Punjab

TUBEWELL TYPE	CCA-DIESEL	CCA-ELECTRIC	NON-CCA-DIESEL	NON-CCA-ELECTRIC
Total Number of Tubewells	765,409	128,236	188,920	31,815
Days Per Year	124	183	124	183
Hours Per Day	4.6	6	4.5	6
Discharge (CFS)	0.725	1.5	0.7	1.5
Pumpage per tubewell (AF)	26,159,276	17,454,933	6,098,525	4,330,521
Total Pumpage (MAF)	**43.61**		**10.43**	

Source: Agriculture Statistics of Pakistan-2017-18 Note: Estimates are for all of Punjab

5.1.5 SURFACE WATER USE

Average annual, Rabi (winter) and Kharif (monsoon) surface water use in Punjab are 49.58 MAF, 16.44 MAF and 33.13 MAF respectively (PID Data 2007-2020). The agricultural tubewells in the seven sub-basins of Punjab are given in **Table 5-2** (Agriculture Statistics of Pakistan 2017-18). Canal water supplies data were collected from PID for the period of 2007 to 2020. Average annual surface water availability is given at the canal head, watercourse head and field level in **Table 5-2.** he important message from the table is that groundwater available in all the sub-basins exceeds surface water at the canal field level. Access to this groundwater has allowed farmers to increase cropping intensities significantly in Rechna Doab. The groundwater in all doabs is vital for food security and to meet municipal and industrial needs and requires urgent attention to improve resource monitoring, modelling and management.

Table 5-2: Share of Surface water supplies and Groundwater Extractions in Punjab Sub-basins.

PUNJAB SUB-BASIN	SHARE OF WATER (MAF)					
	Surface water			Rainfall	Groundwater	
	At Canal Head	At Watercourse Head	At Field	At Field	At Watercourse Head	At Field
1-Bari	11.820	9.24	6.47	7.796	10.755	9.70
2-Rechna	10.957	8.57	6.00	9.537	10.932	9.84
3-Chaj	4.010	3.14	2.20	5.314	4.649	4.18
4-Thal	7.512	5.87	4.11	4.338	6.731	6.06
5-Bahawalpur	11.822	9.24	6.47	1.845	8.120	7.31
6-D.G. Khan	2.747	2.15	1.51	0.787	1.786	1.61
7-CRBC	0.710	0.56	0.39	0.514	0.617	0.56
Total MAF	**49.581**	**38.77**	**27.15**	**30.131**	**43.610**	**39.26**
Total BCM	**61.157**	**47.82**	**33.49**	**37.166**	**53.792**	**48.42**

5.1.6 GROUNDWATER MANAGEMENT AND REFORMS

Punjab faces major challenges in managing and regulating groundwater, these include: (i) growing water shortages which impacts agricultural production, human health and constrains industrial production; (ii) progressive deterioration of irrigation infrastructure which has a significant impact on downstream users such as farmers at the tail end of canals who resort to exploiting marginal quality groundwater; (iii) low water productivity; (iv) lack of transparency and inequities in access to groundwater due in part to water quality constraints; (v) significant lack of capacity within existing institutions for monitoring, modelling and management of groundwater resources; (vi) strengthening capacity to implement the Punjab water policy and Punjab water act; (vi) significant groundwater quality concerns particularly in urban areas due to disposal of untreated industrial and municipal effluents; and (vii) over exploitation of groundwater in parts of the doabs of Punjab.

Punjab's mid-term development framework, 2015–2018 prioritized reliable irrigation supplies, enhanced agricultural productivity, improved rural economy, and broad-based institutional reforms. In 2015, the 'Punjab-ADB dialogue on water' which considered the impacts of the historic piecemeal reforms and future challenges culminated in a recommendation to transform PID into a Water Resource Department with ADB financial support for the Punjab's reform program.

5.1.7 INSTITUTIONAL TRANSFORMATION OF THE PID

Since the 1980's, the use of groundwater for irrigation in Punjab has increased substantially. It now supplies almost 50% of irrigation water for agriculture, and also supplies domestic water for many cities and towns as well as industrial demand. The management of groundwater has long been neglected. With increasing demand for water, PID will need the capacity and institutional support to manage its vast fresh groundwater resources for a sustainable future. Given this scenario the ADB requires a comprehensive policy and institutional review and a transformation of PID into a responsive Water Resources Department (WRD).

The focus of the CDTA with respect to groundwater management is to ensure that the WRD acquire improved capacity in groundwater resource planning and management, groundwater management and marginal quality groundwater management. The key deliverables are as follows:

- Short to medium term plan for Groundwater management including aquifer recharge options in Punjab.
- Water budget at basin and sub basin level.
- Groundwater monitoring plan
- Establishment of groundwater data base for the WRIS
- Proposed Groundwater Structure for IRI

5.2 GROUNDWATER MANAGEMENT PLANS FOR SUB-BASINS IN PUNJAB

Groundwater Management Plans have been prepared for the following regions:

- Bari Doab
- Rechna Doab
- Chaj Doab
- Thal Doab (Sindh Sagar)
- Bahawalpur sub-basin
- DG Khan
- CRBC Sub-basin

The Groundwater Management Plans include: an analysis of historical water table data and trends; a water balance analysis and assessment of sustainable yield; a monitoring plan to assess groundwater levels and water quality; Management options. Details of the Groundwater Management Plans are provided in the separate Report on Groundwater Management Plan (Volume III). The detailed report also contains a section on Groundwater resources of Pothohar and areas outside the CCA.

Water Balance – Punjab sub-basins: The net groundwater depletion was estimated at -1.15 BCM (-0.933 MAF) for the irrigated sub-basins in Punjab (Bari Doab, Rechna Doab, Chaj Doab, Thal doab, Bahawalpur sub-basin, DG Khan sub-basin and CRBC sub-basin). These estimates are based on water balance analysis and are in broad agreement with current estimates of groundwater depletion in Punjab. Generally, as the depth to watertable increases the quality of the groundwater declines. It is evident from groundwater quality trends that lowering of groundwater table leads to deteriorating groundwater quality in the eastern doabs and Bahawalpur sub-basin. In these deep alluvial aquifers both water quality and depth to water will act as constraints, as pumping from deeper depths will also increase the cost of operation for irrigators.

The water balance estimates based on infiltration and seepage estimates from previous studies undertaken by WAPDA, PAD and PID. As the groundwater system is inherently complex with varying temporal stresses, we recommend that a groundwater model be developed as part of future development and implementation of a groundwater management plans for each sub-basin in Punjab.

Water Balance – Bari Doab: In the Bari doab there is a small decline in net groundwater storage of -0.269 BCM (-0.218 MAF) per annum. However, despite a small net loss in storage, long term water level declines are occurring in parts of the Lower Bari Doab which indicates that regulation of pumping will be required to control pumping in hot spots, and also to regulate and license large water users. The depth to watertables in the 10-15m and >15m range has increased substantially. The depletion of the watertable in the >15m depth range is significant, as it covers much of the southern and south-eastern regions of the doab, starting from Pakpattan and extending to cover Vehari, Khanewal, Multan and Lodhran to the south. The depth range from 10-15m covers Lahore and areas to the north and north-east of Lahore; and covers Kasur and Okara which were within 6-10m in 2006.

Water Balance – Rechna Doab: In the Rechna Doab there is a negative net groundwater balance of -0.348 BCM (-0.282 MAF) per annum which will require identifying hotspots and also licensing of high-water users. The mean depth to watertable in Rechna doab does not show much variation other than in 2018, which may be due to lower rainfall. However, there is evidence of declining watertables in selected areas such as Chiniot and Toba Tek Singh. The declines around Chiniot may be attributed to the shallowing of the aquifer due to the Chiniot divide. The declines in Toba Tek Singh area are due to lack of surface water reaching the tail-ends of Burala Branch and Lower Gogera Branch canals and the lack of any flows in the Ravi River.

The area with fit groundwater quality (EC≤1500 µS/cm) was 1,483,678 ha during 2006 which decreased to 799,788 ha in 2019. In 2006 the groundwater quality with EC≤1500 µS/cm covered mostly the mid doab regions in the lower Rechna Doab, however this area has spread to cover a substantial portion of the doab despite minimal water level declines, which may be due to lateral intrusion and/or upcoming of saline groundwater.

Water Balance – Chaj Doab: The water balance for Chaj Doab shows a negative net groundwater balance of -0.122 BCM (-0.099 MAF) per annum. This doab is not overly stressed, however water levels are declining in parts of the lower reaches of the doab. By 2019, SAR in the 10-15 range and >15 range and RSC >5 had increased substantially towards the lower mid regions of Chaj doab towards the tail end of Northern Branch and Feeder Canal. High SAR values are found to the west of Chiniot.

Water Balance – Thal Doab: In Thal Doab the water balance estimates a negative net groundwater balance of -0.260 BCM (-0.211 MAF) per annum which indicates stresses are manageable in Thal doab. The most significant change in depth to water in Thal doab has occurred in the 6-10m range which has increased from 344,112 ha in 2006 to 544,872 in 2020 indicating a gradual decline in the watertable. Most of the Thal doab is in the fit range for SAR and RSC as defined using the PID criteria. Regular and strategic monitoring can provide insight into changes in water quality.

Water Balance – Bahawalpur sub-basin: There is a negative net groundwater balance of -0.361 BCM (-0.293 MAF) per annum, and water level declines are having an impact on water quality. Groundwater in the Bahawalpur sub-basin is under significant stress due to increased reliance on groundwater for irrigation and urban water supply. There are considerable changes in watertable depth between 2006 and 2019 most notably in the 10-15m depth and >15m depth ranges. The depth to water in Bahawalpur sub-basin in the 10-15m range increased from 501,295 ha in 2006 to 569,978 ha in 2019. The area with watertable depths >15m increased from 156,412 ha in 2006 to almost double to 309,548 in 2019 indicating declining watertables in parts of the sub-basin.

The area with fit water quality of groundwater was 2,542,769 ha during 2006 which has been reduced to 858,966 ha in 2019. The area with unfit water quality of groundwater was 442,924 ha during 2006 which has been increased to 2,126,726 ha in 2019. This is a significant change that covers most of the sub-basin and needs improved monitoring and analysis.

Water Balance – DG Khan Sub-basin: There is a positive net groundwater balance of 0.241 BCM (0.195 MAF) per annum in the DG Khan sub-basin. Although the stresses of the groundwater system are low, water levels are declining in selected zones requiring improved monitoring. The area with unfit water quality of groundwater was 327,622 ha during 2006 which decreased to 304,451 ha in 2019. The positive net balance indicated may be contributing to some of this improvement in water quality. Areas where SAR and RSC are changing require close scrutiny and monitoring should be enhanced in these hotspots to ensure that increasing SAR and RSC trends can be identified early.

Water Balance – CRBC sub-basin: The Chashma Right Bank Canal (CRBC) shows a positive net groundwater balance of 0.024 BCM (0.019 MAF) per annum.

5.2.1 SUMMARY OF WATER BALANCE COVERING THE CANAL COMMAND AREAS

The groundwater budgets presented here are based on Conveyance losses/infiltration and recharge parameters which are adopted from IWASRI-WAPDA (2005). Canal diversions are averages taken from PID data from 2006-2020.

Groundwater abstractions are estimated based on their number, type and working hours as given in Agricultural Statistics of Pakistan (2016-17). River losses and gains are assumed as balance. The water budgets at the doab level are at best estimates. We would strongly recommend that the new WRD invest in developing groundwater models for each sub-basin as recommended in the previous sections.

The water balance for the 7 sub-basins in Punjab is summarized in **Table 5-3** for the Baseline scenario representing the present state of the water balance for the sub-basins.

Table 5-3 : Summary of water balance for sub-basins in Punjab (MAF)

NO	SUB-BASIN	CANAL		TUBEWELLS		RAINFALL		NET-RECHARGE MAF
		Diversions	Recharge	Pumpage	Recharge	Volume	Recharge	
1	Bari	11.820	5.343	10.775	3.265	7.796	1.949	-0.218
2	Rechna	10.957	4.953	10.932	3.312	9.537	2.384	-0.282
3	Chaj	4.010	1.813	4.649	1.409	5.314	1.329	-0.099
4	Thal	7.512	3.396	6.731	2.039	4.338	1.085	-0.211
5	Bahawalpur	11.822	5.344	8.120	2.017	1.845	0.461	-0.293
6	DG Khan	2.75	1.243	1.786	0.566	0.787	0.197	0.195
7	CRBC	0.710	0.321	0.617	0.187	0.514	0.129	0.019
Total (MAF)		**49.581**	**22.413**	**43.610**	**12.795**	**30.131**	**7.534**	**-0.888**
Total (BCM)		***61.157***	***27.646***	***53.792***	***15.782***	***37.166***	***9.293***	***-1.095***

The water balance for the 7 sub-basins indicates an annual depletion of -1.1 BCM (-0.89 MAF), which is in line with the estimate of Young et al (2019) of 1 BCM depletion for the Indus Basin. The above estimate may need to be adjusted as improved monitoring data becomes available, as there are inherent uncertainties is estimating pumping accurately for over 1 million tubewells. The water balance is a crucial aspect for improving management of groundwater in the doabs and sub-basins of Punjab, more so because about 53.8 BCM of groundwater is extracted. The total groundwater pumping for Punjab including the Non-CCA areas is estimated at 61.5 BCM, which highlights the need for investing in improved monitoring and analysis of the water balance for each sub-basin through the development of groundwater models. Groundwater models for each sub-basin in Punjab will provide a quantitative insight into various components of the water balance and will also allow assessment of various groundwater management strategies to adapt to changes in surface water supply and to adapt to climate change impacts. The total contribution of groundwater for the agricultural economy in Punjab is about USD 2.5 billion (based on 2003 figures) therefore improved investment in monitoring, modelling and management of this vital resource is justified for the economic wellbeing of rural Punjab and to meet food security needs in Pakistan.

5.3 GROUNDWATER MONITORING PLANNING FOR SUB-BASINS IN PUNJAB

At present Punjab Irrigation Department (PID) has about 3312 monitoring bores in the seven sub-basins in Punjab. The numbers of monitoring bores have increased since 2000 however; monitoring has not been undertaken on a systematic basis. Monitoring from these 3012 bores is used to measure depth to watertable in pre- and post-monsoon seasons. Monitoring of depth to water (DTW) and electrical conductivity (EC) of the groundwater is required for assessing the lateral and vertical movement of saline zones into freshwater zones, and to ensure the long-term sustainable management of freshwater zones. Usually in any given monitoring season less than half of the bores are

monitored, this does not allow proper comparisons between years to monitor changes in depth to water with sufficient accuracy. The aim of this monitoring plan is to utilize the existing network to develop a strategic monitoring plan for PID which is consistent, measurable and economically efficient. To improve understanding of the impacts of groundwater abstraction which are often localized, monitoring measures need to be strategic and utilize a consistent set of monitoring bores. This will ensure that monitoring data serves to support the WRD to improve understanding of the condition of the resource. Consistent spatial and temporal monitoring data will also provide the means to develop accurate basin scale and sub-basin scale maps for groundwater status reporting and groundwater planning. Reliable monitoring data will also enable the WRD to develop groundwater models which can provide a basis for developing groundwater budgets at the basin and sub-basin (doab) scale which in turn will give a much-improved assessment of recharge and discharge for each sub-basin.

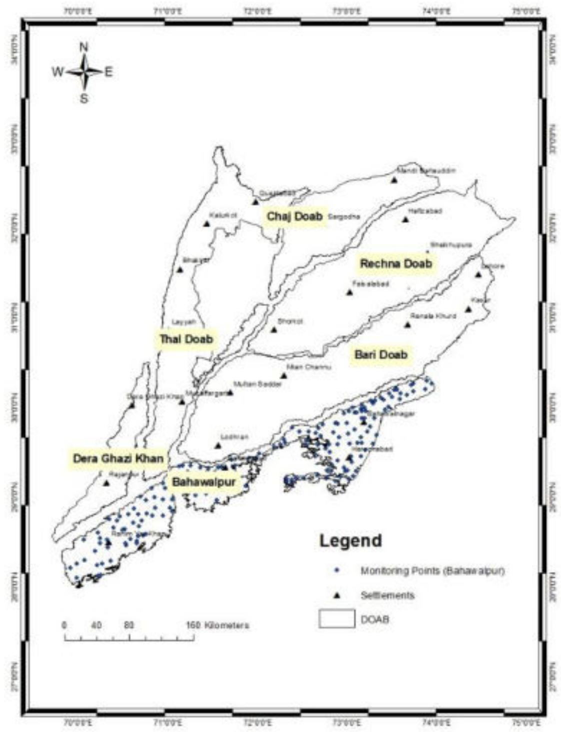
Of the 3312 observation well monitoring points maintained by DLR in different Irrigation zones of PID less than 1400 observation wells are actively monitored and at times less than 400 are monitored. A number of observation wells become non-functional (dead) every year, with many bores that are closed, dead or defective at different times which mean that monitoring is not always consistent from season to season and from year to year. Generally monitoring intensity in deeper watertable areas is less than in shallow watertable areas. There are a number of reasons why almost 50% of the DLR monitoring bores are non-functional. Monitoring bores are not drilled deep enough and when the watertable drops below the bottom of the monitoring well the bore is dry and it is not possible to record water levels. Monitoring bores are often poorly constructed due the lack of guidelines for construction of monitoring bores. Monitoring bores may have been damaged, and there is lack of community ownership of monitoring bores. Additionally, there are errors in recorded data and in coordinates which need to be checked and updated.

5.3.1 RATIONALIZING THE MONITORING NETWORK

Principal component analysis (PCA) was performed on the existing dataset to prioritize the wells which have high significance for monitoring. PCA is a dimension reduction technique, which finds the correlation between the different observations of water level depth and thus reduces the number of total independent variables (number of wells in our case). The reduced number of independent variables provides knowledge of an accepted spatial distribution of the depth to water for mapping purposes from the larger observation dataset.

Observation data is available from Pre-2006 till Pre-2020 and observations are performed on a bi-annual basis i.e. Pre-monsoon and Post-monsoon every year. The PCA analysis was undertaken in two parts for 2006-2012 and 2014-2020 as there were significant discontinuities in monitoring data. The final recommended bore monitoring network consists of 1292 monitoring bores. The rationalized monitoring network in each sub-basin is shown in **Figure 5-2** for Bari Doab (2a); Rechna Doab (2b); Chaj Doab (2c); Thal Doab (2d); Bahawalpur sub-basin (2e); DG Khan sub-basin (2f); and CRBC sub-basin (2g) The details of this analysis are provided in Chapter 5 of the report on Groundwater Management Plan.

8a



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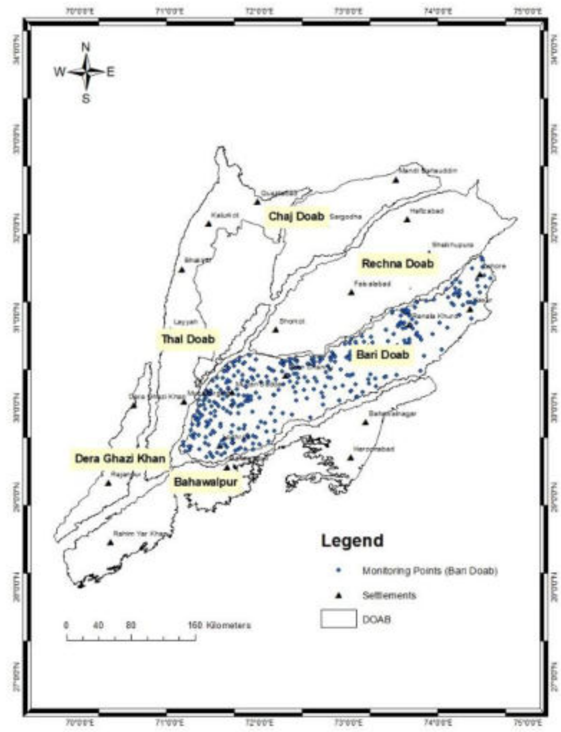

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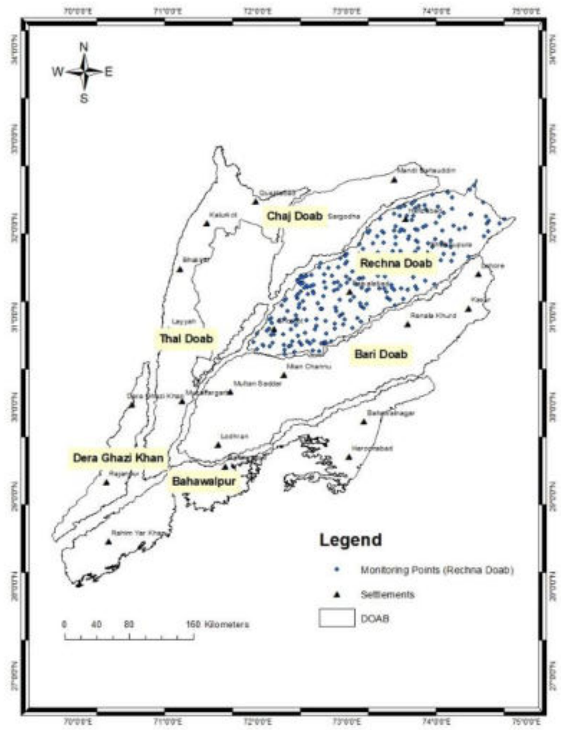

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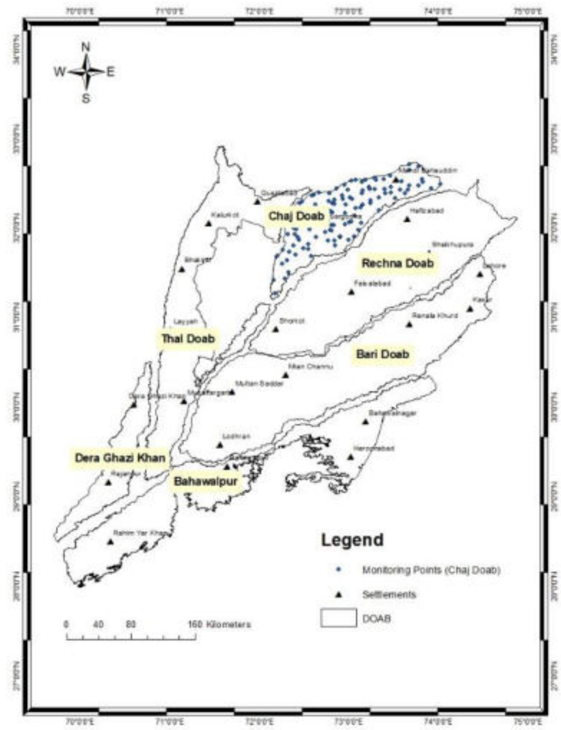

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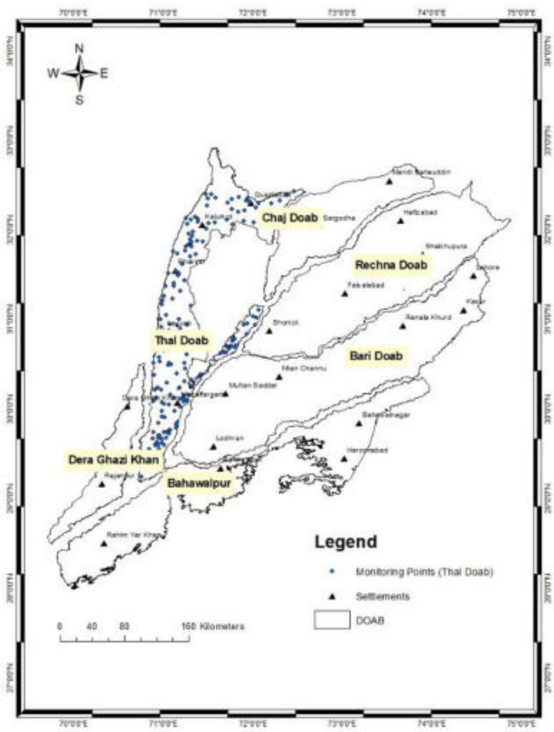

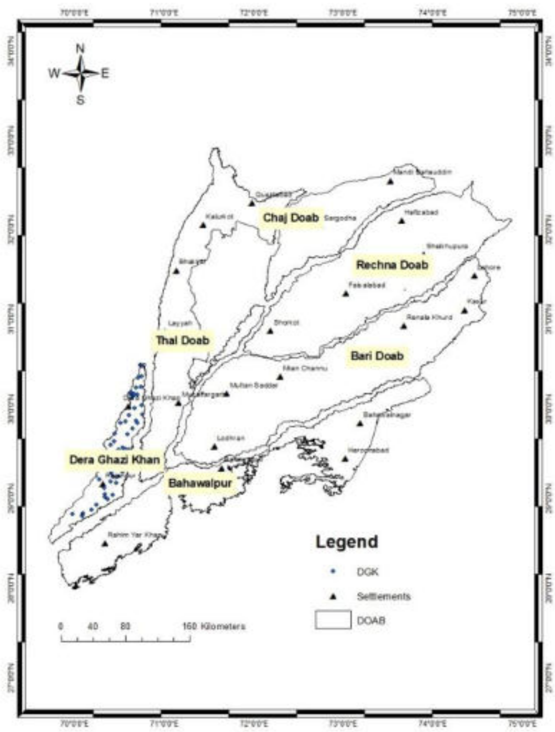

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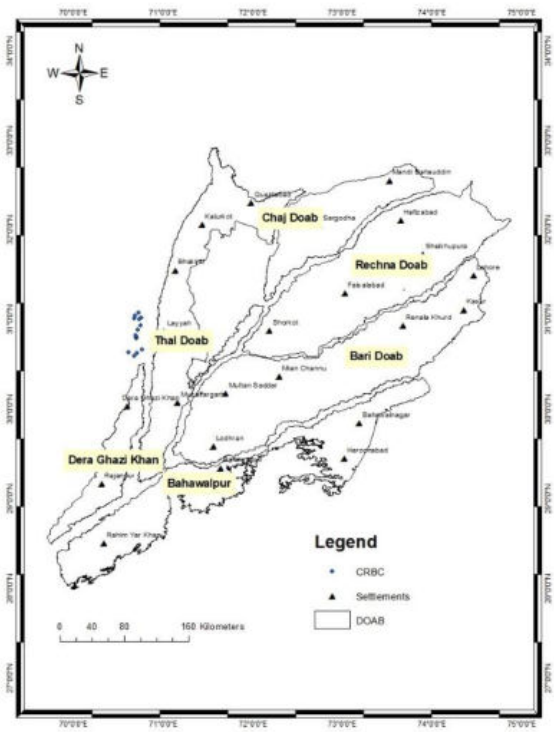


Figure 5-2: The rationalized monitoring network monitoring network in each sub-basin

5.3.2 RECOMMENDATIONS FOR THE RATIONALIZED MONITORING NETWORK

Accessing good quality data for evaluation of aquifer responses is a key constraint. The PID's existing data on depth to water is fragmented with data discontinuities and data errors. Moreover, the same monitoring bores are not monitored consistently, as a consequence, management decisions are based on data that provides a partial understanding of the system resulting in low predictive value. The complexity of flow in aquifers requires extensive data and detailed modelling to answer development questions related to aquifer performance and groundwater management. Comprehensive spatial and temporal monitoring data are key elements for improving understanding of groundwater resources and to provide governments with technical advice to make informed decisions. The analysis undertaken here has rationalized PID's existing monitoring network and recommended continuous monitoring using loggers for a reduced network of 1292 monitoring bores. Equally important are planning and institutional arrangements for regular monitoring and maintenance of monitoring bores and regular downloads from loggers, and management of data sources. We recommend that the WRD ensure that data downloaded from the network of loggers is stored and managed and made available within the Water Resources Information System which will form the basis for managing surface and groundwater resources and associated data on water infrastructure (such as monitoring bores, loggers and telemetry). Such a system once it is operational can be used by WRD to improve sustainable management of groundwater resources, and to provide evidence-based advice to government.

The reduced monitoring network consists of 1292 monitoring bores which is based on the existing functional monitoring bores that are used by PID to monitor depth to water. The rationalized network has reduced the monitoring density to 6,600 ha per monitoring bore, however, with consistent data collected over a 5-year period the monitoring network can be reanalyzed to identify areas where additional bores may be needed. Ideally, monitoring of water levels and salinity should occur from the same monitoring bores. It is also conceivable that as conditions change such as expansion in groundwater pumping, expansion in irrigation areas, and increased cropping intensity additional monitoring points may be needed in some areas. These can be assessed on a five-yearly basis. As the expansion of urban areas in Punjab continues WRD will require an expanded monitoring network in urban areas. This should be undertaken together with WASA's to reduce duplication of effort and to share data and resources.

The WRD needs to make a transition from manual monitoring of bores bi-annually to using loggers to monitor water levels and salinity. By instrumenting monitoring bores with logger's water level, temperature and salinity can be captured at the same monitoring points. Moreover, where monitoring bores are drilled to sufficient depths, loggers can be placed at shallow depth <30 m and also at deeper depths. The use of loggers will reduce errors and data discrepancies from manual monitoring and will be more economical in the long run. We also recommend using loggers to monitor every 12 hours which will provide much needed information about the groundwater system and the temporal changes occurring in response to climate and pumping stresses. There is little use of monitoring several thousand bores if the errors in data are widespread and if critical data are missing (such as bore coordinates, reduced level measuring points, etc.). Monitoring involves a huge cost to the government with little or no value if adequate data is not being used to improve management of the groundwater resource.

The non-functional monitoring wells in Pakpattan, Vehari, Lodhran, Khanewal and Sahiwal as well as other districts identified as hotspots need to be examined with downhole cameras to determine if these monitoring wells can be rehabilitated. If these wells are to be abandoned, then decommission these wells should follow standard practices.

Where water quality issues have been identified, additional monitoring points will be needed to understand risks from heavy metals and microbial contaminants that may have adverse impacts on human or animal health, to enable managers to modify usage patterns or impose restrictions on usage.

The cost estimate for updating the monitoring program includes USD 3.0 million investment in capex, and USD 0.18 million annually in operation and maintenance. The NWP also suggests that at least one percent of the base cost of project be allocated for research. This is a fairly modest cost which can be spread over 2 or 3 years.

5.3.3 MONITORING PLAN OUTCOMES

Resource Condition: A well-planned monitoring network will provide crucial data on water levels, water quality and impact of climate on the resource.

Resource Use: A well planned monitoring network will provide useful data on the groundwater system and will contribute towards minimizing uncertainty in current and future groundwater resource availability and use.

Data Infrastructure: A well designed data information system will allow systematic archiving of data, quality checking data, and allow data to be shared between agencies, researchers, communities and civil society.

Sustainable Yield: A well-planned monitoring network will provide crucial data for developing groundwater models to estimate sustainable yields at the sub-basin and canal command areas.

Manage Pollution: Monitoring to identify pollution hotspots and sources and minimizing pollution from various sources is essential to improve the condition of the groundwater source.

Water Sources: Identify availability and reliability of alternative water source options.

Management Decisions: Data from the monitoring network will provide evidence-based management decisions, and influence data collection efforts to streamline and improve data collection.

Groundwater Management Strategies: Analysis of monitoring data can provide advice on improved groundwater management strategies to manage and minimize groundwater depletion and water quality decline in: (i) major urban centres in Punjab (e.g., Lahore, Multan, Rawalpindi etc.); (ii) in agricultural areas where groundwater is depleting; and (iii) in industrial areas relying on groundwater.

Institutional Capacity: Improving institutional capacity for efficient management and delivery of services is essential for achieving equitable outcomes.

Cost Savings for Government of Punjab: Currently there are over 2000 non-functional bores. There is a significant cost involved in drilling bores and if these are non-functional, they are not serving any purpose. A well-designed groundwater monitoring system which is maintained regularly, with proper design of monitoring bores is essential for judicious use of investment funds in monitoring systems.

5.4 GROUNDWATER MANAGEMENT PLANNING CONSIDERATIONS FOR SUB-BASINS IN PUNJAB

a) Resource Evaluation: Action to improve the management of groundwater is not possible without detailed resource characterization and this requires investigation and monitoring of the groundwater and canal systems. Groundwater aquifers in Punjab are complex and dynamic systems which require a detailed hydrogeological assessment. Although there is some monitoring of groundwater, there is need for regular information on watertable levels, water quality and accurate information on canal flows to increase the understanding of how the aquifer is performing.

b) Resource Monitoring: Groundwater data has been collected for over thirty years by various government agencies but what has been missing is routine evaluation of the data to determine the state of groundwater and whether action is required to prevent irreversible degradation of aquifers. Along with resource monitoring, it is essential that the monitoring information is utilized to evaluate what is happening in the aquifer to make incremental improvements in management. A sound groundwater database should be developed and shared with users (farmers, farmers' organizations, urban managers and other stakeholders). At present, data are patchy, and reporting is not always maintained. There are several data efforts, but they are spread over several organizations and are not coordinated. Moreover, integration of different data sets held by PID, WAPDA/IWASRI and SMO is required.

c) Resource Usage: Abstracting groundwater is very popular with farmers because of the on-demand nature of the resource:
   - Groundwater is available close to the point-of-use
   - Developed quickly with low capital cost by individual irrigators
   - Available directly on-demand for crop needs (given a reliable energy source for pumping) and thus affords small-holders a high level of control year-round)
   - Allows irrigated agriculture to expand in spite of the scarcity and unreliability of canal water due to poor canal maintenance, inability to provide design flows, poor administration that allows unauthorized and/or excessive off-takes and rigid canal-water delivery schedules, unresponsive to crop needs.
   - Effective conjunctive use of groundwater and canal water is capable of achieving:
     - Much greater water-supply security by taking advantage of natural aquifer storage
     - Larger net water-supply yield than generally possible using only one source alone
     - Blending of groundwater with canal water in marginal groundwater areas to decrease salinity impacts and improved quality of return flows
     - Better timing of irrigation-water delivery as groundwater can be rapidly deployed to compensate for shortfalls in canal-water at critical times in the crop-growth cycle
     - Reduced environmental impact, through counteracting waterlogging and salinization of productive land.

d) Inventory of tubewells: All plans to improve groundwater management need a sound inventory of tubewell locations, pump installations, electricity meters and areas irrigated. Identifying the location of tubewells can be done through a combination of field surveys and satellite imagery.

e) Pollution/Contamination control: Groundwater aquifers are very vulnerable to contamination by salinization and residues of agro-chemicals resulting from agricultural activities and point sources of pollution such as discharges from factories and wastewater from urban areas. Remediating polluted aquifers is very expensive and technically challenging due to the slow rate of movement of groundwater. The approach should be to minimize the risk of polluting aquifers, which will require specific attention to be given to identify the potential hazard from different sources of pollution and take the actions necessary to avoid contamination of the aquifer.

f) Abstraction and recharge: Since the introduction of canal water, recharge has been dominated by seepage from canals and irrigation, and in more recent times, by abstraction of groundwater by tubewells. Efficient mechanisms for abstraction, distribution and recharge need to identify and promoted to minimize over extraction of groundwater resources. For example, more efficient field application of irrigation water reduces the requirement for groundwater pumping.

5.4.1 OPTIONS FOR DEMAND MANAGEMENT

Possible options to improve the demand side of groundwater management include:

a) Regulatory Framework: The existing Punjab Water Policy objectives include: *Control Groundwater Abstraction* to balance recharge levels through regulation, reallocation of canal allowances, induced recharge and monitoring; and *Enhance Water Quality* of surface and groundwater through control of pollutants discharged from agriculture, industries, municipal wastes and over abstraction of groundwater near saline groundwater zones. Regulations can be focused on specific targets such as licensing of tubewells and tubewell usage. It is not possible to license over a million tubewells, however, all high-water users and users of high security water should be licensed. Additionally, allocations can be set for a doab and individually for canal commands in Punjab. Once allocations are estimated this would need extensive stakeholder consultation to adjust allocations in hotspots and to get agreement from groundwater irrigators.

b) Economic Instruments: Groundwater resources tend to be undervalued, especially where their exploitation is uncontrolled – when the resource exploiter (in effect) receives the benefits of groundwater use but (at most) pays

only part of the costs – and this undervaluation often leads to economically inefficient resource use (Strand 2010). Unfortunately, controlling irrigation use is not as straightforward as that of industry or commerce. Alternative techniques that could be used to estimate actual abstraction or use, include:

- Estimation of volume pumped from metered electricity use;
- Estimation of volume abstracted from pump capacity and assumed schedule
- Assessment of actual consumption by crop type and cultivated area.

c) Stakeholder participation: A degree of community stakeholder participation is essential for groundwater resources management, given the frequently very large number of individual groundwater users involved regardless of whether regulatory and economic instruments are also deployed. It can take many forms and can take place at various territorial levels ranging from village to aquifer system or even river-basin level – and should be comprehensively nurtured as an important contribution to groundwater conservation, management and protection, otherwise its effectiveness may be reduced. It is desirable that active participation of users in groundwater resource management be promoted, in which users exert peer pressure for the achievement of management goals and collaborate through provision of data on tubewell use and water levels (Garuno and Foster, 2010).

d) Awareness raising and publicity: Introducing regulations or economic instruments to change how stakeholders use groundwater will require a focused campaign to raise awareness amongst stakeholders as to why such changes are necessary. Small farmers are under severe financial pressures as the price of inputs increase while the prices paid for many crops are in long-term decline. The reasons for curtailing groundwater need to be explained and agreed by groundwater irrigators. Farmers know that watertables are declining and the quality of pumped groundwater is deteriorating and will need to be convinced that controls are necessary to prevent the collapse of the current way of irrigation. Awareness raising includes explaining the vulnerabilities of the groundwater system but also showing more efficient ways to irrigate and growing crops that use less water.

e) Water Conservation: Productivity per unit of water is low in Punjab, Pakistan as compared to many similar parts of the world. Therefore, high efficiency irrigation systems and low delta crops can be introduced. This is discussed in more detail in Section 4.11.3.

5.4.2 CONJUNCTIVE WATER USE

Conjunctive use is often incidental as water users intuitively shift between surface water and groundwater sources or mix the two, to cope with changes and shortages. While conjunctive use may prove successful for an individual or group of water users, it is also possible for conjunctive use to unintentionally harm the groundwater basin and other groundwater users who are reliant on the same groundwater basin. Conjunctive water management involves using surface water and groundwater in combination to improve water availability and reliability with acceptable quality. But it also includes important components of groundwater management such as monitoring, evaluation of monitoring data to develop local management objectives, and use of monitoring data to establish and enforce local management policies. Conjunctive management can involve a variety of water management components and different operational approaches that may cross political or institutional boundaries. There is not clearly "one-size-fits-all" approach to conjunctive water management. It requires balancing recharge with recovery and monitoring to validate the conjunctive water management. Management should be at local levels where the unique set of conditions is well understood and where interested water users can participate and remain informed. Institutional constraints, environmental concerns, economic considerations, and the political climate are also important when implementing conjunctive water management. In urban water supply system, some form of conjunctive use of groundwater and surface water sources is common – but in rapidly-expanding cities like Lahore in Bari Doab, it is often unplanned and not recognized as such, nor optimized in terms of the complementary hydrological characteristics of the two sources. Spontaneous conjunctive

use for agricultural irrigation occurs widely and increasingly in Bari Doab, through private initiatives of farmers due to a combination of declining service levels in main irrigation canals and growing irrigation demand.

5.4.3 WATER CONSERVATION

The greatest effort in water conservation should be made in the irrigated agriculture sub-sector because this is by far the greatest user of water. Even relatively modest improvements in irrigation efficiency will result in reductions in water use. Farmers should be encouraged to adopt water conservation measures. Adoption of water conservation strategies can save up to 25% of the water resources without compromising on crop yields (Qureshi and Bastiaanssen, 2001).

Resource conservation technologies such as drip irrigation for fruits/forest plants and vegetables provide an alternative option for farming and resource conservation in these areas. Therefore, there is a need to introduce these systems with operations that are cost effective and adaptable to farmers, crops and physical local conditions. Adoption of these measures will reduce water application at the field scale. However, these water savings do not necessarily translate into water savings at the sub-basin or basin scale. Therefore, introduction of these techniques requires careful irrigation scheduling as reduced irrigation applications may increase the threat of salinization and reduce recharge to groundwater, which is vital for downstream users. Therefore, evaluation of the impact of these techniques at different scales for different agro-climatic conditions within a basin is inevitable.

The crops types grown needs to be rationalized to maximize water use efficiency and economic productivity. Traditional crops include rice and sugarcane, with rice being a water-intensive crop. It is essential to review whether Pakistan should continue to grow rice for export or grow other crops with a higher economic return. In rice-growing areas of Pakistan, more than 70% of irrigation water is supplied through tubewells. Therefore, limiting the rice area according to the country's demand for rice can help a great deal in reducing the extraction of groundwater. Adoption of other irrigation water strategies can also help save groundwater. Studies have shown that direct seeded rice requires less irrigation water than traditional transplanted rice under Pakistani conditions. Similarly, strategies should be developed to replace sugarcane with low water demanding and high market value crops. This can only be achieved by incentivizing farming communities to change crop selection practices. The RAPS (Representative Agricultural Pathways) approach is being trailed in Sahiwal and Okara with selected farmers under the ACIAR project with the aim of improving Groundwater Management to enhance agriculture and farming livelihoods. This approach has successfully trailed crops such as moong bean, sunflower and sesame that use less water and fetch better returns for farmers. Change can be slow, but introduction of high- value crops like sunflower, pulses, vegetables and orchards can increase farm incomes.

5.4.4 GROUNDWATER MODELS AND SCENARIO MODELLING

A groundwater model can help managers to understand the overall groundwater situation in a sub-basin or canal command area and to assess the groundwater conditions for different hydrological and water management specific scenarios. In order to develop a groundwater model a detailed understanding of the hydrogeology is required. Building a conceptual model of the aquifer is essential, so that critical stresses on the groundwater system are incorporated in the modelling process. A robust groundwater model will require adequate spatial and temporal data, to ensure modelling results are acceptable. Spatial data on aquifer characteristics, aquifer geometry and hydraulic parameters are needed along with temporal data on water levels and water quality, abstraction, river/canal and climate data. A calibrated model will provide information on groundwater trends and also the groundwater budget, which is a critical component for estimating the sustainable yield of the sub-basin and a useful component for development of groundwater management plans. A calibrated groundwater model also allows simulation of various scenarios for planners and policy makers so that decisions made are evidence based.

5.4.5 RECHARGE OPTIONS

The alluvial aquifer in Punjab has relatively high hydraulic conductivities and transmissivity and reasonably good storage potential. The alluvium is the largest store of water in the Indus Basin, thus improved management of aquifer storage can improve water security in Pakistan. Strategies to recharge groundwater using monsoon floods need to be tested, as well as utilizing abandoned canals and dry riverbeds such as the Sukh Beas. A study of groundwater availability and conjunctive management (ACE et al. 2011) suggested diverting flood waters through BS link to the Sukh Beas area and to use it as storage in drought years. This would also have the added benefit of recharging the aquifer along the mid and western part of Bari Doab.

The advantages of groundwater recharge are:

- groundwater is less affected by evaporation and leakage (than surface water);
- groundwater is less prone to pollution than surface water, and if polluted, pollutants get diluted during underground movement;
- subsurface storage is achievable without loss of cultivable areas, property and dislocation of people;
- groundwater can be used where and when it is required;
- there is less ecological hazard compared to surface storage projects.

In spite of the many advantages mentioned above, there are some constraints that hinder groundwater recharge, such as:

- clogging of recharge wells is a concern and requires regular maintenance
- wells interfere with each other adversely when large supplies are required;
- groundwater storage withdrawal is a highly energy intensive process, meaning high operation costs while surface water is often available by gravity flow;
- Mineralization is generally higher in groundwater, so quality is poorer as compared to surface water;
- Recharge conditions will vary between sub-basins and canal commands; thus, field studies and detailed modelling is required.

5.4.6 INSTITUTIONAL OPTIONS

The most critical factor in improving groundwater and canal water management is to ensure appropriate institutions are in place to support groundwater management systems. At present, institutions dealing with water resources are fragmented and focused on specific aspects such as operation and maintenance of main canals and barrages (PIPD), operation and maintenance of distributary and minor canals (PID) or reservoirs (WAPDA). A glaring omission is that no institution is responsible for groundwater, even though in Bari Doab and other canal commands, groundwater provides 52% or more of the irrigation water. There is a real need to develop institutions with the capacity required to manage groundwater in Punjab. Part of the development process will require introduction of groundwater to the curriculum of universities and colleges where water resource specialists are being trained.

Water managers in Punjab are focused on the supply and movement of surface water and the contribution and role of groundwater in the water resources of Punjab have been neglected. Unfortunately, the neglect of groundwater continues, for example within the PID, groundwater is not seen as an integral part of their business. There are now more than a dozen agencies involved in groundwater development and monitoring, but there is a lack of coordination, inadequate staffing and insufficient logistical support.

There is also the need to have an Institutional set-up equipped with better information and knowledge to design and implement appropriate, coordinated, management-focused responses for conjunctive use of water. None of these agencies have complete knowledge of the issues and none have operational responsibilities for groundwater management (van Steenbergen and Gohar 2005). A focal point for groundwater management needs to be sanctioned

and developed to enforce regulation, coordinate activities by various agencies and to compile an integrated database. Preferably, the WRD in Punjab would be responsible for groundwater monitoring and evaluation, management and regulation. However, to fulfil its functions a major transformation will be required, which will involve significant resources and capacity development and a 10 to 15-year transition plan to develop capacity and human resources.

5.4.7 ESTABLISHING PARTNERSHIPS -GROUNDWATER USER ASSOCIATIONS

The On-Farm Water Management and Water Users' Associations Ordinance was introduced in 1981 and amended in 2001. It provides for the establishment of WUAs for the purposes of on-farm water management, conservation and optimum utilization of irrigation water sources, and the reconstruction, maintenance, and improvement of infrastructure. Reportedly many WUAs did not remain functional after construction of related infrastructure. Once established, WUA's require ongoing technical, financial, and capacity support. The Khal Panchayat Bill has been passed by the Punjab Assembly during 2019. Groundwater management can be added to their responsibilities. Alternatively, an Aquifer Management Organization (AMO) can be established for each doab/sub-basin, which would require technical support and knowledge dissemination by the Groundwater Authority.

5.5 DESIGN TWO PILOT PROJECTS ON MANAGED AQUIFER RECHARGE IN AREAS WHERE GROUNDWATER LEVELS ARE DECLINING

5.5.1 CONCEPT DESIGN

Groundwater is dependent on natural recharge from rainfall, rivers, canals and irrigation. Surplus rainwater and flood flows in rivers during the monsoon season provides an opportunity for Managed Aquifer Recharge (MAR). Rainwater harvesting and in-stream flood flows, are available over a short time during the monsoon months for capture and artificial recharge. The primary benefit of MAR is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit. PID has planned to take up the MAR systematically. Given that governmental water management institutions exist at town, city and provincial levels, the opportunities for effective coordination for groundwater management and institutionalizing MAR, largely exist.

Various options for groundwater recharge were discussed and a qualitative analysis of their advantages and disadvantages was carried out. The groundwater situational analysis revealed that the capital city Lahore has critical conditions in terms of groundwater decline and increasing demand. Given a reasonable average annual rainfall of 673 mm and 1.3 million buildings, a pilot scheme for rooftop rainwater harvesting and recharge (RRWR) was selected for Pilot Project No 1. It was estimated that around 149 million cubic meters (MCM) can be harvested and recharged annually. This includes a potential of 8.6 MCM of RRWR from the public buildings and 140.4 MCM from private houses. The proposed pilot project for RRWR from a public sector was designed, which included the rainwater conveyance system from rooftop to the tank, tank size and recharge pipes from an area of 2,000 m^2 from a public sector building. The cost of one RRWR system was estimated as USD 6500 which includes the major cost items of civil works for USD 3000 and drilling work for USD 2500. The other cost items including earthwork, repair of rooftop and the cost of water conveyance pipe and gutter system was estimated at lump sum of USD 1000. The operational management and data collection and analysis will be the responsibility of PID.

The proposed Pilot Project No 2 was planned and designed to enhance recharge through a filter well in the bed of River Ravi immediately downstream of the BRBD syphon. The volume of water available during the three-month monsoon season at the site is 3.9 billion cubic meter (BCM). It was assessed that a 10-m diameter filtration well was required to infiltrate floods up to the 25-year return period event. One well is estimated to have a recharge capacity of 350,000 m^3 during the season, which is a small fraction of the water availability. Therefore, successful demonstration of the Pilot Project No 2 will have a high potential of replication. The cost of the second pilot project varies from PKR9.0

million ($56,250) to PKR18.7 million ($116,875) along left bank and PKR20.0 million ($125,000) to PKR29.5 million ($184,375) along right bank.

The detailed planning and design of the two pilot MAR projects in Punjab are contained in a separate volume (Managed Aquifer Recharge for Punjab, Pakistan). This report develops a framework for planning and designing of MAR projects, which will help prepare PID for future MAR projects.

Managed Aquifer Recharge (MAR) offers significant opportunities and benefits for improving the groundwater condition in Punjab. The primary benefit of MAR is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit. The annual average rainfall of 556 mm (State of Pakistan's Climate in 2020, http://www.pmd.gov.pk/) in Punjab and the annual monsoon floods allows for significant opportunities to harness rainfall runoff and monsoon floods.

Once the pilot projects are implemented and proven to be successful, scaling out of these projects will result in significant benefits for Punjab. These benefits include improvement in groundwater recharge and storage volume which will have a beneficial impact on groundwater quality; reduction in groundwater level declines in hotspots; reduce water bills; and environmental benefits; improvement in aquifer water quality.

5.5.2 EXPECTED BENEFITS OF PROPOSED MAR PROJECTS

Scaling out of these pilot projects will result in:

- Improvement in groundwater recharge and storage volume will have a beneficial impact on groundwater quality.
- Increased recharge to the aquifer will reduce the decline in groundwater levels which will reduce the cost for WASA which needs to pump from deeper groundwater and deepen wells.
- Positive environmental benefits, improvement in aquifer water quality.

5.5.3 NEED FOR REGULATION

In various parts of the world particularly in India aquifers are being recharged by rainwater. Buildings in large cities of India are required to install rainfall recharging systems. The Centre for Science and Environment (CSE) in India reported an increase of 5 to10 meters in the groundwater levels over a two-year period from May 2002 to May 2004 in Delhi and Gurgaon in Haryana. This is a considerable improvement given that these were pre-monsoon measurements.

In Pakistan, regulation needs to be introduced and implemented in Punjab to ensure all government buildings, universities and schools are equipped with rooftop rainfall harvesting and recharge systems. All large houses and housing colonies should be required to install rooftop rainfall harvesting and recharge systems. There are also many commercial buildings, and factories, which also needs to be brought under this regulatory framework.

5.6 COMPREHENSIVE GROUNDWATER DATA BASE TO COMPLIMENT WRMIS DEVELOPED.

Groundwater data obtained from PID has been scrutinized and cleaned, with redundant data separated. These data sets have been used to develop maps for each of the sub-basins in Punjab. The data sets are available for the Database Specialist team developing the Water Resources Information System.

5.6.1 MONITORING DATA AND MAPPING THE RESOURCE

The monitoring and mapping of water resources in sub-basins needs to be based on a well-designed and accessible Water Resources Information System (WRIS):

(i) The data structure should be simple and easy to understand.
(ii) The data files need a consistent and simple naming protocol. Abbreviations should be avoided where possible.
(iii) Each monitoring bore should have a unique identification number linked to each sub-basin, and similarly each production bore or tubewell should have its own unique identifier.
(iv) There should be as little as possible data duplication.
(v) All data needs clear, self-explanatory metadata.
(vi) The temporal data (canal flows, groundwater level and water quality measurements etc.) should be in a separate database. In other words, the spatial data should not be mixed with temporal data.
(vii) Groundwater and other relevant data sets from various organizations should be integrated in the WRIS.

Further details are provided in the Groundwater Management Plan report.

5.6.2 IMPROVED TUBEWELL TECHNOLOGIES AND PRACTICES

When farmers plan to install a tubewell, they need information on the depth to the watertable, groundwater quality, aquifer characteristics, well design, materials and construction. At present, farmers consult their fellow farmers, drillers, tubewell equipment dealers and occasionally government institutions like Agricultural Engineering Department. However, for most procurement decisions, farmers rely on the advice from a driller referred by his fellow farmers. In view of their limited knowledge, farmers follow the driller's recommendations within the limitations of their financial ability to pay. Hence capability and experience of local drillers is of major importance in groundwater development. In the present scenario the drillers are required to install tubewells with turbine or submersible pumps. In the areas of thin freshwater layers skimming wells may be required. Most of the local drillers are not well equipped to deliver on such changes due to a lack of appropriate knowledge, skills, trained manpower and equipment. Increasing the capabilities of local drillers will benefit farmers through the construction of more efficient and durable wells. This requires updating the skills, materials awareness and well construction methods of the local drillers. In addition, farmer groups should be aware of local aquifer conditions, well construction materials, their cost, and performance. This is intended to produce a good relationship of informed buyer (farmer) and informed seller (driller). Improvements in the tubewell technologies and practices can be achieved through training, extension and sharing knowledge through developing linkages and coordination. The main stakeholders include farmers, WRD/PID, tubewell drillers, tubewell equipment dealers/suppliers, Agricultural Engineering Department, soil and water quality laboratories of the Agriculture department, Directorate of Land Reclamation (DLR), and PID. For adoption of best practice by farming communities and drillers and a close liaison between drillers, Agricultural Engineering Department and government research and monitoring agencies like DLR is necessary. WRD/PID should play a role as coordinator. PID should keep the record of data such as drilled depth, water table depth, thickness and depth of layers of sand and clay (lithology), water quality, length of blind pipe and strainer used for future reference. Under the prevailing system, management of ground water is not in jurisdiction of PID. Moreover, a representative body of drillers does not exist. It is suggested that establishing a Drillers Association may strengthen this relationship.

5.7 GROUNDWATER DIVISION WITHIN IRI

Presently, several research and strategic management institutions/groups work under various departments on a piecemeal basis. Coordination is lacking and results of analysis are not shared. Lacking a strong scientific basis decision-making is generally based on past experiences, past practices, or personal preferences.

Upgrading the Irrigation Research Institute (IRI) will provide an opportunity for science-based solutions and coordinated efforts in research, strategic planning and scenario analysis. The proposed structure for including groundwater within the IRI is shown in Figure 5-3. The IRI is headed by the Chief IRI with experience in research and

development. To accommodate the existing functions of IRI a Deputy Chief will lead the Groundwater Division. Other functions may also be headed by separate Deputy Chiefs, depending on the agreed overall structure of IRI.

The leadership of the new IRI is provided by the Chief IRI. The role of the Chief IRI has been developed by the Institutions Team. IRI can be split into several divisions or sub-divisions as per need (for example Deputy Chief Hydraulics Division). The field formation for groundwater data monitoring, acquisition and sharing will be administratively responsible to the relevant executive engineers and for technical backstopping to the groundwater division in IRI.

The proposed Groundwater Division will have a Division Chief who will be responsible for management of all the activities in the Division, providing strategic policy, planning and research directions, coordination of internal and external clients and capacity building to the level that the Groundwater Division becomes a hub for science-based decision-making in the region. The groundwater Division will have six major Sections, and each Section will be led by a Sector Specialist, which are described below:

5.7.1 RESOURCE MONITORING AND DATA ANALYTICS SECTION

The main function of this Section is the management of the WRIS and Field Monitoring. The WRIS should be led by a database specialist with experience in data analytics. The team in the WRIS will have database specialists and IT specialist. The Field Monitoring sub-section will be administratively responsible to the relevant executive engineers who will provide technical backstopping, and field monitoring will be headed by an engineer with experience in monitoring systems, loggers and field equipment.

5.7.2 GROUNDWATER RESOURCE MANAGEMENT SECTION

The main functions of the Groundwater Resource Management Section is to build a competent groundwater modelling team that can develop and apply groundwater models to improve understanding of water balances at the regional and sub-regional level and can undertake specialized modelling studies such as modelling salinity transport, groundwater pollution, and to support the groundwater pollution management team. The team would need to build expertise in scenario modelling and groundwater modelling to support the Groundwater Licensing and Policy Section.

A secondary function for this section is Mapping and Remote Sensing to support the Modelling, Monitoring, Ecosystems, and the Policy Sections. This unit will also focus on remote sensing and build capacity in GRACE to understand long term changes in groundwater storage.

5.7.3 ECOSYSTEM MONITORING AND MANAGEMENT SECTION

The Ecosystems Monitoring and Management Section has two vital functions, Groundwater Pollution Management which will cover point and non-point sources of pollution, and the emerging need in Punjab for improving the health of ecosystems. In this capacity the management of environmental water will be an important function and role for the Ecosystems team. The Environmental Water Management team will need to work in close coordination with the Groundwater Planning and Allocation Section, and to pay particular attention to improving the health of ecosystems by minimizing contaminants entering the surface waters and groundwater.

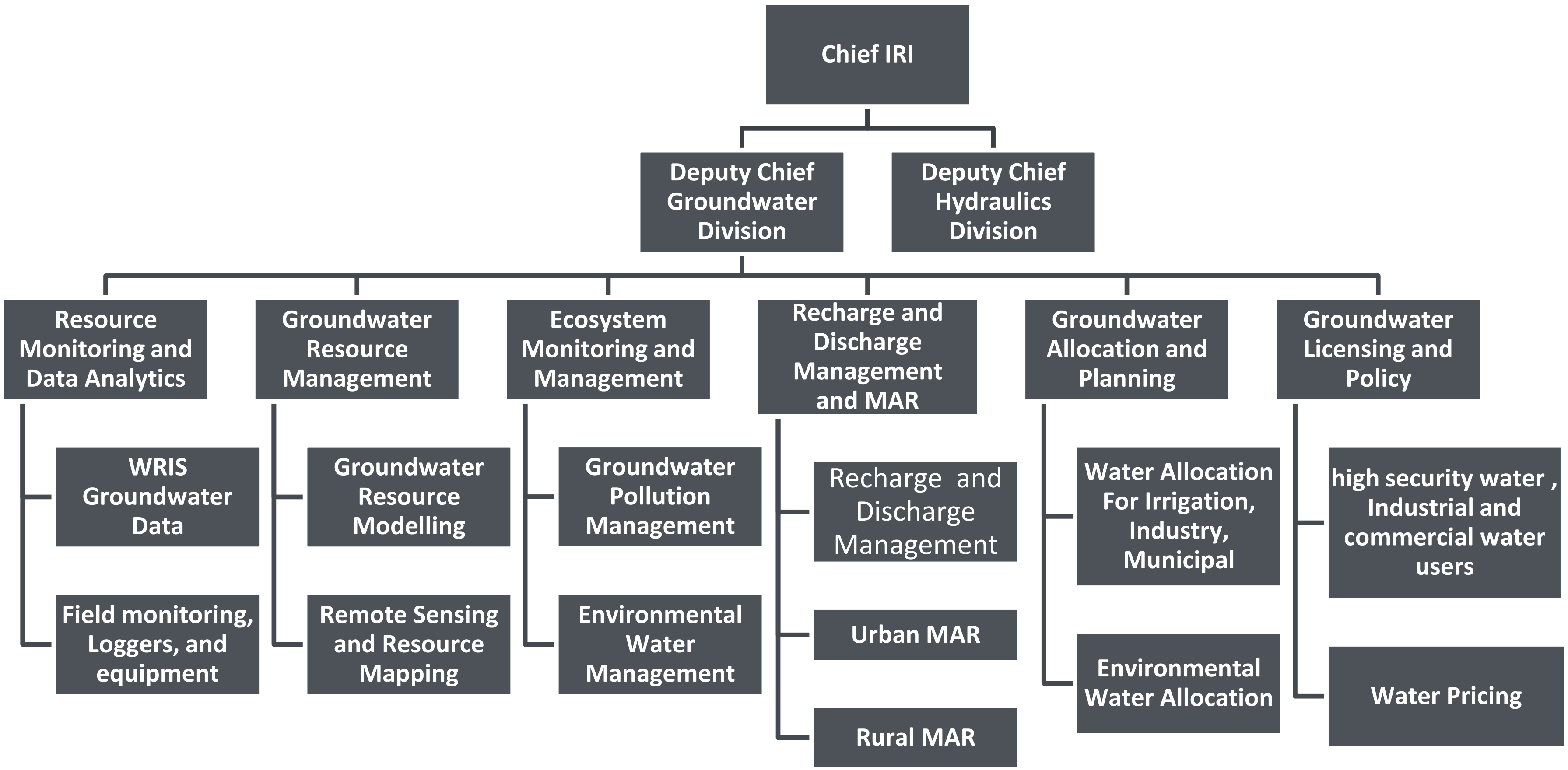
5.7.4 RECHARGE AND DISCHARGE MANAGEMENT AND MAR SECTION

This Section will develop expertise and capacity in investigating options for recharge and discharge Management and will need to work closely with the Resource Monitoring and Data Analytics Section, the Groundwater Resource Monitoring Section, and the Ecosystems Monitoring and Management Section. This Section will also focus on the following extractors: high security water users, commercial and industrial water users, and large water users.

The Managed Aquifer Recharge Sub-Division has a vital role to play in water management in Punjab. There are only two sources of additional water in Punjab, rainfall and monsoon floods. It will therefore be essential for Punjab's water future to build expertise in Managed Aquifer Recharge. The two key areas are Urban MAR and Rural MAR.

The report on Managed Aquifer Recharge which includes the plan and design of two pilot projects, also has key sections which provide examples of MAR projects in Australia and Pakistan, as well as guidelines for planning and designing MAR projects. Moreover, several examples of MAR projects that are relevant for Punjab are provided, for example revival of Johads in rural Punjab to enhance recharge to the aquifer. MAR projects also offer an excellent opportunity to involve communities in improving groundwater management. Setting aside a budget to involve smallholder farmers and community groups in operation and maintenance of MAR projects will increase likelihood of success as well provide incentives for community participation.

Figure 5-3 Proposed Structure for the Groundwater Division within IRI



5.7.5 GROUNDWATER ALLOCATION AND PLANNING SECTION

The Groundwater Allocation and Planning Section will provide leadership in Water Allocation for Agriculture, Industry/Commercial, and Municipal Water with the key aim to work towards a sustainable allocation policy. This will require coordination with other Sections within the Groundwater Division, such as the Resource Modelling Section as allocation planning will require a good understanding of sustainable extraction rates.

A key team within this section is the Environmental Water Allocation team. This is an emerging area of research within Pakistan and is also indicated in the National Water Policy. This team will need to coordinate and work closely with the Environmental Water Management Team.

5.7.6 GROUNDWATER LICENSING AND POLICY SECTION

Groundwater Licensing and Policy are areas which need capacity in legal and policy areas. This Section will be led by a Sector specialist in Policy with proven expertise in Allocation Planning and Water Policy. This Section will be required to work in close coordination with the Groundwater Resource Modelling Section, the Ecosystem Monitoring and Management, the Managed Aquifer Recharge Section and the Groundwater Allocation and Planning Sections.

5.8 KEY CONSIDERATIONS

Water Balance - Punjab sub-basins: Regulation of pumping will be required to control pumping in hot spots, and also to regulate and license large water users. Individual hotspots in these areas will require enhanced monitoring and improved groundwater management. For each of the sub-basins we have provided management options for consideration. These options include supply options that can be considered, the need for groundwater modelling to support groundwater management planning, the need for on-going review and adaptive management, and steps for safeguarding and improving water quality management for each sub-basin. However, a word of caution is warranted. Groundwater management in Punjab is fraught with difficulties as there are a large number of smallholder farmers that rely on over 1.2 million tubewells in Punjab. Although these are smallholder farmers, they underpin the future of water productivity improvements and economic development of the agriculture sector in Punjab. To develop effective groundwater management plans WRD will need to undertake extensive community consultation and have community support to implement management changes. This can only happen through consultation and mutual consent supported by effective knowledge transfer and access to information for groundwater users. It will not be possible to implement groundwater management plans without a participatory and consensus approach involving groundwater users, principally farming communities. WRD must avoid going down the path of *permission and punishment* which for all practical purposes is unlikely to produce desirable outcomes for sustainability of the aquifer.

Development of Groundwater Models: The complexity of the aquifers in the Indus Basin in Punjab together with the groundwater in the basin being the largest supply source for domestic and industrial requirements and close to 50 percent of supplies for irrigation require sufficient investment in developing a robust groundwater model for each sub-basin in Punjab. This should be a requirement for improving management of groundwater so that an improved understanding of groundwater and salinity dynamics in the sub-basin is understood by resource managers.

Managed Aquifer Recharge: Once the pilot projects are implemented and proven to be successful, scaling out of these projects will result in significant benefits for Punjab. These benefits include improvement in groundwater storage which will have a beneficial impact on groundwater quality; reduction in groundwater level declines in hotspots; reduce water bills; and environmental and health benefits, improvement in aquifer water quality. Following recommendations have been made on the basis of conclusions:

- Ground survey and geotechnical investigations should be carried out for detailed site investigation of pilot projects.

- Stakeholders' consultation, co-design and ownership are critical for implementation and operational management.
- Pilot projects require close monitoring and analysis to inform future projects.
- Implementation of large-scale rooftop rainwater harvesting, and recharge may require new regulations.
- Out-scaling of the successful MAR pilot projects may require significant investment.
- Appropriate institutional mechanisms to implement, run and evaluate MAR will be required.
- An effective coordination among the water use departments and stakeholders is important for the success of MAR.

Regulation: Co-designing a sustainable future with groundwater users which leads to some controls on pumping and controls on continued expansion in tubewell installation in stressed zones may be required, depending on the rate of depletion, to bring the groundwater system to a sustainable level of management. The new WRD may wish to rush a licensing regime, however; we do not advocate this approach. Instead, we suggest establishing groundwater management zones together with representative stakeholders from groundwater users to co-design an agreed allocation limit for stressed zones. This can be a difficult and time-consuming process, but one that will yield a more sustainable outcome. A blanket allocation for a doab is less likely to succeed and less likely to produce the desired outcome. A licensing regime accompanied by a monitoring regime is required and is more likely to succeed in regulating pumping for urban water supplies and for large industrial and commercial users.

Groundwater Division: Upgrading the Irrigation Research Institute (IRI) should provide an opportunity for science-based solutions and coordinated efforts in research, strategic planning and scenario analysis and setting of management directions. The IRI will be headed by the Chief IRI with experience in research and development. To accommodate the existing functions of IRI a Deputy Chief will lead the Groundwater Division. Other functions may also be headed by separate Deputy Chiefs depending on the agreed overall structure of IRI. The proposed Groundwater Division will have a Division Chief who will be responsible for management of all the activities in the Division, providing strategic policy, planning and research directions, coordination of internal and external clients and capacity building to the level that the Groundwater Division becomes a hub for science-based decision-making in the region. The groundwater Division will have six major Sections, and each Section will be led by a Sector Specialist comprising: (i) Resource Monitoring and Data Analytics Section; (ii) Groundwater Resource Management Section; (iii) Ecosystem Monitoring and Management Section; (iv) Recharge and Discharge Management and MAR Section; (v) Groundwater Allocation and Planning Section; and (vi) Groundwater Licensing and Policy Section.

Gender and Diversity: A key recommendation for the Groundwater Division in IRI is to allow entry points for a wider range of disciplines including but not limited to, Specialists in Remote Sensing, Hydrogeology, Geology, Groundwater Modelling, Groundwater Quality Specialists, Ecosystems Specialists, Socioecological Specialists, and Policy Experts. Achieving an improved gender balance to allow for increased intake of female specialists will be crucial to the success of the Groundwater Division.

Groundwater Training and Capacity Building: Training in various aspects of groundwater resource management for IRI staff will be essential and is probably the most important investment for IRI to be successful. The training and capacity development should support the intended structure for the Groundwater Resources Division in IRI. Areas where capacity and expertise are required include: (i) Monitoring, database management and data analytics; (ii) Groundwater modelling and remote sensing; (iii) Groundwater pollution and environmental water management; (iv) Manage aquifer recharge; and (v) Groundwater allocation, planning, licensing and policy

Systemic Co-inquiry: The Punjab level groundwater management planning process where the institution is the main focus, covers over 8 million ha of irrigated agriculture land and 1.2 million tubewells (a scale bigger than many countries). It would not be possible to implement various groundwater management plans without a participatory and consensus approach involving groundwater users, principally farming communities to co-design improved crop, land, and water management practices. A systemic co-inquiry is a facilitated process *(in this case should be facilitated by PID/WRD)* which allows people with differing experience, backgrounds and perspectives whose voices must be heard.

The processes are designed to enable emergence of ideas and opportunities for improving the situation and to co-develop an inclusive *(though still partial)* view of what the current situation is, and what can be done to change the situation to a better or more sustainable state. In order for WRD to improve sustainability of the aquifer, WRD will need to adopt new approaches that incorporate social aspects and inclusivity and adopt a consensus approach that factors socioeconomic considerations, rather than the Business-as-Usual Approach. On the basis of critical analysis and benefitting from the international best practices, we have recommended the most suitable approach which essentially empowers PID to develop and implement a purposeful approach to monitoring and modelling and to develop a consensus on sustainable extraction regimes with communities for site-specific solutions that will promote a sustainable future.

5.9 INVESTMENT PLAN FOR GROUNDWATER MANAGEMENT

In Table 5-4 presents a proposed invest plan for improving groundwater management in Punjab as part of the Vision 2050 for Punjab. The investment plan aims to support the proper functioning of a groundwater Management Division within IRI that is able to significantly improve the management and governance of groundwater resources for present and future generations. Some aspects of the investment plan are identified such as *Water Productivity and Conjunctive Management*, which are covered under agriculture and irrigation and costed separately. The total investment plan for groundwater management over the 30 years corresponding to Vision 2050 is $259.5 million or about $8.65 million per annum.

Table 5-4: Tentative Investment Plan to Implement Vision 2021-2050 for Groundwater Management.

TASKS	MAIN COST ITEMS	TENTATIVE COST
Resource Monitoring and Data Analytics Groundwater monitoring, data sharing and processing for use for decision-making (gradual coverage to the entire system) including farmers organizations	• Gradually expand the monitoring network • Establish relevant institutional structure for data monitoring and management	○ $30 million (On an average $1.0 million a year) ○ $1.5 million (a part of cost is covered under institutional component ○ Partly covered under capacity building.
Resource Management, Mapping & Remote Sensing Groundwater modelling for each of the doabs and priority canal command areas; mapping and remote sensing	• Focus on modelling, mapping and remote sensing at sub-basins (including doabs) • Focus on priority canal commands where groundwater decline is significant, supported by mapping and remote sensing. • Resource modelling in Non-CCA areas	○ $20 million (on average 2 million per year based on a 30-year program). ○ 10 million for priority canal command areas ○ 10 million for Non-CCA areas
Ecosystem Monitoring and Management Groundwater pollution management (agricultural areas) and vital ecosystems	• Survey of groundwater pollution • Requires monitoring bores in areas where trace metals are identified • Specialized monitoring and analysis	○ $5 million for survey ○ $15 million groundwater quality monitoring bores and O&M ○ $15 million monitoring and analysis
Water Productivity and Conjunctive Management Irrigation water management to reduce groundwater use and improve water productivity	• Improved irrigation application efficiency and reduce unaccounted losses • Improve water productivity	○ Covered under agriculture and irrigation ○ Covered under irrigation/agriculture

TASKS	MAIN COST ITEMS	TENTATIVE COST
Water supply and sanitation Groundwater management for water supply and sanitation	• Reduce unaccounted flow • Efficient operational management of abstraction • Introduce smart metering.	○ Covered under WASH ○ Covered under WASH ○ Covered under WASH
Managed Aquifer Recharge Artificial groundwater recharge and monitoring of MAR sites	• Infrastructure development ▶ Rainwater harvesting and recharge ▶ Floodwater harvesting and recharge	○ ○ $20 million (on an average $0.65 million/year) ○ $90 million (on an average $3.0 million/year)
Water quality management (Urban)	• Water quality monitoring • Laboratory upgradation • Data management	○ $10.0 million ○ Covered under WASH and Irrigation/Agriculture ○ Covered under WASH and Irrigation/Agriculture
Groundwater Allocation, Licensing and Policy	• Community engagement to set acceptable allocation limits for stressed groundwater zones • Capacity development in licensing and implementing regulation	○ $10 million
Institution and capacity building	• Establish groundwater institution, equipment and training • Establish, equip and train community-based organizations	○ $10.0 million ○ $10.0 million
Cross-sectoral coordination	• IWRM: coordination with the main stakeholders (departments and agencies) • Dispute resolution • Evaluation, planning and implementation	○ Covered under IWRM ○ $1.0 million ○ $2.0 million
Total		***$259.5 million (on an average $8.65 million a year)***

6 INDUS RIVER BASIN PLAN AND MANAGEMENT

6.1 GENERAL

Over the last 60 years most countries have developed their water resources with construction of large dams and other infrastructure to store and regulate water which has produced substantial economic and social benefits. In many countries there is little additional water to exploit and increasing competition between existing and new users for available water, as urban populations increase, priorities for water use change and climate change affects water availability. As a result, there has been a shift away from 'technical' and Master Planning approaches for basin planning, to more strategic Integrated Water Resources Management (IWRM) approaches.

An important part of this approach is the management of water resources at a basin scale, recognizing the connection between all water resources in a basin and its uses. Resolution of competing interests over access to water, particularly in dry times, can only be addressed at the river basin scale.

The primary purpose of water resources and river basin management is:

- Equitable sharing of the river basin’s connected water resources (quantity and quality, surface and groundwater) between the different and competing water using sectors, including the environment.
- Water resource protection (quantity and quality) to ensure access to acceptable water resources for present and future generations.
- Bulk water supply to all water users in a fair and equitable manner.
- Manage water in an integrated and balanced way, recognizing all costs and benefits.

The River Basin Plan (RBP) (Figure 6-1) involves firstly making a detailed basin assessment (river basin profile), which provides a benchmark of water related issues in the basin, to map a way forward to improve economic, social and environmental outcomes. In due course the RBP comprises priority thematic plans that regulate water use in the basin and will result in the different water using sectors developing their own plans, consistent with the RBP requirements. The plan is also likely to identify hotspot locations (certain rivers, urban, irrigation areas, watersheds) in the basin which require urgent action to address local problems such as river conditions, water quality, salinity, water availability.

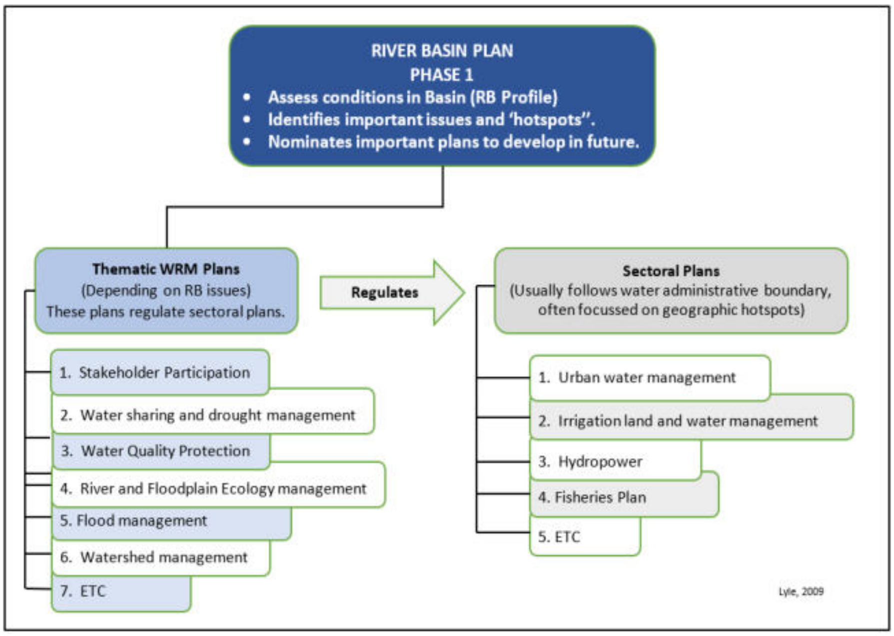


Figure 6-1: Structure of a River Basin Plan

The river basin planning process (Figure 6-2) is cyclical. Development of the first Plan will take several years and should then be revised regularly (e.g. every 5 years).

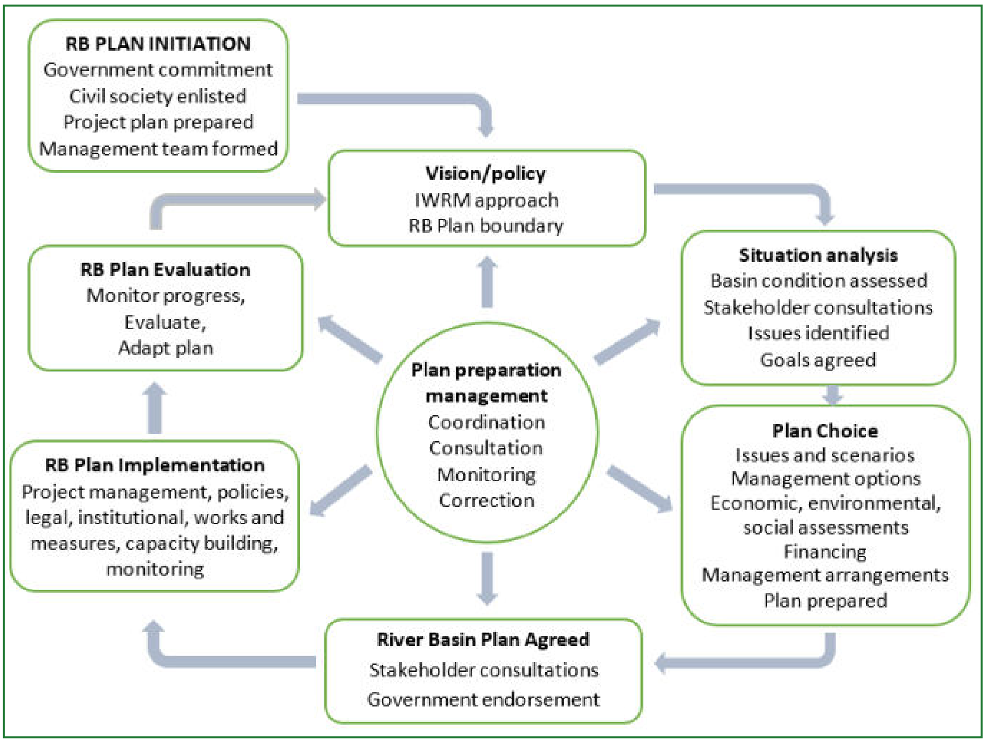


Figure 6-2: The River Basin Planning Process

Critical to the development and success of a RBP are:

(i) Strong and capable project management and technical specialists.

(ii) Information and information management/assessment tools such as GIS, remote sensing, monitoring data, surface and groundwater models, DSS tools. This capacity is developed continuously to improve successive plans.

(iii) Participation of water using sectors (government and non-government) as well as other members of civil society.

(iv) Involvement of leaders to that the plan receives final government endorsement.

(v) Links from the agreed Plan into government budget cycles.

This report on the Punjab Indus River Basin is in effect a River Basin Profile, or situation analysis, in the above diagram. It was developed without the usual extensive stakeholder consultation, which was prevented because of the Covid 19 situation. This executive summary provides an overview of the findings. More detailed findings and recommendations are to be found in the respective chapters.

6.2 AN OVERVIEW OF PUNJAB RIVER BASINS

Punjab has a large population of 110 million (2017) and a very large irrigation system, which together place a high demand on the available water resources. Agriculture is important to the provincial economy, contributing 21% of the GDP and employing 47% of the work force. Half of the population of Punjab lives in rural areas, where poverty is as pervasive as it is in the slums of urban areas. About 31% of the Punjab population live below the poverty line, compared to 40% in Pakistan on an overall basis. About 45% of the rural population is landless and 44% of rural households

derive their income either directly or indirectly from agriculture. Government policy is pushing to restructure agriculture to improve productivity and to produce higher value crops to improve economic conditions.

Punjab has 4 seasons: (i) the hot-dry, pre-monsoon (April to June) (ii) the slightly less hot but humid monsoon season (July to September), (iii) the cooler / mild and mostly dry season (October to November) and (iv) the cold rain season (December to March). Annual temperatures typically range from -2°C to 45°C.

The geography of Punjab can be sub-divided into:

a) the extensive and flat alluvial plains of central Punjab. This area is transected by five rivers the Indus, Jhelum, Chenab, Ravi and Sutlej. The land between each of these rivers is flat and referred to as Doabs. These plains comprise deep, fertile alluvial deposits with associated alluvial aquifers. Irrigation is extensive in this area.
b) the Pothohar area in the north of the Province, near Islamabad. Annual rainfall is about 750 mm and crops are mostly rainfed, although small tanks are becoming common.
c) the Piedmont deposits of the Sulieman range to the west of the Indus River, where annual rainfall is 125-130 mm. The hill torrent areas are located here, along with two smaller irrigated command areas KG Khan and CRBC.
d) the Cholistan desert to the south of Punjab.

The main rivers the Indus, Jhelum, Chenab, Ravi and Sutlej emanate from upstream countries. The latter four combine as the Chenab, which is the main tributary of the Indus River. It is of significance that the runoff upstream of Pakistan from the Ravi and Sutlej rivers is allocated to India under the Indus Waters Agreement. Smaller rivers, including the Haro and Soan, flow from the Pothohar plateau on the right bank of the Indus river. The Kabul river originates in Afghanistan and flows though Khyber Pakhtunkhwa Province (KPK), before entering Punjab and joining the Indus river.

In Punjab, surface water is mostly allocated for agriculture and groundwater is the property of the land holder. Groundwater is the main source of urban and rural drinking water. The dominant water user is agriculture. About 50% of the cultivated area in the province is irrigated and about 50% of the irrigation water is derived from groundwater. Other water users include cities, towns and a wide range of industries spread across the province.

The province has extensive irrigation water supply infrastructure with 13 barrages, 25 main canals with a combined length of 6,390 km, 13 inter-river link canals with a length of 845 km, 2,794 distributary canals with a length of 31,000km and 58,000 canal outlets within the five rivers (Indus, Jhelum, Chenab, Ravi and Sutlej). In addition, there are 57 small to medium sized dams, 9,795 km of surface drains and 3,360 km of flood embankments. The province uses 98 BCM of water for irrigation annually.

Two thirds of the total cropped area of Punjab is dedicated to three crops, namely wheat, cotton, and rice.

6.3 WATER RESOURCES AND RIVER BASIN GOVERNANCE

6.3.1 RIVER BASIN, RIVER, AND LAND MANAGEMENT UNITS

The logical water resources planning unit for Punjab province is the Punjab Indus River Basin. The Water Resource Plan should aim to share and protect of its water resources. Alternatively, the 5-rivers area, which forms the Panjnad as the tributary to the Indus river, could be treated as a river basin. However, since this area is connected to the Indus river via link canals the larger area is preferred.

The Doabs lend themselves to be land management units. Land and Water Management Plans or Groundwater Management Plans can be developed for Doabs to manage the surface water, groundwater and land resources sustainably.

Rivers are important natural resources management units. The health of rivers and floodplains is important as they provide many services including water supply (drinking, irrigation, industry), ecosystems, recreation, fisheries, tourism, flood management and navigation. River flow, water quality, bed and bank conditions, and sedimentation require management.

6.4 STAKEHOLDERS AND MANAGEMENT ARRANGEMENTS

Management arrangements for the Punjab Indus River Basin are complex, with shared responsibilities between federal and provincial agencies and with the usual multiplicity of sectoral water users (domestic and stock use, urban and recreation, flooding, irrigation, fisheries, hydropower, industry, environment, navigation, catchment and tourism uses). Significantly from an operational efficiency and effectiveness perspective, the O&M of river and link canal infrastructure is shared between different governments and agencies, which is unlikely to be optimal.

The main government departments, agencies and organizations involved in the administration of water resources include:

a) **National level**: The Ministry of Water Resources, Indus River System Authority (IRSA), the Water and Power Development Authority (WAPDA), the Planning and Flood Commission and the National Disaster Management Authority.
b) **Provincial level**: Punjab Water Resources Commission (WRC), the Water Services Regulatory Authority (WSRA), Irrigation Department (PID), Agriculture Department (PAD), Public Health Engineering Department (PHED) through Water and Sanitation Agencies (WASAs), Environment Protection Department (PEPD) and Environmental Protection Agency (PEPA), Department of Forestry, Wildlife and Fisheries (PFWFD). The Department of Local Government is involved with rural water supply and sanitation and the Department of Industry is involved with industrial water use. Khal Panchayat (KP) are farmer based tertiary canal level water managers.

In order to maintain independence and accountability in the management of water resources it is now internationally accepted that best practice separates the responsibilities for (i) regulator/standard setter; (ii) resource management, and (iii) operator/service provider. Sometimes the operator responsibilities for bulk and retail water supply are also separated. The introduction of WRC and WSRA provides strengthening (although incomplete) of the regulator role. Introducing a Water Resources Department would further strengthen this role. There are however some roles (within the Punjab Province) that remain absent or weak, such as: river management; bulk and retail water supply; and shared responsibility for the management of water assets (e.g. of link canals). More in depth study is needed to see whether these short comings represent a serious issue or not.

As the Punjab Indus River Basin is the preferred water management unit, a river basin organization is not considered necessary at this stage and that function could largely be carried out by the new Water Resources Commission (WRC) and Water Services Regulatory Authority (WSRA), supported by a Water Resources Department (WRD). The WRC could be strengthened by including a community advisory committee, with membership drawn from the community throughout the province, representing the different water users and interest groups.

6.5 WATER ENTITLEMENTS, ALLOCATION AND WATER SHARING

Pakistan's Water Apportionment Accord (WAA) provides provincial water shares (entitlements), as well as the basis for making seasonal water allocations. Some aspects of the accord remain contentions. (e.g. Anwar and Bhatti 2018). The WAA does not address water quality and does not properly addresses environmental flow requirements with environmental flow requirements only specified at Kotri Barrage, at the end of system. Analysis of deliveries to Punjab by Anwar and Bhatti found that the that supplied volumes were substantially less than the seasonal allocations. There are a number of potential causes for the discrepancies and it is important to investigate and resolve these discrepancies.

Currently entitlements are assessed using rudimentary water balance approaches and could be improved by downscaling the surface water and groundwater models developed for Pakistan's Indus Basin. This would provide a better tool for assessing the sharing of allocation between command areas and other water users (such as urban areas), and for assessing the implications of climate change, declining storage capacity in reservoirs and availability of groundwater.

Internationally a range of different mechanisms may be applied to adjust water entitlements between water users, such as: by decree which is usually politically difficult and unlikely to be optimal; water markets enabling trade between water users (however while likely to approach economic optimality this requires a well-developed water measurement and accounting system); and government, city or industry payment for infrastructure renewal in order to reduces losses and/or achieve water savings, with transfer of an agreed water entitlement in return. All require safeguards and feasibility assessment.

Once an allocation is made, water is supplied via a 7-10.5 day Warabandi system with minimal other water regulation. The Water Policy notes that the current approach assumes that there are no water conveyance losses in the earthen canals. This is clearly not true and results in reduced delivery volumes to users at the tail of the system. The Warabandi system is simple to apply, but does not deliver a fair outcome.

Modern irrigation systems adopt technologies that enable water releases to be accurately controlled and measured and supplied on demand, ensuring compliance with water allocations. Precise measurement enables volumetric irrigation service fees to be adopted.

6.6 WATER AVAILABILITY, USE AND DEMANDS

The following conclusions are made from the water budget analysis:

i) There is insufficient water to meet all water demands at present. All sub-basins have shortfalls in water supply, except for DG Khan sub-basin, Pothohar and the Hill torrents
ii) Inflows and outflows have been estimated for each sub-basin including canal command areas, rain fed areas, hill torrent areas and the Pothohar region.
iii) The water budget for the seven sub-basins indicates a water deficiency, which agrees with past studies. However, this doesn't give a true picture, as most of the water balance components are estimates and they have a high degree of uncertainty. This highlights the need to invest in improved analysis of the water budget for each sub-basin through the development of computer models.
iv) Water balances at basin and sub-basin levels do not identify issues such as 'tail end supply shortfalls', capacity constraints and water seeping to saline aquifers etc. A detailed canal level water balance is required to identify these issues.
v) Water supply sources are likely to decrease due to factors such as: climate change; siltation of dam storages and canals; and deteriorating irrigation asserts. These issues need to be considered in the water budget.
vi) A holistic approach towards water management and conservation needs to be implemented.
vii) Surface drainage outflows are not properly gauged and have been ignored in the water budget analysis.
viii) Models at the Doab scale are useful for the Irrigation Department to improve planning and management of surface and groundwater resources. This will require increased capacity for irrigation agencies, as well as institutional reform.
ix) Expansion of the irrigation area is desirable but is currently constrained by limited water resources. The sustainable and cost-effective option to facilitate expansion is to enhance water productivity. This requires enhancement of crop productivity and reductions in crop water use. This is possible by adoption of water efficient technologies, improved production practices, more productive and higher value crops and varieties, improved operation and maintenance of irrigation systems, and reduced non-beneficial losses of water.
x) The PID is an irrigation department with a focus on supply of water to irrigation command areas, although it has other responsibilities including flood control, operation and maintenance of river infrastructure and hill

torrent management). A result of this focus is that information on water balances has been focused on command areas, rather than the overall water resources of the Province.

xi) A Water Resources Department would have a stronger recognition of rivers and their values and uses including environmental, recreational, heritage and cultural uses, as well as traditional irrigation, drinking water and industrial water uses.

6.7 RIVER WATER QUALITY

Water pollution in Punjab rivers, canals and nullahs derives from three major sources: i) entry of untreated domestic effluents and stormwater from the large urban towns; ii) untreated industrial effluents; and iii) return-flows from agricultural lands which may contain high levels of nutrients (from fertilizers), chemicals (pesticides and herbicides) and salinity (mainly from irrigation using brackish groundwater).

Major water pollutants include heavy metals, faecal coliforms, phosphorous, sodium, nitrogen, and sediments, as well as pathogenic bacteria and viruses. Low BOD and COD is common. Agriculture is a source of salinity, nutrients (fertilizers), highly toxic pesticides and persistent organic pollutants (POPs). Pollution is exacerbated by low river flows and hence low dilution.

As a result, water is often unfit for drinking. Agrochemicals in groundwater, especially pesticides, are a major source of human poisoning in Pakistan. Poor water quality also negatively impacts fish diversity and fish population numbers and affects other uses. Groundwater quality can be marginal for irrigation, due to over exploitation and this problem is worsening.

The available water quality data for most canals/drains show pollution levels that are well above the permissible limits provided by the Pakistan National Environmental Quality Standards (PNEQS). signifying significant impacts on the health of downstream water users and the health of the aquatic ecosystem. There are no national surface water quality standards for the disposal of treated wastewater into freshwater bodies.

The collection and treatment of urban and industrial effluents in Punjab is low, with the mostly untreated effluent discharged into canals, drains and rivers. Seepage of contaminated surface water into aquifers results in the aquifers becoming polluted and unfit for drinking. There is very little separation of municipal wastewater from industrial effluents, with both discharging directly into open drains before flowing into the nearby natural water bodies.

There is no established water monitoring programme for assessing the water quality of surface waters in Punjab province. While there have been studies of water quality in the rivers, these have been piecemeal and not part of a systematic monitoring approach.

Water quality in the rivers is variable and season specific. The Chenab River has very high heavy metal concentrations in both the water column and sediments, which significantly exceed PEDS standards. This is of concern as the river water is used for drinking. Of the few canals sampled, the Lower Jhelum canal was unfit for stock or irrigation purposes, with high E. coli levels at most sampling points due to faecal contamination. Ravi and Sutlej rivers have the poorest water quality Punjab. The Ravi River in particular is in a highly degraded state.

Departmental responsibilities for water quality monitoring should be reviewed to ensure all aspects are addressed. Suggested roles include: EPD and WRD lead the coordination and overview of surface water and groundwater quality management. EPD - pollution control and auditing of industry self-monitoring; industry- self-monitoring for point sources such as industrial effluent discharge and city wastewater disposal; PID- monitoring water quality in rivers, canals, drains, nullahs and groundwater, including assessment of nonpoint pollution from agriculture. WRD - assess river flow needs (environmental flows) in the annual water allocation and river operations plans and designation of groundwater protection zones where land use is controlled.

A range of important recommendations are made including:

a) Development of an action plan to improve water quality.

b) Awareness raising education campaign for downstream water users on the risks from using polluted waters from drains and irrigation canals for human and livestock consumption.
c) Improved water quality monitoring, especially for nutrients and highly toxic agrochemicals that impact surface and groundwater quality.
d) Develop water quality standards.
e) Education of farmers on proper use of agrochemicals and enforcement of environmental regulations for urban wastewater discharge and industrial effluent discharge and agricultural practices.
f) Urgent implementation of measures to minimize pollution and to regulate levels, with systematic monitoring and evaluation of water quality in drains, canals and rivers.
g) Accelerated action with the installation of wastewater treatment plants for urban sewage and industrial effluent.
h) Review of responsibilities of regulatory and implementing agencies, their coordination and collaboration, and strengthening their capacity. Training and recruitment to improve staff capabilities and provide additional facilities/equipment where needed.

6.8 GROUNDWATER MANAGEMENT

Groundwater has become a significant source of water in Punjab, providing 50% of irrigation water and 70% of drinking water. The contribution of groundwater to irrigation has increased from about 10% in the 1960's to more than 50% in 2018. Groundwater pumping by over one million farmer-owned tubewells has enabled an increase in cropping intensity from 67% to around 131%.

Increased groundwater use resulted from the conjunction of several factors including: (i) groundwater is the property of the landowner and as a result its use is not regulated; (ii) surface water supplied irrigation water contributed to a significant increase in groundwater recharge so that the groundwater resource grew rapidly, and, (iii) groundwater can be used flexibly by the farmer to meet crop demand, thereby offsetting lack of water resulting from the Warabandi system or from drought.

Analysis of the water balance however shows that groundwater usage exceeds recharge in the 5 Doab areas of Bari, Rechna, Chaj, Thal and Bahawalpur. Only the 2 irrigation areas on the right bank of the Indus (DG Khan and CRBC) have recharge that is greater than abstractions. Excess abstractions for the Doab areas represents 1-2% of inflows (rainfall and canal supply) annually with groundwater level Doab declines of 0.1 - 0.2m/y. However, there are localities where depletion is more serious. The suitability of groundwater for irrigation (based on water quality) has declined significantly from 65% in 2006 to 30% 2019. (Note that mixing poorer quality groundwater with better quality surface water allows groundwater to be utilized when the water quality is otherwise not suitable.)

Groundwater levels are declining seriously in the vicinity of cities, for example in Rawalpindi groundwater levels are declining at 1.7 m/y and for Lahore groundwater is projected to decline to 70m in 2025 and 100m in 2040. As groundwater levels decline there is generally a corresponding decline in water quality, increasing pumping costs and a decline in water resource availability.

Groundwater levels and quality are monitored by both the SCARP Monitoring Organization (SMO) of WAPDA, and the Directorate of Land Reclamation (DLR) of the PID. Monitoring networks, systems, and data should be integrated with on-line and free data sharing.

Domestic, industrial and agricultural water demand is expected to increase by an additional 37 BCM (30% of the 2020 demand) by 2050, which places additional pressure on existing surface and groundwater sources. Reallocation of water from irrigation to meet increasing urban and industrial demands is inevitable and has already started in some areas. This will require improved efficiency in agricultural water use.

It is important that future water resource planning recognizes the connection between surface water and groundwater with the surface and groundwater resources to be managed conjunctively. Options for additional water are limited and

places extra responsibility on departments to ensure sustainable management of all available water resources. However, there is a significant lack of capacity within existing institutions for monitoring, modelling and management of groundwater resources.

The immediate roadmap for improving groundwater management comprises:

Institutional and regulatory arrangements: Currently groundwater regulatory arrangements are very weak and there is little capacity within government. An effective GW regulatory framework and laws are required for Punjab and a dedicated GW management division should be established within WRD.

Groundwater Management Plans in priority Doabs. These are referred to as Land and Water Management Plans as they involve integrated management of land and surface and groundwater. Integrated plans are needed to identify the best management of surface and groundwater. Community participation is needed. The TRTA groundwater report provides guidance for development of these plans.

Managed Artificial Recharge has potential to use flood and excess drainage water to recharge the aquifer storage system. Suitable locations and configurations need to be identified and investigated. It is recommended that pilot studies be trailed for proof of concept prior to full implementation.

Conjunctive Water Use aims to make best use of available water resources by planning water use and allocation for both surface water and groundwater accounting for both water availability and quality. For example, head reaches usually have the best quality groundwater, but mostly use canal water, while the reverse is the case in the tail end. A more effective arrangement would be for the head reaches to use more (good quality) groundwater allowing a greater volume of surface water to be available for tail reaches.

Strengthen GW Information and Knowledge Management: This involves (i) developing and implementing a comprehensive groundwater monitoring plan, and (ii) applying modern groundwater modelling approaches to develop better policy and better Groundwater Management Plans. This approach would be a major improvement on the current water balance and groundwater analytical approaches.

Community Awareness Raising and Participation is needed to consider water user and land holder needs, as well as to enlist their cooperation.

A standalone, detailed report on groundwater management in Punjab was prepared as part of this TRTA project.

6.9 ENVIRONMENTAL CONDITION OF RIVERS

The key elements of the environmental condition of rivers are captured in river health assessments including: (a) river hydrology; (b) water quality; (c) aquatic life (instream, birds and other wildlife); (d) river form including bed and bank condition; and (e) the condition of the streamside zone including wetlands, riparian vegetation, floodplains, land use and settlements.

Significant economic and social benefits result from good river environmental conditions including recreational values; fisheries; amenity and living conditions; groundwater recharge from wetlands; improved agricultural production (poor water quality leads to lower productivity), reduced water supply treatment cost, lower prevalence of water born disease.

Studies of the Indus River and its tributaries in Punjab show that environmental conditions have deteriorated and the deterioration is accelerating. Pollution and reduced river flows are profound problems. Low and unhealthy fish populations are a key indicator of ecological problems.

River ecosystems are degraded by many other factors including:

1. Water quality data clearly demonstrate the effect of point and non-point source pollution on the riverine ecosystem. Contaminants are responsible for an increase in occurrence of water-borne diseases within the

human population, as well as a reduction in the biodiversity of flora and fauna. Pollution control is a fundamental requirement.

2. Flow in the basin's rivers is much reduced especially in the Ravi and Sutlej rivers. This negatively impacts the ecology and contributes to poor water quality due to the lack of dilution flows. The WAA has provisions for ensuring minimum environmental flow in the basin's rivers, but these provisions have not been actioned.
3. Riverbank erosion is significant along some Punjab rivers causing damage to agricultural land, settlements and local infrastructure, which impacts people's livelihoods. A biproduct of riverbank and water shed erosion is river sedimentation which badly affects the river ecology.
4. The construction of barrages and dams has created habitat fragmentation and provides barriers to fish migration. The loss of wetlands has impacted the ecology, reduced flood storage, reduced groundwater recharge and reduced nursery conditions for fish, aquatic birds and other aquatic life. This threatens survival of certain flora and fauna.

Water quality monitoring networks should be established to quantify key parameters (BOD5, COD, DO, NH3-N and TP) across the river basins and to identify key sources of pollution. Monitoring of the river condition should also be undertaken including flows; channel condition; condition of wetlands; number and diversity of fish, birds and other aquatic species; aquatic and riparian vegetation.

Three main initiatives should be taken:

1. River Flow Requirements

   Develop and apply a methodology for determining river environmental flow requirements and include these requirements under the water allocations system.

2. River health assessment and river improvement program

   Develop and implement a river health index system to monitor the condition of rivers and use this as a tool to inform River Basin Management Plans.

3. Capacity building and training

   Training and capacity building for WRD, PID, FWFD and EPD staff on river health.

6.10 FLOOD MANAGEMENT

Floods usually occur from July through October as a result of torrential rains during the monsoon season, sometimes exacerbated by snowmelt runoff. The frequency of floods has considerably increased in recent years with five consecutive extreme flood events occurring in 2010, 2011, 2012, 2013 and 2014. This is consistent with the expected impacts of climate change. Severe flooding in the Indus Basin results in loss of life and high flood damages, for example damages exceeded $10 billion in the 2010 event.

The current approach to flood management involves flood forecasting and warning; flood gauging (although there is a limited network of such gauges); source control of run off, especially by dams; flood protection by levee construction; emergency management (including evacuations); post flood recovery; and flood reporting. However, the current reports are limited in the information they contain which limits their value for future flood planning. There appears to be no asset inventory with information on the various flood control structures and their condition, and there is no asset management plan for their maintenance, rehabilitation or replacement.

There is a large library of flood related legislation in Pakistan and a large number of agencies involved in flood management. For Punjab this includes the PID and its Flood Risk Assessment Unit (FRAU), WAPDA, PMD and the Federal Flood Commission (FFC). The capacity and effectiveness of these organizations was not assessed during this assignment.

The Flood Risk Management (FRM) approach in Punjab should be strengthened by taking a more comprehensive approach. This would involve strengthening institutions; strengthening data and information management and capacity to model floods for planning and forecasting purposes; flood planning including a whole of landscape approach and spatial planning/zoning; flood preparedness and asset management; flood forecasting and warning; flood protection; flood disaster management; flood recovery, and flood communication and reporting.

Internationally an integrated approach to flood risk management is taken where risk is calculated as:

risk = frequency x cost of damage.

This is used to determine the priority actions. Hydraulic modelling is a critical tool to assess flood risk, impacts and to assess mitigation options. Models are also used to forecast flood events and inform flood warnings.

The proposed roadmap for improved flood risk management recommends:

a) Strengthening of FRAU (staff, resources) and updating its mandate to take a more comprehensive approach.

b) Review and adapt international best practice for Punjab.

c) Build a strong data and information management system including monitoring networks, undertake flood mapping informed by modelling, apply flood planning, preparation of a 5-year rolling risk based provincial flood management plan, spatial zoning, drainage plans, including climate change in planning.

d) Update and implement improved flood preparedness, flood warning and recovery programs.

6.11 WATERSHED AND HILL TORRENT CONDITIONS

The barani (rainfed) areas of Punjab cover about 40% (7 Mha) of Punjab and are home to over 19 million people. The Barani areas have been neglected by government, as much of the focus is on irrigation. Dry lands sustain about 80 percent of livestock and contribute to provincial production of wheat 12%, rapeseed & mustard 73%, barley 53%, gram 65%, sorghum 65%, and ground nuts 89%. The focus of this chapter is the Pothohar Plateau, Hill torrent areas and the Cholistan desert.

6.11.1 THE POTHOHAR PLATEAU

The Pothohar Plateau is 22,275 km2 with a population of 17.6 million. It is drained by the Haro and Soan rivers and rainfall is 380-510 mm annually. Its soils are very fertile.

The productivity of Pothohar has decreased by 2.5 to 7 times due to over grazing and removal of vegetation for fuel wood. Issues in the area include unreliable rainfall; subsistence- farming system; old cultural practices; small size and fragmented farms; low soil fertility; unsuitable cropping pattern; soil erosion; limited farm inputs.

Only 3% of the 4.3 BCM annual runoff is regulated through small and mini dams. The remaining 3.4 MAF goes to the Indus and Jhelum rivers. There is considerable scope to construct more dams, reduce large-scale soil erosion, mitigate floods, and conserve soil. Past projects have demonstrated the feasibility of rainwater harvesting and raising livelihoods.

The area is managed by the Barani Area Development Authority which works under the Planning and Development Department (PDD) and is also responsible for soil conservation works. Once a WRD is formed, this Soil Conservation Department could be transferred to PID to work under Chief Engineer, Pothohar.

Participative integrated watershed plans should be developed for the Soan and Haro river watersheds and comprise measures such as:

- Identification of interventions for reducing rainwater runoff
- Prioritization of watersheds and sub watersheds

- Identification of rainwater storage sites
- Assessment of site-specific conservation approaches
- Suitability assessment of perennial crops/trees
- Interventions in agriculture practices
- Public awareness and community mobilization.

6.11.2 THE CHOLISTAN DESERT

The Cholistan Desert covers an area of 25,800 km2 and it joins Thar Desert in Sindh and India. The mean temperature is 28.3o C and the hottest month is July with a mean temperature of 38.5o C. Average annual rainfall is 180 mm, falling mostly in July and August. Droughts are common with an annual rainfall in drought years of less than 10 mm. Groundwater is found at a depth of 30-40 m but is mostly brackish and unsuitable for plant growth. The people follow a nomadic life and the backbone of the economy of area is animal rearing with Tobas (ponds).

The area is under the management of the Cholistan Development Authority, which together with the Pakistan Council of Research in Water Resources, constructs and maintains the watering ponds.

The water resources of the region can be developed by construction of additional ponds; plantation strips along canals; development of aquifer recharge areas; and transfer of flood waters to the dried out water course of the Hakra river. Transfer of the Cholistan Development Authority to PID to strengthen water management should be considered.

6.11.3 HILL TORRENT AREAS

This area includes two Districts (Rajanpur and DG Khan) between the right bank of Indus River and the Suleman range. It has a population of 4.2 million and total area of 21,575 km2. It can be divided into two parts: (i) The CRBC, DG Khan canal commands located on the plains with canal offtakes from river barrages and, (ii) Hill Torrents area which include spate irrigation. Of the total area of 2.39 Mha, 17% is canal commanded, 35% spate irrigation, and 48% mountainous and sub-mountainous.

Annual rainfall is about 350 mm and mostly falls during the June to September monsoon. The mean annual summer daytime temperature is 34 C and June is the hottest month with a mean maximum temperature of 41.5 C. The minimum temperature is 4.2 C in January.

Land use is less than 3% in the upper catchment. Approximately 12% of cultivable land is irrigated in the Pachad area, where the torrents flow through the piedmont (fan) area. Various crops are grown under irrigation and for the non-irrigated areas livestock are the main source of income. Natural shrub vegetation is used for livestock grazing and firewood.

In the hill torrent areas, the land has high runoff potential due to the soil type and slope. Flooding and resulting damages are significant in the Pachad area, which is the most underdeveloped area in Punjab.

Problems faced by the farmers of these areas include low crop yields in spate irrigated areas; high maintenance requirements for bunds; high cost of diversion structures; poor financial resources; damage from floods; heavy sediment load; low priority by researchers and the government.

Hill torrents are managed by Project Circle D.G. Khan under the administrative control of the Chief Engineer of the Zone of PID. There have been quite few projects investigating management of hill torrent areas and possible interventions. The main objective of recent hill torrent management projects has been to reduce the flood damages and improve water availability for irrigation.

Increasing the capacity and support for local staff is important and requires: more staff with a clear mandate and authority; improved knowledge of decision and policy makers; innovative technologies.

6.11.4 ROADMAP

The proposed roadmap includes:

a) Development of participative, integrated 'watershed/area' management plans in each area, which are accepted by communities and government. The plans should cater for climate change, raise local livelihoods, protect local land and water resources, and also protect downstream water resource conditions.

b) Participation, awareness raising and capacity building for farmers and government staff in each area.

c) Implementation of agreed integrated 'watershed' management plans. Depending on local conditions works could include- revegetation, erosion control, sustainable grazing; rehabilitation of existing and construction of new infrastructure; flood forecasting and warning; groundwater recharge and rainwater harvesting; improved irrigation efficiency, conjunctive use, management of salinity and reduction of drainage outflows.

6.12 IRRIGATED AGRICULTURE

Large scale irrigation development started in the British Raj era. Soon after annexation of the territories of Punjab in 1849, the British rulers started an integrated gravity-run canal construction program. This system became the world's largest contiguous canal command irrigation network supplying irrigated agriculture for 33 million acres of land in the Indus Basin.

On independence, the international border between Pakistan and India divided the Irrigation System. The irrigated agriculture on the Ravi and Sutlej rivers in Punjab was truncated, without consideration to any geographical or environmental issues and the Lower Riparian areas of command in Pakistan Punjab were deprived of irrigation supplies.

The dispute with India on water rights was eventually resolved under the auspices of the World Bank by the signing of the Indus Water Treaty in 1960 between the two countries. Under the Treaty India was entitled to the exclusive use of the three eastern rivers (Ravi, Beas and Sutlej), while the western rivers (Chenab, Jhelum and Indus) were allocated to Pakistan.

Indus Basin Project was launched with financial aid from the World Bank and International consortium to undertake works for restoring the supplies of the western river irrigation system by transferring water from eastern rivers. Two large storage dams, 8 inter-river link canals, one sub link, one syphon, one canal crossing complex and 5 barrages were constructed under the Indus Basin replacement works.

The construction of storage and link canals allowed the operation of the Indus irrigation system in an integrated manner, with greater control and improved river water utilization. As a result, the average annual withdrawals increased from 67 MAF in 1949-52 to 85 MAF by 1959-60, and 95 MAF just after the construction of the Mangla Dam in 1967-68. The withdrawals further increased to 101 MAF just after the Tarbela Dam was completed and reached a peak of 108 MAF in 1979. The canal withdrawals remained at this level up to 1989-90 but have now declining to around 105 MAF due to a reduction in reservoir capacities caused by progressive sedimentation. This withdrawal is likely to be restored and further enhanced on completion of Mohmand Dam on river Swat and Basha-Diamer dam on river Indus.

The irrigation infrastructure comprises 13 barrages / headworks, 25 main canals (3,993 miles long with total off-take capacity of 120,000 cusec), 528 miles of inter river link canals (with total off-take capacity of 110,000 cusec), 2,794 number of distributaries and minors of 19,387 miles length. In addition, 57 small dams and an extensive network of surface drains (6,122 miles long), 2,100 miles' flood embankments are operated and maintained by PID. The system serves 8.5 ha (20.78 million acres) of culturable command area through 58,000 outlets and has an average cropping intensity of 125%–150%.

The current Punjab irrigation system supplies on average 107.2 BCM (86.9 MAF) of water annually to 21.71 million acres (8.79 million hectare) of Culturable Command area. There are 15 Diversion structures with 45 main canals which have a discharge range from 15 to 42.5 m3/s.

Surface Drainage is supplementary and complementary to any irrigation system. The irrigation canals cut across drainage lines which impeded natural drainage and therefore man-made drains are required to capture drainage from trapped areas. Drains are also required to take seepage flow and irrigation excess from the agriculture fields prevent waterlogging and to attain acceptable yields. Drains also play an important role in managing salinity. The irrigation system was initially constructed without drainage which was added in an ad-hoc fashion to address flooding and water logging issues. The current drainage system is therefore suboptimal.

Major challenges include:

- Growing demand
- Available water already committed
- Aging infrastructure
- Poor water use efficiency
- Low productivity
- Low value crops
- Inadequate water information management system
- Inequalities in water distribution
- Unsatisfactory operation and maintenance
- Over exploitation of groundwater
- Deteriorating water quality in drains, canals and rivers
- Financial constraints
- Institutional constraints

Improvement opportunities include:

- Upgrade, reconfigure and modernize irrigation supply system
- Selectively line canals
- Construct large dams on the main rivers and small dams on tributaries to increase storage and capture of flood flows.
- Improve the monitoring and decision support system including use of real time data
- Land levelling and use of more efficient irrigation methods
- Change cropping patterns
- More efficient operation of irrigation delivery system
- Improved maintenance of canals, gates/barrages, and drains
- Revise water allocation system
- Revise pricing/tariff structure

6.13 URBAN WATER SUPPLY, SANITATION AND URBAN INTEGRATED WATER MANAGEMENT

Punjab has the largest provincial population in Pakistan with of 110 million people, with 37% living in urban areas and 63% in rural areas. Drinking water and sanitation services are lacking (e.g. less than 1% of Lahore has a functioning water supply scheme). Provision of drinking water supply and sanitation facilities for the increasing population is a serious challenge.

Challenges to providing clean drinking water supplies in urban areas are:

- surface and groundwater are contaminated by untreated industrial, commercial, and domestic effluent.

- Inadequate operation and maintenance of infrastructure.
- Significantly increased arsenic levels and other heavy metals in the groundwater.
- Leakages from old water and sewerage pipelines contaminating urban drinking water.
- Uncontrolled land conversion from irrigation to urban uses reducing groundwater recharge.
- In rural areas 88% of water is unfit for drinking, due to brackish groundwater.
- Lack of water storage or artificial recharge to augment the deleting groundwater resource.

A high proportion (75%) of households in Punjab have access to improved sanitation. However, this varies widely across the province and between urban and rural areas. Disposal of raw sewerage however is poor and used for irrigation or disposed directly into drains and rivers. This is a serious health risk as evidenced by widespread infection by water borne diseases in the province.

Both the ADB and the World Bank work with the government to improve infrastructure and management aspects of water supply and sanitation.

From a water resource perspective urban water is an important sector, with important consequences for the Basin's water resources and how they are managed:

- Groundwater resources and their quality are diminishing, and alternative good quality water supply is needed.
- Water availability in the Ravi and Sutlej rivers is insecure and therefore other mechanisms to supply water are required.
- Raw sewerage is disposed into drains and rivers, degrading water quality.
- Stormwater causes local flooding and downstream pollution. It is a potential source of water for agriculture and recreation, following rudimentary treatment by wetlands.

Proposed actions relevant to the river basin plan include:

a) Prioritizing settlements with critical water supply issues so that the RB Plan and Doan plans can consider options for providing/arranging surface and groundwater.
b) Prioritizing sections of rivers and aquifers with poor water quality so that wastewater pollution control policies and investments can be targeted.
c) Prioritizing urban areas with drainage and flooding issues to target investments and manage local river flooding.
d) Prioritizing sections of rivers which have high community value such as for recreation, so they can be addressed by river management plans.
e) Adapt the international IWM approach for urban water management to better manage and utilize stormwater and wastewater.
f) Capacity building for adoption of IWRM to lessen non-point source pollution loads and to use stormwater beneficially.

7 DESIGN OF WATER RESOURCES INFORMATION SYSTEMS FRAMEWORK

7.1 PUNJAB PROVINCE WATER RESOURCES

The Punjab Irrigation Department (PID) is responsible for the operation, maintenance and rehabilitation of one of the largest contiguous irrigation systems in the world comprising 13 barrages, 25 main canals (3,993 miles), 528 miles of inter-river-link canals, 2,794 distributary canals (19,387 miles). In addition, PID also maintain 55 small dams, an extensive network of surface drains (6,122 miles) and flood embankments (2,100 miles). The irrigation system serves approximately 8.5 million ha (20.78 million acres) of agricultural land and has gradually achieved an average cropping intensity of 125%–150%.

Water resources in Punjab are facing severe challenges from growing water demand, competition for water, excessive surface and ground water exploitation, deteriorating water quality, climate change, variability in intensity and periodicity of river flows and floods, increasing scarcity of fresh water, very limited opportunity to find new sources or increase water availability. In addition, environmental Issues such as decline of freshwater ecosystems and loss of river system functions compound the challenges.

7.2 NEED FOR IMPROVED WRIMS

The need for a long term sustainable and reliable water resource/supply to meet all demands including that of the environment require better governance of the available resources. Data, information and data/information management are key to better governance and more effective in management of this finite resource.

The objectives of this task were to design a comprehensive Water Resources Information Management System (WRIMS) to:

- collate and store real-time water related data and information
- proactively monitor, forecast and manage water demand and use
- continually assess water resources availability (surface and groundwater), sectoral water demand, and use
- provide information to decision support systems
- provide information to develop and manage water resources infrastructure for:
    - increased agricultural productivity
    - optimal water use in all sectors
    - environmental protection and
    - improved water services provision
- help reduce risk of water-related disasters
- meet national, basin and provincial reporting commitments
- build public awareness of current state and forecasts of water resources
- support water-related research, commercial and industrial activities.

PID has an existing WRMIS which has been updated several times in the past. A careful analysis was required to review the numerous and piecemeal earlier attempts and identify the reasons for previous failures and/or limited successes.

7.3 WRMIS - CONCEPTUAL FRAMEWORK

7.3.1 A WRMIS TO SUPPORT KEY OBJECTIVES

Systematic water information/data gathering, verification, management, analyzing, forecasting and informed decision making are keys to successful water management. This requires a database with tools including forecasting and decision support/making systems to ensure water resources are managed in an integrated way.

Key objectives are:

1. To continually assess:
   - water resources availability (surface and groundwater);
   - Sectoral water demand;
   - Water use; and
   - Plan optimal water usage.
2. To manage water resources infrastructure for:
   - Equitable water supply;
   - environmental protection; and
   - improved water services provision.
3. To reduce risk of water-related disasters.
4. To meet reporting commitments.
5. To build public awareness of current state and forecasts of water resources.
6. To support water-related research, commercial and industrial activities.

A general overview of a conceptual framework is provided in Figure 7-1.

7.3.2 DECISION SUPPORT SYSTEMS (DSS)

DSSs need to be developed in stages to ensure they meet the needs of PID/WRD and suit local conditions and requirements. There have been several DSSs developed all over the world for water allocation and management. Lessons learnt from these projects should be considered where relevant to Punjab and Pakistan. For example, a DSS developed in Australia is unlikely to be suitable for Punjab. However, the approaches could be modified to suit local conditions rather than developing a first principle approach.

Table 7-1 provides a list of potential DSS that could be developed for PID/WRD to manage its resources.

WRMIS

- Irrigation area – area, crop types, season
- Soil types -
- Climatic data – rainfall, evaporation
- Tributary inflows – gauged and ungauged
- Rim stations
- Storage information - level, available volume
- Barrages
- River flow and level data
- Canal flow and level data
- River system
- Irrigation System - Canal network, Link canal, Water User Association
- Water allocation
- User information and demand patterns
- Environmental water requirements
- Groundwater – bore data and usage
- Water quality data
- Asset data
- Topographic information – LiDAR, Contours etc
- Aerial images

TOOLS - DSS

- Demand Forecast
- Resource Management
- Rainfall runoff forecast
- Canal operation
- Canal water allocation
- Canal water balance at various levels
- Basin/sub-basin water balances
- River operation
- Storage operation
- Drought Management
- Asset Management
- Groundwater recharge estimation
- Groundwater usage estimation
- Flood forecasting / management
- Drought management
- Risk based management tools

REPORTS

- Canal performance reports at various level
- Tail end performance reports
- River operation
- Storage operation
- Water balance reports
- Works programs - capital and maintenance forward work programs and costs
- Financial performance reports
- Asset Management Reports
- Other reports required by WRD/ PID/ Government

Figure 7-1: Conceptual Framework

Table 7-1: Potential DSS

DSS	Objectives
Water Allocation	• to allocate water equitably to all users based on their entitlement and current season allocation
Irrigation Water Management	• to improve water productivity • to determine crop water demand and supply by adopting satellite-based technology together with physical measurements • to generate planned, forecasted (7 and 14 days in advance) and optimized canal flows for all canals; • to smooth canal flows based on demand forecast to improve water efficiency • to plan and manage canal operations to meet demands • to develop irrigation system performance indicators
Water Resource Management	• To estimate river flows (unregulated and regulated) including rainfall runoff • To estimate canal flow requirements

DSS	Objectives
(wholistic management with sophisticated computer models)	• To manage storage releases to meet shortfalls (demand + losses - river flow + rainfall runoffs)
River Basin Management and IWRM	• For the efficient and effective management of the Indus River Basin
Groundwater Management	• to improve water productivity • to have a greater understanding of groundwater availability during the season • to monitor and record real-time groundwater extraction • to ensure sustainable groundwater use
Flood Management	• to manage floods in a way to minimize flood damage (flood alerts, forecasting and mapping) • to use floodwaters productively (i.e. increase water harvesting potential and groundwater recharge)
Drought Management	• to minimize drought impacts • to optimize water use and water productivity
Asset Management	• To be sustainable irrigation department • To account for all assets and improve asset management • To understand and capture whole of life cycle costs • To develop forward asset maintenance and replacement programs based on improved/real-time data
Canal Operation	• To operate canals using real time data for efficient water delivery and to minimize water losses
Infrastructure Management	• To minimize water losses • To improve water security • In lower whole of life cycle costs
Irrigation Area Management	• Reduce Irrigation Footprint • No way all lands can be irrigated (Not an option)
Agriculture Productivity	• Smart Farms and Farmers • Don't need more irrigation water • Need to improve farm productivity • Need to find ways to increase income with the available water
SCADA	• Identify requirements • Develop stepwise and sustainable implementation plan
Water Footprint	• to better account for water consumption and to improve overall water and agriculture productivity

7.4 REVIEW OF EXISTING WRMIS

The existing WRMIS is a web-based Water Resource Management Information System (WRMIS) and is partially integrated with other PID systems for assisting in daily operations. This system is an enhanced and upgraded version of PID's older System IMIS. In addition, the WRMIS also incorporates a GIS based real time flow monitoring system and several other modules.

The new WRMIS has been partially implemented but only a few Program Monitoring and Implementation Unit (PMIU) staff have access.

A public website of Punjab Irrigation has also been made available to the general public, which provides essential information such as river and canal discharges, groundwater monitoring maps, rotational program and the tail status of all channels. The public website address is www.irrigation.punjab.gov.pk.

The existing WRMIS has several modules – some are well developed and others in the conceptual stage.

7.5 CONCEPTUAL DESIGN VS EXISTING WRMIS

7.5.1 WRMIS

Table 7-2 shows the status of the existing and proposed design of Punjab WRMIS.

Table 7-2: Status of the existing and proposed design WRMIS

DATA / INFORMATION	EXISTING WRMIS	PROPOSED DESIGN
Irrigation area – area, crop types, season	Not available	Yes
Soil types -	Not available	Yes
Climatic data – rainfall, evaporation	Not available	Yes
Tributary inflows – gauged and ungauged	Yes	No Change (integrate with other modules)
Rim stations	Yes	No Change (integrate with other modules)
Storage information - level, available volume	Yes	integrate with other modules
Barrages	Yes	integrate with other modules
River flow and level data	Yes	integrate with other modules
Canal flow and level data	Only at canal head	Yes
River system	Yes	Upgrade
Irrigation System - Canal network, Link canal, Water User Association	Yes	Yes
Water allocation	Yes	Integrate
User information and demand patterns	No	Yes
Environmental water requirements	No	Upgrade
Groundwater – bore data and usage	Yes	Integrate
Water quality data	No	Yes
Asset data	No	Yes
Topographic information – LiDAR, Contours etc.	No	Yes
Aerial images	No	Yes

7.5.2 DECISION SUPPORT SYSTEM (DSS)

Table 7-3: Status of the existing and proposed design of DSS shows the status of the existing and proposed design of Punjab WRMIS data storage system (DSS).

Table 7-3: Status of the existing and proposed design of DSS

DSS	EXISTING WRMIS/DSS	PROPOSED DESIGN
Water Allocation	No	Yes
Irrigation Water Management	Demand Forecast (Limited)	Upgrade
Water Resource Management (holistic management with sophisticated computer models)	Very limited	Upgrade as discussed with PID
River Basin Management and IWRM	No	Yes
Flood Management	Yes	Integrate
Drought Management	No	Yes
Asset Management	No	Yes
Canal Operation	No	Yes
Infrastructure Management	No	Yes
Irrigation Area Management	No	Yes
Agriculture Productivity	No	Yes
Water Footprint	No	Yes

7.5.3 REPORTS

Table 7-4: Status of the existing and proposed design of DSS shows the status of the existing and proposed design reporting system.

Table 7-4: Status of the existing and proposed design of DSS

REPORTS	EXISTING WRMIS/DSS	PROPOSED DESIGN
Canal performance reports at various level	Yes	Integrate
Tail end performance reports	Yes	Integrate
Canal/River operation	No	Yes
Storage operation	No	Yes
Water balance reports	No	Yes
Asset Management Reports	No	Yes
Works programs - capital and maintenance forward work programs and costs	No	Yes
Financial performance reports	No	Yes
Other reports required by WRD/ PID/ Government	Not sure	Yes

7.6 DESIGN TO UPGRADE EXISTING SYSTEM

7.6.1 WATER RESOURCE INFORMATION SYSTEM (WRIS)

Based on an in-depth study and analysis of the existing WRMIS, improvements and additional capabilities have been identified. An upgraded WRIS conceptual framework for a fully automated and integrated decision support system is shown in Figure 7-2. Figure 7-3 shows the proposed WRIS architecture. A description of major components is provided below.

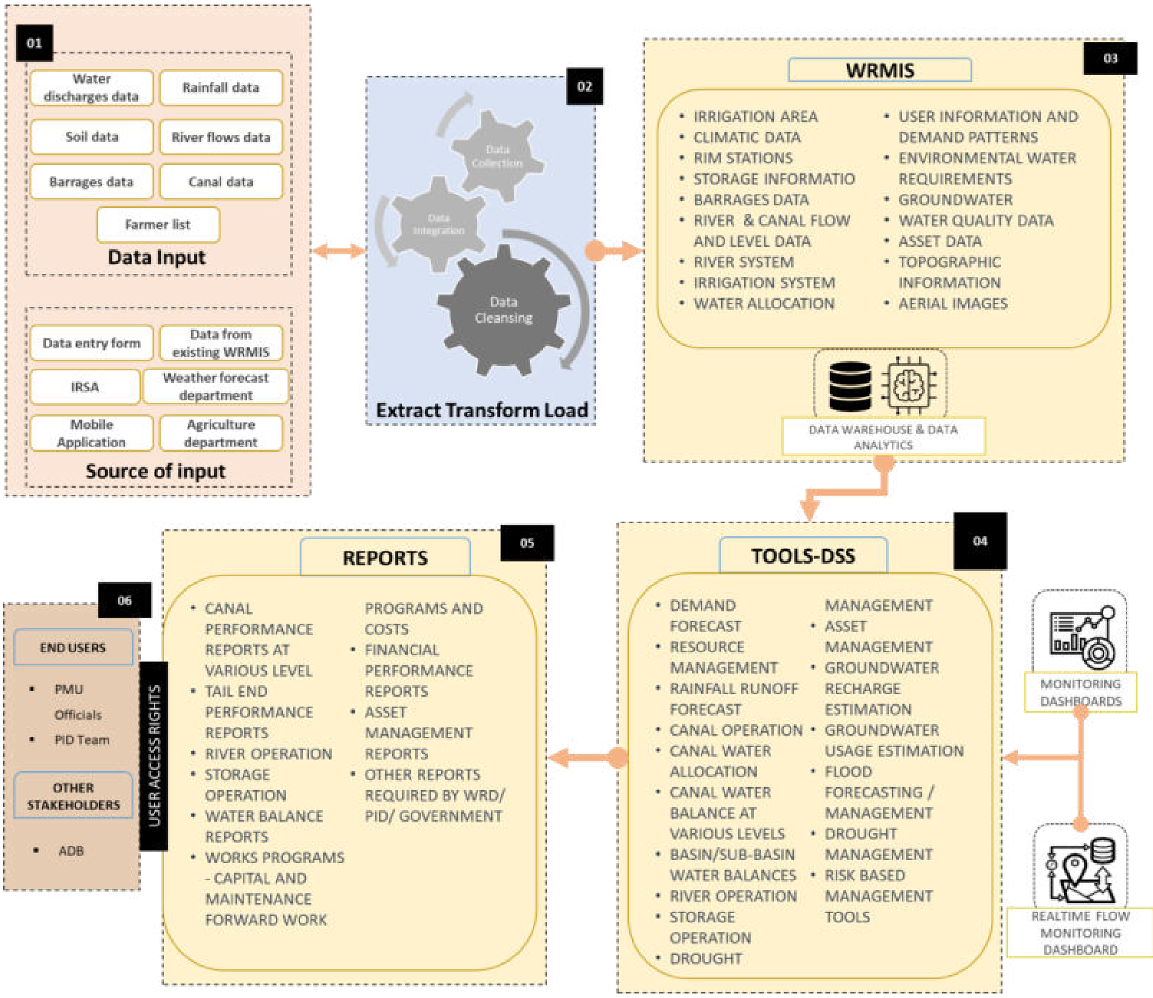


Figure 7-2: Conceptual View of AWRIS Dashboard

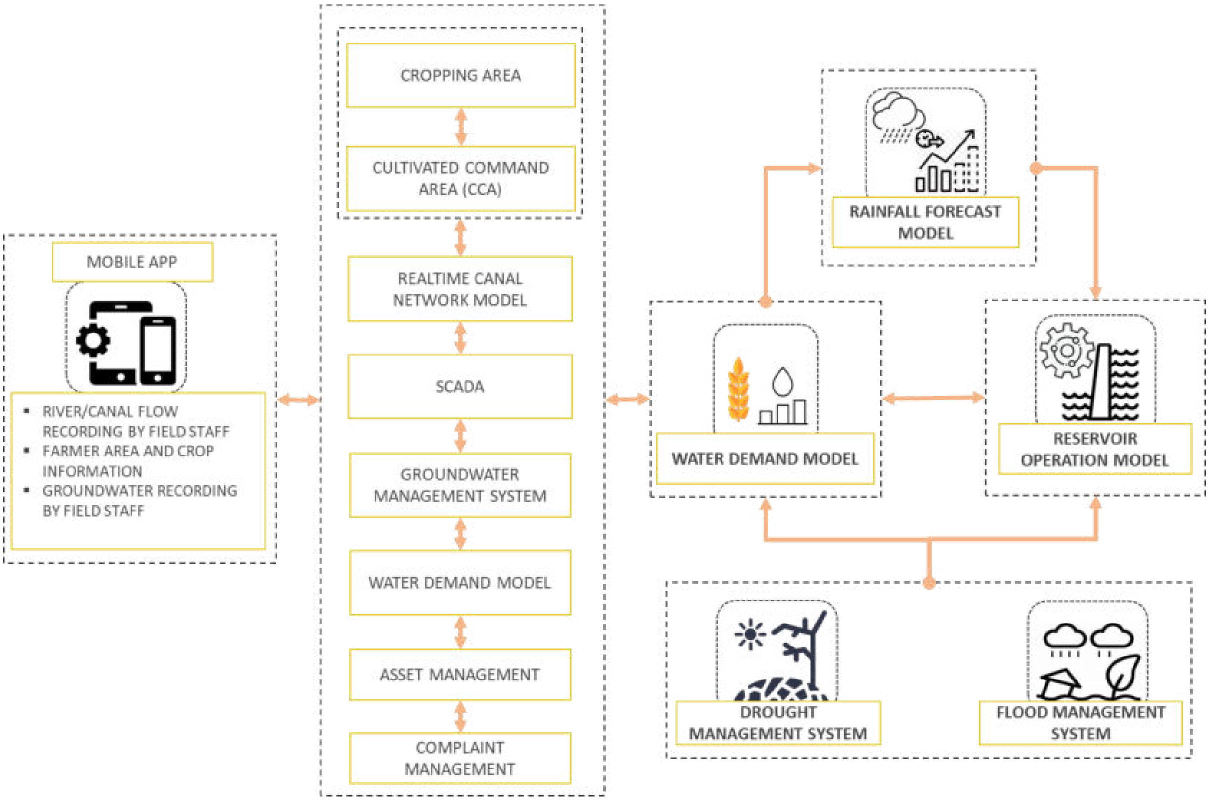


Figure 7-3: AWRIS Architecture

7.6.2 MOBILE APPLICATION FOR FARMERS AND SURVEYOR

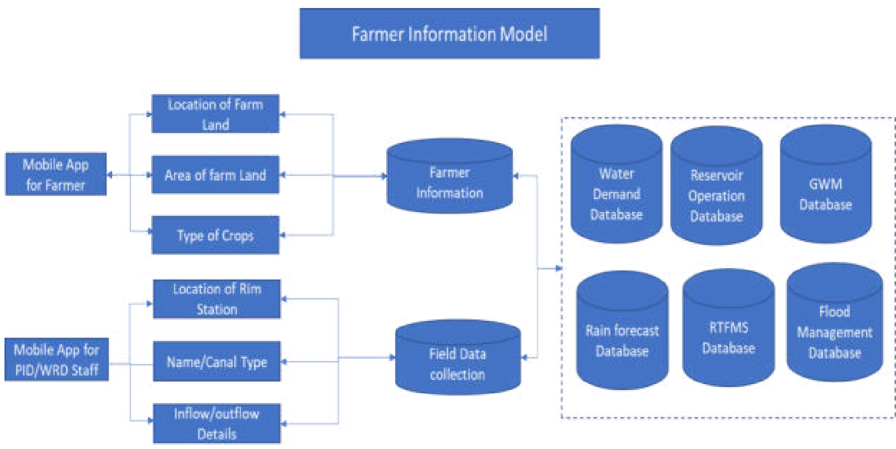
Mobile App development of farmer data collection.

Development of mobile application for the farmers to enter the following information:

- Location` information of the farmland
- Area of the farmland
- Type of crop which will be grown
- Period of crop
- Canal network to which the land will be connected

Upon selection of crop type, farmer should be able to view the water distribution plan and accordingly should provide a set of instruction to help the farmer to grow the crop.

The farmer should be able to see the information of suggested crop to be grown or any other news, which will be provided by the government of Pakistan to meet the country crop demand.



Mobile App development of field data collection.

Currently all the data regarding the River/Canal flow is being updated manually. Development of mobile application to collect field data by surveyors and collect the information of RIM station and river/canal inflow and outflow data. The mobile application will collect the following information

- Location of the station – Once the field operator logins to the mobile app, it will record the location of that person using the mobile GPS and will store the information of data entry with timestamp.
- Name/canal type – Field person must fill the basic information about the location and select the correct station for which the data is being recorded.
- Inflow and outflow information – Inflow and Outflow data will be filled in the section provided in the mobile application for that station.
- Site photos/videos – The field person will take a daily photograph/video of the location while entering the data to maintain the proof of data recorded.
- Route Data – The mobile app should also record the total distance covered by the field staff using the mobile GPS. This data should also generate the total fuel consumption per field staff based on the distance covered and the vehicle used and other necessary parameters.

7.6.3 REAL TIME RIVER/CANAL NETWORK MODEL

The read-time river/canal DSS aims to help address the decision-making problems regarding equitable water allocation to all users and at different canal levels to improve water allocation process. ***Figure 5-3*** provides a framework that involve two processes that contribute to developing an and implementing water allocation - the crop water requirement and irrigation scheduling. The crop water consumption calculation considers water entitlement, availability, cropping pattern, climatic data, soil data, reference evapotranspiration and channel system capacities and account irrigation water quotas, water right areas, channel hydraulics and cropping patterns. The second process works out the irrigation scheduling based on channel capacities, remaining water allocation, water availability etc. This DSS combines these two processes to assist in equitable water delivery and improve water delivery efficiency.

7.6.4 GROUNDWATER MANAGEMENT

A groundwater monitoring module is already available but needs upgrading. Punjab Irrigation Department (PID) has about 3312 monitoring bores in the seven sub-basins in Punjab. The number of monitoring bores has increased since 2000. However, monitoring has not been undertaken on a systematic basis. Monitoring of depth to water (DTW) and electrical conductivity (EC) is required for assessing the lateral and vertical movement of saline zones into freshwater zones, and to ensure the long-term sustainable management of freshwater zones.

This upgraded groundwater module shall incorporate

- aquifer information, soil condition and land use land cover data and will be capable of estimating groundwater recharge.
- calculators to estimate sustainable and permissible diversion volumes.
- incorporate the existing information/structure with improvements to allow better use of the data to improve water management.
- integration with RTFS and Mobile app to record the information about the ground water level
- a web-based dashboard.

7.6.5 DROUGHT MANAGEMENT

A drought management module is not available in the existing WRIS, the objective of this module is to create a proper tool for the decision makers and administrators to take effective and consistent actions.

The data requirements for a drought management system include the following:

- Climate data
- Water availability – river flow, groundwater
- Reservoir data
- Short, medium and long-range forecasts
- Water demand

Following are the key outputs of this module:

- Monitoring drought
- Drought forecast
- Drought response system - water management plan, water allocation plans/hierarchy, water conservation steps
- Storage level

7.6.6 SCADA

Operating a conventional upstream controlled canal system is a difficult and demanding task. Control, reporting, historical data, rising costs of energy, limited water supplies and labour represent only a few management concerns. Supervisory Control and Data Acquisition (SCADA) will allow the water manager to operate the system automatically or remotely, continuously monitor the canals and to take appropriate corrective steps as required. This will allow the managers to respond immediately and make effective decisions to reduce canal spillage and operational losses.

The SCADA module would make use of the crop water requirements (or orders placed) as well as the irrigation schedules from the Real Time River Canal Network Model (refer Section 7.6.3) as key inputs. The SCADA facilitates the automatic operation:

- Adjusted demand requirement is sent to the customers outlet which automatically opens at requested time, continually adjust to deliver the ordered flow rate and close.
- Upstream flow gate anticipates the downstream demand using feed forward control and continuously adjust to maintain the water level immediately downstream based on real-time water level and flow information.
- As each regulator adjusts to maintain the water level in the downstream pool, upstream regulator in turn adjusts right through to the main offtake and to the reservoir.

This automated operation minimizes spills and losses which occurs in traditional manually operation irrigation water supply system. The process also ensures that the exact reservoir releases are made, the exact amount of water required is drawn from the reservoir.

7.6.7 ASSET MANAGEMENT

The objective of an asset management system to make proactive decisions that lower the asset failure risks as well as to ensure optimal asset expenditure over the full lifecycle. This module will be a holistic dashboard to provide information which covers asset acquisition, maintenance, operation and life. The key aspect of the asset management is to provide WRD a tool in order to become a sustainable irrigation department.

The module will cover the following major key points:

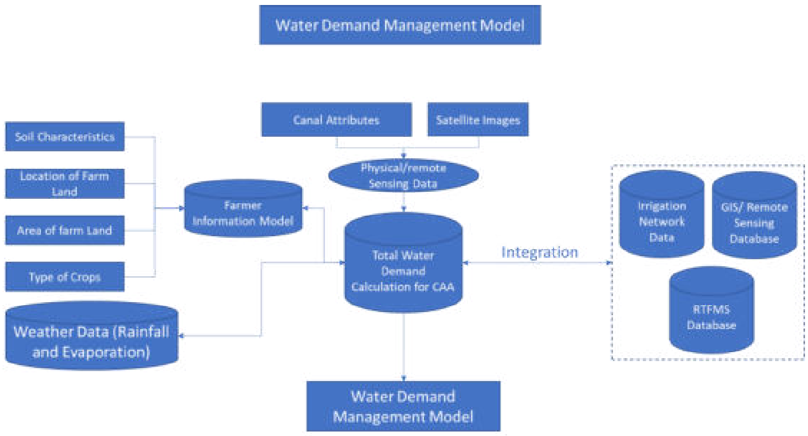
- Compile asset information in one place
- Managing risks
- Keep track of true cost of the entire system and parts of the system
- Provide replacement, renewals cost
- Develop routine maintenance and capital investment programs

7.6.8 COMPLAINT MANAGEMENT SYSTEM.

PID has a complaint management system where all the information is loaded manually and the system is a standalone tool. This needs to be upgraded and integrated with the proposed WRIS.

7.6.9 WATER DEMAND MANAGEMENT MODULE

A demand module is proposed to improve water productivity and to monitor irrigation performance indicators. The total water demand will be calculated based on the crop data provided by the farmers, climate data as well as remote sensing data such as satellite images. This will form the basis for the water demand management module. This module will be integrated with the existing and proposed irrigation network modules and GIS/remote sensing module to generate, forecast and optimize canal flows.



7.6.10 FLOOD MANAGEMENT MODULE

A flood operations and flood early warning system is available in the existing WRMIS. In order to become flood resilient, more advance and comprehensive features need to be incorporated in this module, including:

- Realtime daily recording of rain gauges
- Realtime water level recorders with rated sections or measuring structures to provide river discharge measurements
- Climatological data, particularly to provide an estimation of evaporation losses and water balance
- General topographical and land use mapping to define catchment characteristics
- Detailed topographic survey of river and adjacent flood plain (the flood corridor or functional flood plain)
- More detailed topographical survey and accurate flow measurement for identifying areas at risk.

Using the above key input parameters, the module for flood management will offer three key services:

1. Threshold-based flood alert, creating such services will allow more resilience to mitigate the risk.
2. Flood forecasting to estimate and predict the timing, duration and magnitude of flooding. This service will be evaluated regularly in order to calibrate the model after any flood event.
3. Vigilance mapping will provide conscious decisions of the areas which need to be considered in flood disasters.

Figure 7-4 shows the flood management conceptual module.

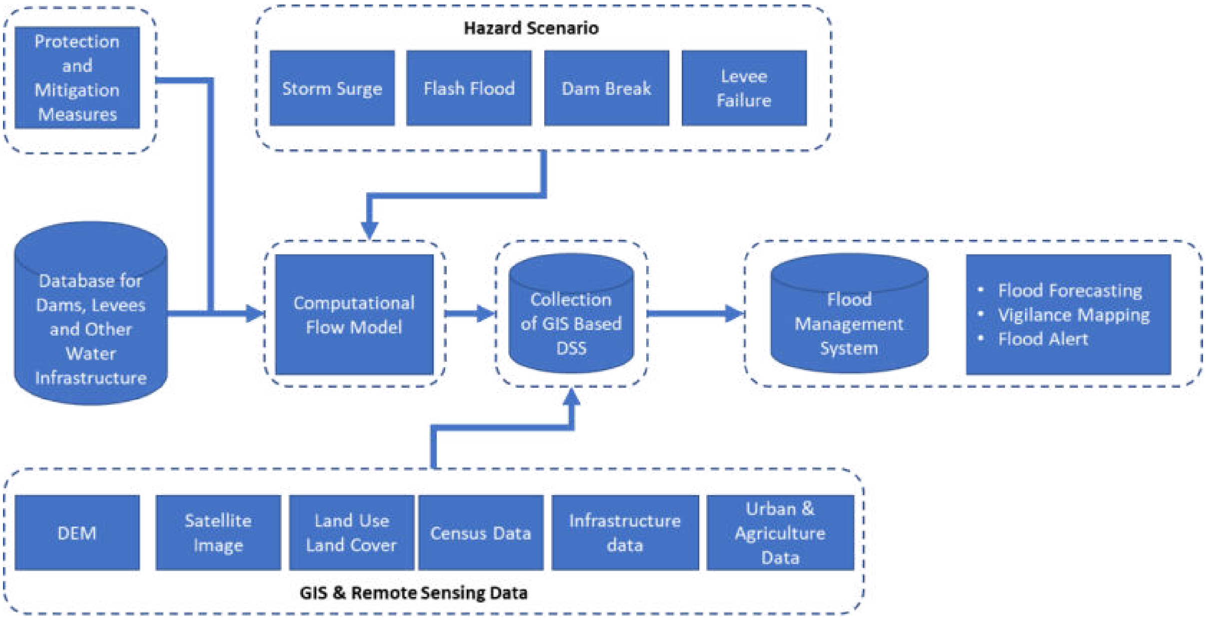


Figure 7-4: Flood management module

7.6.11 RESERVOIR OPERATION SYSTEM

PID currently has a spreadsheet model that contains basic information about the reservoir such as current storage water level, inflow, outflow, IRSA inputs, etc. The model doesn't provide any inputs to storage operation decisions.

An integrated river operation system (refer Figure 7-5) would assist PID and WRD in managing the storage efficiently and improve water productivity.

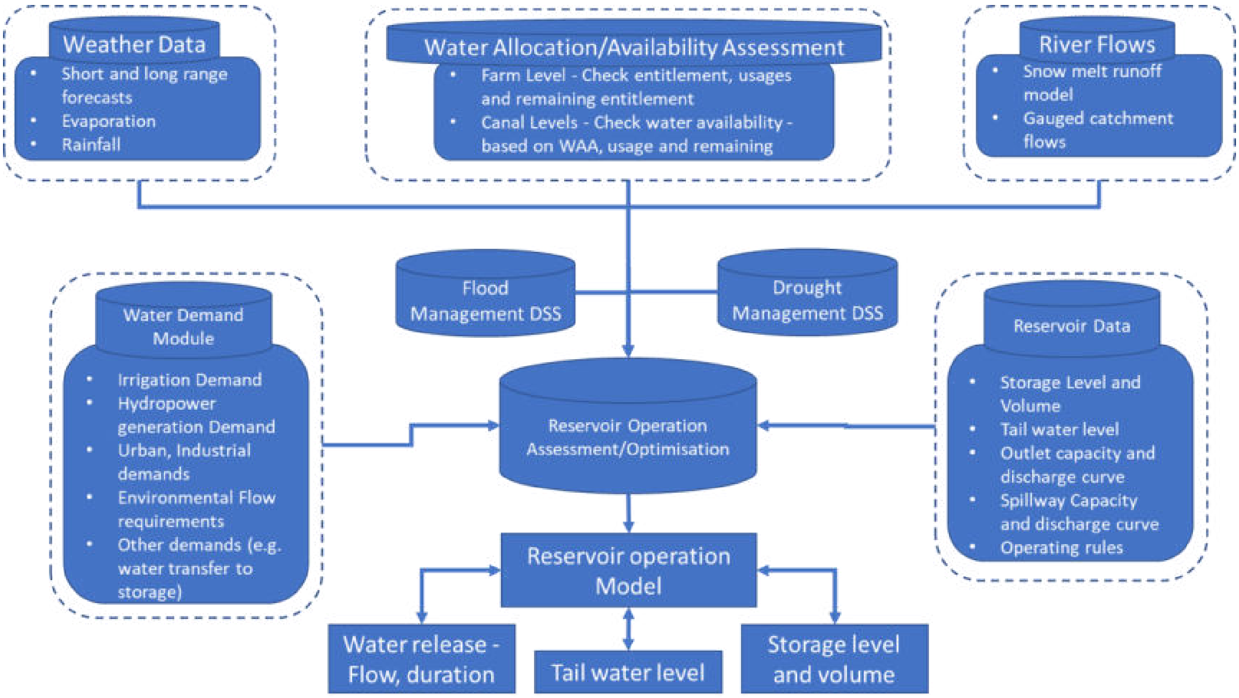


Figure 7-5 Process Diagram for Reservoir Operation System

7.7 NEXT STEPS

The following next steps are recommended:

- Consultation with all stakeholders
- Confirm design
- Develop a realistic implementation plan – consider pilot development and refinement before implementing at the Indus Basin level
- Identify capacity building requirements and potential international/national partners
- Seek funding
- Execute the implementation plan

8 UPGRADING OF THE IRRIGATION RESEARCH INSTITUTE (IRI)

8.1 GENERAL

The Irrigation Research Institute (IRI) was established in 1974 as a Research Zone to meet provincial research needs relating to water. The IRI continues to function through its three research directorates for hydraulics, physics and design. The IRI capabilities have been in decline due to capacity constraints. The changing water environment in Punjab and emerging research needs, necessitate modernization of the IRI.

Punjab Water Policy 2018 outlined the need for strengthening and capacity building of PID and IRI, whilst the need for rejuvenation of the IRI was highlighted in the terms of reference of the ADB financed Capacity Development Technical Assistance and subsequently in the Contract for Consultant's Services (CCS).

When the IRI was first established there was a focus on the use of physical scale models to assist in the design of hydraulic structures associated with large scale irrigation and hydropower development projects. Research needs and available technology have changed dramatically since that time which requires very different skills and technology, with a heavy shift towards advanced computer modelling techniques.

8.2 CURRENT STATUS

The Irrigation Research Institute (IRI) of PID undertakes diverse research on water management. Since its establishment, its research domain has been expanded to hydraulics and hydraulic structures, soil reclamation, testing of materials and water quality and geo-technical Investigation. Recently, groundwater and GIS units have merged with the IRI. The IRI functions through its three research directorates: Hydraulic, Physics and Design. The IRI is well known for its Hydraulic Directorate and Nandipur Research Station (NRS), where physical hydraulic model studies are conducted for rivers and large hydraulic structures. The NRS serves the country as well as regional requirements, but its capacity has diminished significantly due to loss of experts and financial constraints.

The organization structure of IRI is shown in **Figure 8-1**. Historically the IRI included four Directorates, but a recent restructure of IRI has resulted in the Directorate of Land Reclamation being *moved to PID. The responsibilities of each Directorate are provided in ***Table 8-1***.

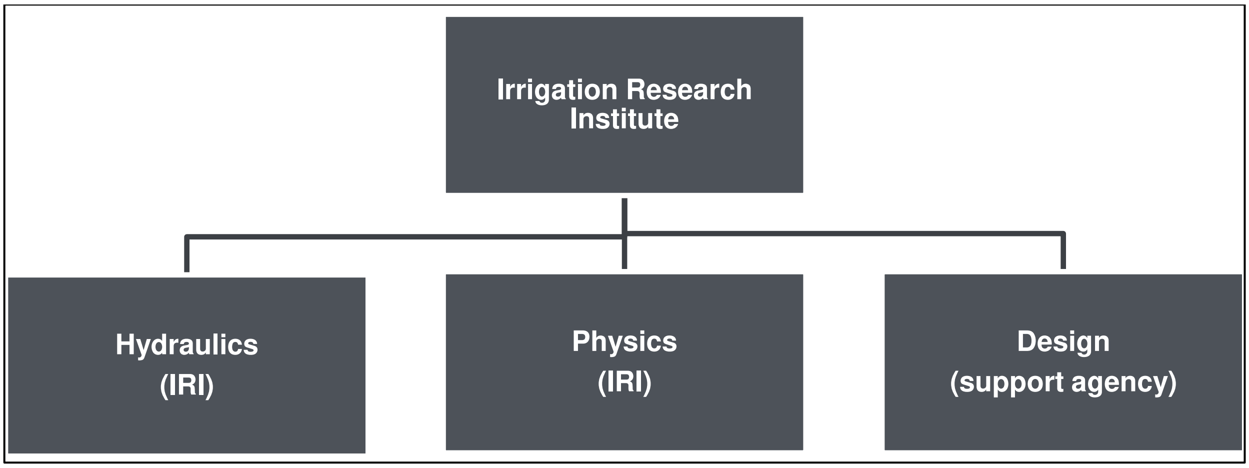


Figure 8-1 : IRI Organization structure

Table 8-1 : Organizational functions of IRI

<table>
<tr>
<td>Hydraulic Directorate
• Conduct model studies and propose the solutions for Flood Protection Works, Flood Management and Control Dams, Spillways, Barrages Weirs, River Bridges and Hydraulic Structures of Canals / Drains, Outfall locations and structures etc.
• Optimize design of Hydropower Projects
• Optimize design of Barrages, Dams and Reservoirs
• Authenticate and validate Hydraulic conveyance capacities.</td>
<td>Physics Directorate
Established in 1924, the Physics Directorate aims to conduct basic and applied research at field and in semi-field conditions.
• Investigation/Testing for engineering Materials
• Research activities related to:
▪ Soil Mechanics
▪ Hydrology, Environment & Groundwater
▪ Engineering. Materials & Quality Control
▪ Geo-Synthetics & Canal Lining
▪ GIS & Computer Section
▪ Water Conservation & Soil Physics
▪ Surface & Sub-Surface Drainage</td>
</tr>
<tr>
<td>Directorate of Land Reclamation (now with PID)
• To study the:
▪ Soil, water and plant relationship
▪ Saline, saline-sodic, sodic and waterlogged soils
▪ Conjunctive use of Groundwater for agriculture
• Irrigation techniques and farm water management
• Having organization, coordination and technical control of land reclamation operations on the farmer fields in the canal circles where water is available
• To generate, acquire and disseminate information and knowledge relating to problem of soil and water
• The collection, compilation and checking of waterlogging and salinity data throughout the Punjab
• Groundwater Monitoring and data logging</td>
<td>Design Directorate
Established in 1926 and upgraded in 1973, the Design Directorate has designed:
• Five small dams in the Pothohar area.
• Outfall structure (B.S Link) & Tail regulator of D.G. Khan canal and fall structures of link-III.
• Babakwal head regulator and subsidiary weir.
• Head and X regulators of B.S Link-I and allied bridges.
• Head and cross regulators of Hakra & Eastern canals
• Cross regulators / syphons of LBDC.
• Hydraulic structures bridges of MBL of BRBD, PML (U), UCC, LJC & Southern Branch.
• Bridges on Aik-Nullah, Eastern Sadiqia Canal,
• R.C.C slab on combined railway & village road bridge</td>
</tr>
<tr>
<td colspan="2">Current Main Activities (2020)
• Training on GIS and Capacity Building of staff.
• Groundwater, Modelling and Management Component of LBDCIP.
• Monitoring of Pollution in Ravi River and its Impact on Groundwater.
• Geo-technical and Geo-chemical Investigation for different Projects of Public and Private Sectors.
• Construction Materials Testing for Quality control of different projects.
• Establishment of Field Research Station at Babakwal and up-gradation of Labs</td>
</tr>
</table>

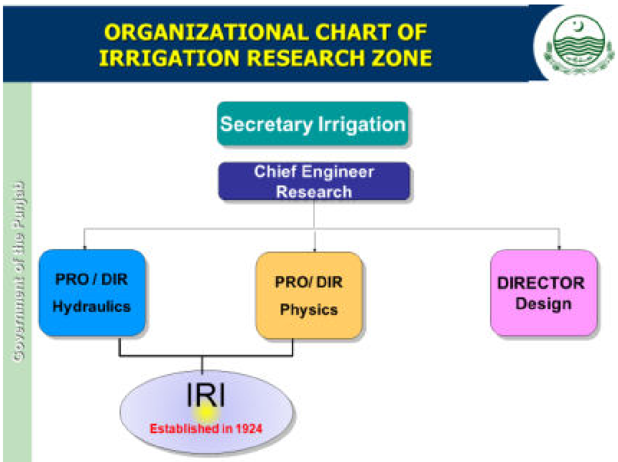
8.3 EMERGING TRENDS AND EXPECTED CHANGES

Extensive changes have occurred in the water landscape of Punjab during last 6-7 decades including rural to urban migration, population growth, increasing irrigation development and increased use of groundwater. These changes have resulted in competition for water and water quality degradation. The increasing role of groundwater as a supply source, demands more effective conjunctive use of surface and groundwater for both agricultural and urban use. Poor

drainage causes land degradation, which reduces productivity. Channel changes have impacted the carrying capacity of the rivers for both water and sediment. Flood management is now directly linked with poor drainage, land use changes and urbanization. There is a pressing need to rehabilitate and modernize the aging infrastructure to improve water use efficiency. All these challenges demand a strong research capability for Water Resources in Punjab, but a very different skill set and technological capability to the traditional IRI.

8.4 REVIEW OF IRI

8.4.1 PRESENT STRUCTURE OF IRRIGATION RESEARCH INSTITUTE, LAHORE



Irrigation Research Institute (IRI) is headed by the Chief Engineering Research Zone Lahore. It has two research directorates, namely Directorate of Hydraulics and Directorate of Physics and a design directorate. Principal Research Officers/Directors oversee each research directorate and the design directorate is headed by a Director.

Key functions of the directorates are:

Hydraulics Directorate - Responsible for research in the fields of river morphology, diversion structures, river erosions, silting & scouring, sediment transport, authentication/validation of hydraulic structures design, river embayment, flood protection of strategic locations, flood management, river training layout, component designs of dams, barrages, bridges etc.

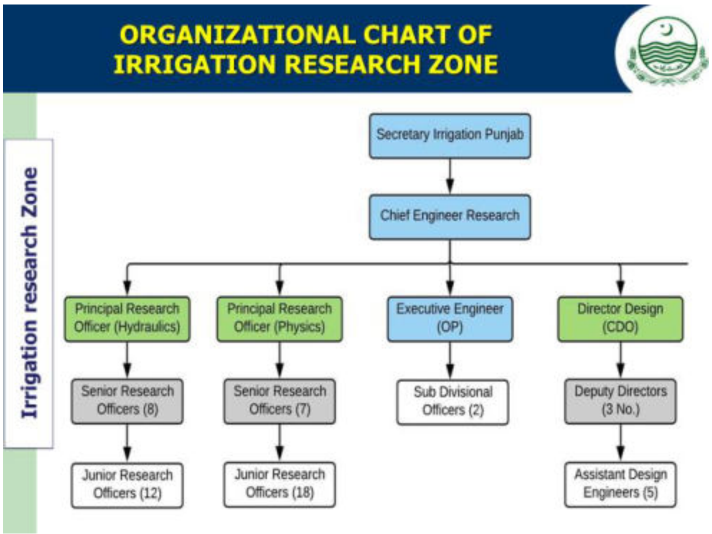
Physics Directorate – Undertaking research and development related to soil physics, soil chemistry, groundwater managements, groundwater recharge, materials of construction, geotechnical investigation, water quality, evapotranspiration seepage management, canal regime, canal lining, seepage investigation and control, GIS mapping etc.

Design Directorate - Design of dams, hydraulic structures, canals and other associated infrastructure for the Punjab Irrigation Department.

8.4.1.1 THE HYDRAULICS DIRECTORATE

Irrigation Research Institute is predominantly known for its research carried out in the hydraulic directorate in the field of Physical scale modelling. The directorate is headed by a Principal Research Officer/Director (Hydraulics) and has an establishment of eight senior research officers and twelve junior research officers.

The main functions of the directorate are:



- Physical Model Studies - conduct physical model studies and propose optimal solutions of hydraulic problems across the country for Flood Protection Works, Spillways, Weirs, Bridges, Regulators, Distributors and Hydraulic Structures of Canals / Drains.
- Design Optimization – Develop optimal design of Barrages, Dams, Reservoirs and Hydropower Projects
- Validation - To authenticate and validate capacity of hydraulic structures for their hydraulic performance, design requirement and layout.
- River training and erosion control - To provide guidance and solutions for river training/ control for flood and erosion protection at any single strategic point and/or along all reaches from control point to control point.

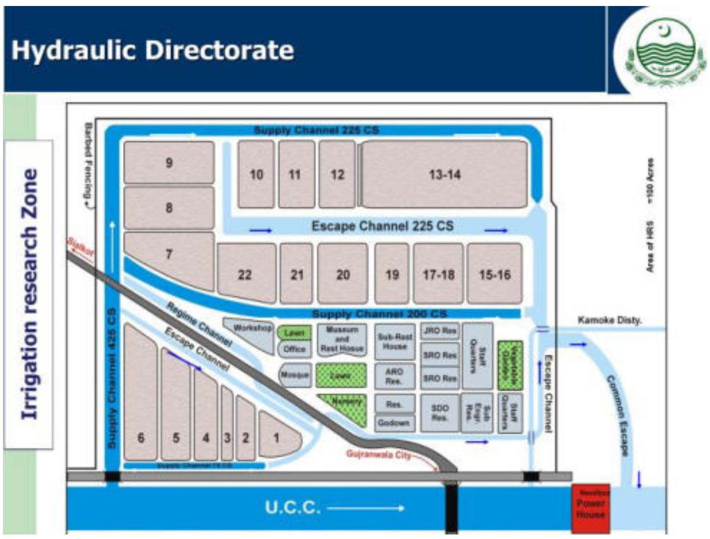
The directorate of Hydraulics has two research stations. One situated in Lahore called Hydraulic Laboratories and other called Hydraulic Research Station Nandipur.

8.4.1.1.1 HYDRAULIC RESEARCH LABORATORY LAHORE

This Laboratory was established at Lahore for testing various components of hydraulic structures to validate their hydraulic performance. The laboratory has a huge water supply system and a water tank to run sectional models for different hydraulic structures and is equipped with all specialist measurement instruments.

The condition of the laboratory and its equipment has deteriorated due to lack of maintenance. The capacity of the laboratory is also negatively impacted by a shortage of skilled/trained staff. There is a dire need to resurrect this laboratory to assist in improving water management within Punjab and other parts of Pakistan.

8.4.1.1.2 HYDRAULIC RESEARCH STATION NANDIPUR



This Hydraulic Research Station (HRS) Nandipur was established in 1953. The station has a total 22 hydraulic model trays. The research station is capable of conducting more than 20 field model tests of various scales simultaneously. The layout of the laboratory is shown in the adjacent sketch.

The capability of HRS Nandipur is unique in this part of the world. Several scale models of large dams, spillways, power & irrigation tunnels, basins, plunge pools and cisterns were successfully tested at this station under supervision of international and national specialists for the Indus Basin Projects.

8.4.1.2 EXISTING DIRECTORATE OF PHYSICS

The Physics Directorate is situated at Lahore in the main IRI building and is headed by the Director Physics. The directorate has evolved into seven sections each headed by senior research officers who are supported by 18 junior research officers.

The objective of the directorate is to provide basic and applied research under field and semi field conditions for geo-technical, canal seepage, construction materials, Geo-synthetics, sediment studies, drainage, groundwater management discharge/recharge, water conservation, evapotranspiration etc. Table 8-2 shows major divisions of the physics directorate.

Table 8-2 : Major Divisions of Physics Directorate

MAJOR DIVISIONS	FUNCTIONS
1. Soil Mechanics	• Geo-Technical Investigations, • Foundation Investigations, • Seepage Control
2. Engineering Material Testing	• Construction material tastings • Quality control
3. Sediment Investigation and Testing	• Sediment measurement • Sediment analysis
4. Soil Physics and Water Conservation	• Seepage control and measurement • Canal lining issues • Geo-synthetics testing and measurement
5. Groundwater	• Groundwater Modelling • Groundwater Management • Solute Transport • Water Balance • Conjunctive Use of Marginal quality • Groundwater Quality Management • Aquifer mapping and zoning
6. GIS and Remote Sensing	• Groundwater mapping on GIS coordinate and remote sensing • simulation
7. Surface and Sub-Surface Drainage	• Drainage need assessment • Waterlogging • Drainage Impact Assessment • Wastewater Measurement and Impact Assessment

8.4.1.3 DESIGN DIRECTORATE

The Design Directorate is responsible for producing hydraulic and structural designs of hydraulic structures. It is headed by the Director Design assisted by two Deputy Directors and five Assistant Directors and their supporting staff. There is an extensive technical library attached to this directorate, however the lack of funds has prevented the purchase of new references.

The design directorate was a well-regarded and pioneer institution at the time of construction of large irrigation systems. However, it has lost its prestige and is now underutilized.

The design directorate designs hydraulic structures and does not undertake research. Therefore, it could be argued that they do not below with a research Institute. However, the hydraulic structures designed by the Design Directorate have many unique design challenges relating the geotechnical conditions (including poor water pressure), hydraulic forces and operational requirements that require highly specialized experience which generally not available in the private sector.

8.4.2 BUDGET OF IRI

Historic budget allocation and expenditures are summarized in Table 8-3. There has been a steady decrease in both allocations and expenditures:

- IRI budget has seen a cut of 23% in the last 3 years.
- IRI expenditure matched the budget allocations closely in most years except for 2020-21. In 2020-21, the budget was significantly underspent.
- Central Design Office budget is very small about 3-5% of the overall budget allocation.

Table 8-3: IRI Budget Allocations and Expenditures

INSTITUTE - OFFICE	YEAR	ALLOCATION	EXPENDITURE
Irrigation Research Institute	2018-19	612,311,000	595,102,000
Irrigation Research Institute	2019-20	578,575,000	558,411,000
Irrigation Research Institute	2020-21	476,206,000	343,712,000

8.4.3 IRI STAFF

The IRI operation is headed by a Chief Engineer and is supported by 535 staff, Table 8-4 provides a breakdown of staff by post.

Table 8-4: IRI Staff

SR. NO.	NAME OF POST	TOTAL
1	Chief Engineer	1
2	Principal Research Officer	2
3	Senior Research Officer	12
4	Executive Engineer	1
5	Junior Research Officer	26
6	Subdivision Officers	2
7	Assistant Engineer	2

SR. NO.	NAME OF POST	TOTAL
8	Research Assistant	27
9	Sub Engineers	10
10	Photographers	3
11	Model Foremen	2
12	Silt Analyst	14
13	Commuters	15
14	Silt Observer	45
15	Head Laboratory Attendants	1
16	Laboratory Assistants	20
17	Laboratory Attendants	131
18	Technicians	53
19	Officials	35
20	Supporting staff	134
	Total	**535**

8.4.4 LIMITATION OF EXISTING SERVICES OF IRI

The limitations of the existing institute can be grouped into knowledge gaps, lack of finance, lack of fundamental research, service offering and current business model. Each of these limitations are discussed in Table 8-5.

Table 8-5 : IRI Limitations of Existing Services

LIMITATION	DESCRIPTION	SOLUTION
Knowledge gaps	IRI was last revamped in the 1960s during the peak of the Indus Basin project with international finance and supervision. There has been very little change of procedures since the last upgrade 60 years ago.	A large-scale capacity building program with inputs from international specialists is required to upgrade the institute to international standards.
Financial Issues	Due to limited funds the Institute has scaled back its operations and has reduced capability.	Develop a sustainable business model
Service offering	IRI has reduced its service offerings over the years and also hasn't kept pace with the current and emerging international technologies.	Develop a sustainable business model and identify service offerings. Improve research and development.
Research and Development	Basic research needs to be reinstated particularly in the areas of sediment transport, seepage and stability of banks, rationalization of water allocation, treatment of industrial and municipal effluent, use of grey water etc.	Reinvigorate research and development
Business model	The present business model of IRI does not provide sufficient funding or meet the requirements of potential end users. A new business model is required.	Develop a sustainable business model

8.4.5 SWOT ANALYSIS OF IRI

An assessment of the IRI was made during the CDTA project. Results of this analysis as well as assessments and experience of the team identifies that following range of Strengths-Weaknesses-Opportunities-Threats (SWOT) for the Institute, are illustrated in Figure 8-2.

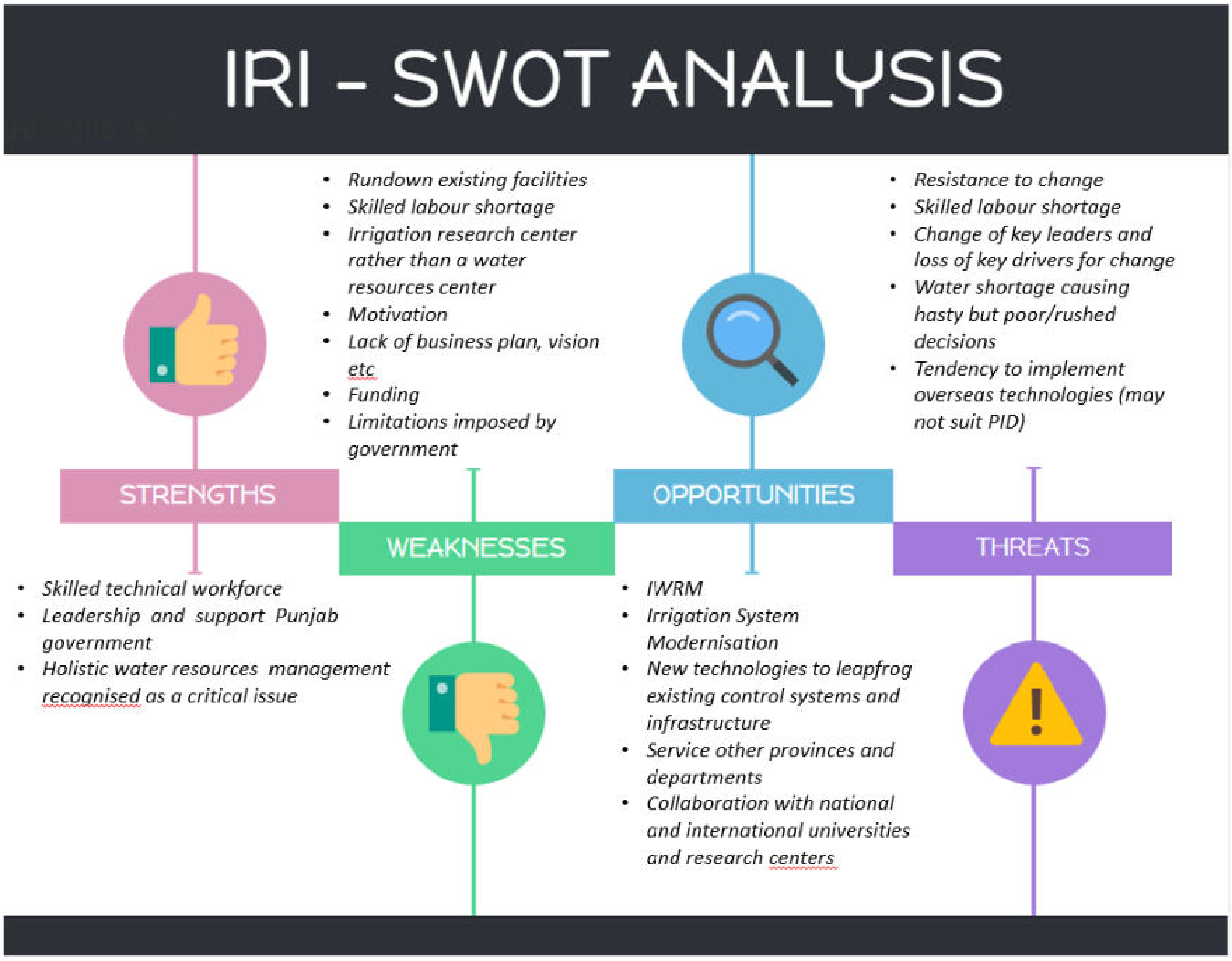


Figure 8-2: SWOT Analysis

8.4.6 UPGRADING OF IRRIGATION RESEARCH INSTITUTE

The Irrigation Research Institute is required to be upgraded. Its primary mandate should be to undertake research and development to solve current challenges, as well as undertaking proactive research and development to make PID and WRD world class organizations. In addition, a suitable business model should be developed for the revamped institute to services other provinces and departments in providing leading edge solutions to complex water challenges.

8.5 FUTURE OF IRI

IRI's work to date has been for regional organizations, however, there is a dire need for a national research institute that searches for practical and innovative solutions to complex water problems. Transformation of the IRI presents an opportunity to develop such an organization.

A number of options were considered for the future of the irrigation research institute which are presented below:

- Option 1 – Maintain the existing IRI in its current form – this is not a viable option as the current institute is run down and eventually lose all its expertise leading to closure.
- Option 2 – Shutdown the institute – a viable option to close the IRI immediately and integrate remaining staff and facilities with PID.
- Option 3 – Modernize the existing institute. This is also a viable option and possibly a first step in revamping the institute. The modernization plan would target the areas of immediate need in collaboration with partners under a new business model. However, this option doesn't address all the requirements of the PWP 2018.
- Option 4 – Complete revamp of the existing institute as an independent Advanced Water Research Institute based on a self-funded long-term model. The intention of this option is a complete revamp of the existing IRI to become a leading water research institute to meet the requirements of the PWP 2018 and build a sustainable business model to serve the nation and potentially international clients.
- Option 5 - Privatize the institute.

The only option that addresses the requirements of the PWP 2018 and the restructured PID and the WRD is Option 4. Hence, the development of revamping and upgrading the existing IRI has been based on this option.

8.5.1 POTENTIAL FUTURE CLIENTS AND PARTNERS

Potential clients and partners of the revamped institute are provided in Table 8-6.

Table 8-6 : Potential Clients and Partners

CLIENTS	PARTNERS
Punjab Irrigation Department	Punjab Irrigation Department
Punjab Water Resource Department	Punjab Water Resource Department
Punjab Agriculture Department & Meteorological Department	Water and Power Development Authority (WAPDA)
National Disaster Management Authority	Federal Flood Commission
Environment Protection Department	International Water Management Institute (IWMI)
City Governments and Corporations	Punjab Agriculture Research Board (PARB)
Water and Power Development Authority (WAPDA)	Pakistan Council of Research in Water Resources
Federal Flood Commission	Universities - both national and international
Ministry of Ports and Shipping	Other Provincial Irrigation and Agriculture Department
Provincial Energy Development Departments	International Research Organizations
Federal Flood Commission and Ministry of Water and Power	Private companies and Consultants
Communication and Works Department	Development partners (e.g. ADB, World Bank, international donors)
National Highway Authority (NHA)	
Water and Sanitation Agencies (WASA)	
Ravi Urban Development Authority (RUDA)	
World Wildlife	
Other provincial and federal departments	
International clients	

8.5.2 FUTURE RESEARCH NEEDS

Table ***8-7*** presents future research needs.

Table 8-7 : Organizational functions of IRI

RESEARCH NEEDS	AVAILABLITY WITHIN IRI
Physical Model Studies	
• Irrigation and Water supply Infrastructure	Yes, however the existing facility is antiquated and mostly in unusable state
• Upgrading design	No
• River training, flood protection and erosion control works	Yes, need upgrading and modernization
• Environmental protection	No
• Waterway structures (e.g. Bridges, levees etc.)	Yes, need upgrading and modernization
Mathematical Modelling	
• Computational Fluid Dynamics (CFD)	No
• Hydraulic structures	Yes, need upgrading and modernization
• Dam break modelling and consequence assessments	No
Sedimentation Studies	
• Reservoir Sedimentation	No
• Sedimentation transport (intakes, canals etc.)	No
Groundwater and geotechnical	
• Water logging and salinity	Yes, limited
• Conjunctive water use	Yes, limited
• Managed Aquifer Recharge	Yes, limited
• Recharge from canals and rivers	Yes, limited
• Sustainable groundwater use research	No
Flow Measurement	
• Hydrography	No
• Discharge measurement calibration and validation	No
Irrigation System Modernization	
• Canal Automation	No
• Best management practices	No
• Canal lining and seepage control measures	Yes, limited
• On-farm automation	No
• On-farm irrigation (e.g. Drip irrigation	No

RESEARCH NEEDS	AVAILABLITY WITHIN IRI
Water Quality	
• Monitoring	Yes, limited
• Laboratory testing	Yes, limited
Design Development	
• Continual development of new standards	No
• New design standards and designs for modernization	No
IWRM	
• Water Productivity - Water accounting, efficiency and productivity	No
• WRIS	No
• Training and capacity building	No
River Basin (state water management)	
• Modelling	No
• Planning and Management	No
• Hydrology and Climate Change/Adaptability	No
Physics and Chemistry	Yes, need upgrading and modernization

8.6 BUSINESS MODELS

As noted earlier, research institutions like IRI now face a much greater burden primarily due diminishing funding from governments and are increasingly having to be user and market focused. In the case of the IRI, the available funding doesn't cover fixed and administrative costs leading to the IRI scaling back its service offerings, reducing essential maintenance and not updating the facility.

A new business model may help to provide solutions to these emerging challenges.

8.6.1 FRAMEWORK

The development of a successful business model requires significant consultation, hypothesis, testing and revisions to ensure a cohesive sustainable model. For upgrading IRI, a framework proposed by Osterwalder consisting of nine elements (or building blocks) has been considered as a way of building a business model. These are described in Figure 8-3 and Table 8-8.

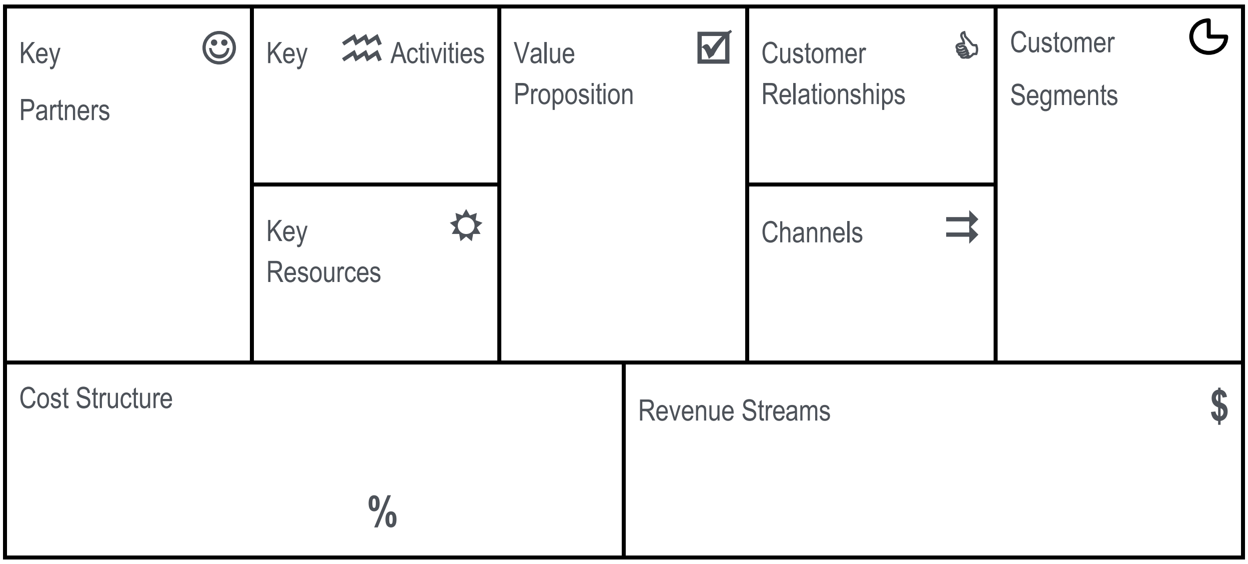


Figure 8-3 : Osterwalder Business Model Canvas

Table 8-8: Osterwalder Business Model Elements

Business Model Blocks	Description
Value proposition of the business	Value proposition refers to the product or service the firm intends to offer to its customers to meet their needs. It is unique to an organization as it sets it apart from its competitors. The description may be qualitative, outlining the intended outcome and customer experience, or quantitative, describing the efficiency and price.
Infrastructure	The organization's infrastructure comprises three key elements and they are: • The **key activities** that generate the value proposition • The **key resources** it used to create value for its customers • Its alliances or **key partner networks** and the things that motivate them to be part of the business model Considered together these describe how the company delivers the value proposition.
Customers	The model analyses three aspects of the customers of the business. They include: • **Customer segments** break the total market down to help identify and describe its target customers more specifically. • **Channels** of delivery connect a customer segment to the value proposition. For example, an organization can deliver value to its clients using its own channels, major distributors or both. Perhaps customers access it online, maybe they visit a store. • The type of **relationship** between the business and its customers. For example, transactional, long-term, self-service, co-creation, etc. Considered together, these describe how the customer expects to access the value proposition.
Cost structure	The cost structure section outlines all the monetary costs the business incurs while operating under the model. They could be fixed costs incurred to pay employee salaries and rent for the premises, economies of scale, variable costs and economies of scope.
Revenue streams	This is the last of the nine components of the Business Model Canvas. It describes how the company makes money from its target market. For example, businesses can generate revenue through the sale of a physical product, selling a continuous service in the form of subscriptions, renting or leasing an asset such as a car, licensing or charging fees to advertise products.

8.6.2 BUSINESS MODELS

Several different forms of business models exist and are applicable to research institutions like IRI, however, there are three conventional forms of business models are commonly adopted by research institutions internationally. In general, the depiction of business models is challenging since a model should not be static.

Business Model	Description
Business Model 1: Conventional Model (Current IRI Model)	• Governments/Funders pay for products and services that are meant for beneficiaries. • Governments/ Funders in this model have an interest in seeing beneficiaries' capacities being developed and enhanced through products and services such as research and development, research papers, training sessions and other technical expertise being provided free of charge. • The value proposition in this model has to satisfy both the donors and the beneficiaries, and both have different needs/expectations. • Funders might not only be providing a source of revenue in this model but could also be users of the products and services; for example, PID funds IRI and also benefits from the research products of IRI. • In addition to not putting a monetary value on research products and services, this model raises the question of product quality. That is, the funders and beneficiaries might be more willing to accept an imperfect product because it is low cost (or free) but would have demanded an improved product if they had to pay full cost.
Business Model 2: Private Sector Model	• Customers pay for the organization to achieve its mission • The foundation of this model is to get customers to pay a fair market price for products and services – thus the key activities of the organization are to bring its products and services to the marketplace and offer them to customers at a fair market price. • The value proposition in such a model has to do with satisfying customers, i.e. providing quality products and services at as competitive a price as possible. • Results can be measured in terms of revenue streams and may also benefit key partners.
Business Model 3: Hybrid Model – Mix of Private Sector and Conventional Funding Components	• In this last model, the organization has a mix of private and non-profit sector components. • Hybrid organizations have now started thinking about the monetization of their products and services for an example through the development of a consulting practice or have found clients who are willing to pay for their expertise. • This model encourages the organizations to offer different product lines through distinct channels. It has several advantages for research institutions, one being that they are able to use the products of their consulting practice to help their beneficiaries. Even though they are turning to private sector practices, they still have the ability to achieve a social impact if goods produced by the consulting practice are linked to the mission of the organization. • The hybrid model uses two different channels to get revenues: funders and commercial clients. Beneficiaries are still not expected to pay to access research products and services. Under this model, organizations need to somewhat rethink their value proposition in order to feed the three distinct channels it wants to reach: funders, commercial clients and beneficiaries. As with the second model, donors in this model can also be considered as users of the research products and services.

8.6.3 AWRC OPERATIONAL CONCEPT

Ideally the institute should be self-supporting and operate as a business rather than a government-controlled institute. However, it is a quantum leap for the exiting IRI to go from a government owned business to a self-supporting operation. A stepwise plan is required for it to become a business including initial financial and/or project support by an external entity.

Possible operational concepts are:

1. Continue to be government owned institute
2. Self-supporting business model
3. Collaborative research institute – collaboration with Pakistan National Universities, governments and private sector
4. International research institute
5. Merger – Find a suitable merger partner or entity (e.g. IWMI)

Concept No.	Concept Description	Advantage	Challenges
1	Continue to be government owned institute	• Maintain status quo • Limited funding provided by the government	• Current issues will continue • No productive research is likely
2	Self-supporting institute – operates based on full cost recovery	• Control its destiny • Freedom to take decisions • Reinvests profits in new technology development • Have adequate funds to maintain facilities and provide quality service to customers. •	• Need an internationally reputed leader with business and research acumen • Financial motivation may lead to research concentrating in areas of high financial returns to the institute rather than the need of Punjab and Pakistan • Need initial funding to commence operation
3	Collaborative research institute – collaboration with Pakistan National Universities, governments and private sector	• Wider resource and expertise pool • Integrated research and development with university and industry partners • Control its destiny • Freedom to take decisions • Reinvests profits in new technology development • Have adequate funds to maintain facilities and provide quality service to customers. • Likely to have adequate funds from collaboration partners	• Need an internationally reputed leader with business and research acumen
4	Become an International research institute	• Control its destiny • Freedom to take decisions • Reinvests profits in new technology development	• Need an internationally reputed leader with business and research acumen • Competition from other international institutes • All facilities are needed to be maintained to international standards

Concept No.	Concept Description	Advantage	Challenges
		• Have adequate funds to maintain facilities and provide quality service to customers.	• Need initial funding to commence operation
5	Merger – merge with and international institute (e.g. IWMI)	• Wider resource and expertise pool • Integrated research and development with IWMI • Career progressions	•

8.6.4 BUSINESS MODELS VS OPERATIONAL CONCEPT

The below table shows the business models versus the operational concept.

Operational Concept	Business Model 1: Conventional Model	Business Model 2: Private Sector Model	Business Model 3: Hybrid Model
Continue to be government owned institute	✔	✔	
Self-supporting business model		✔	
Collaborative research institute	✔		✔
International research institute	✔		✔
Merger (e.g. IWMI)	✔		

8.6.5 BUSINESS MODEL FOR WRRI OR AWRS

Operation concepts 3, 4 and 5 are well suited for the revamped IRI as these concepts are based on a collaborative approach. It would be advisable to find a suitable and willing international partner very early and this could fast track the upgrading of the IRI. A collaboration partner like IWMI can not only make use of the facilities for their own research but also help promote the institute internationally.

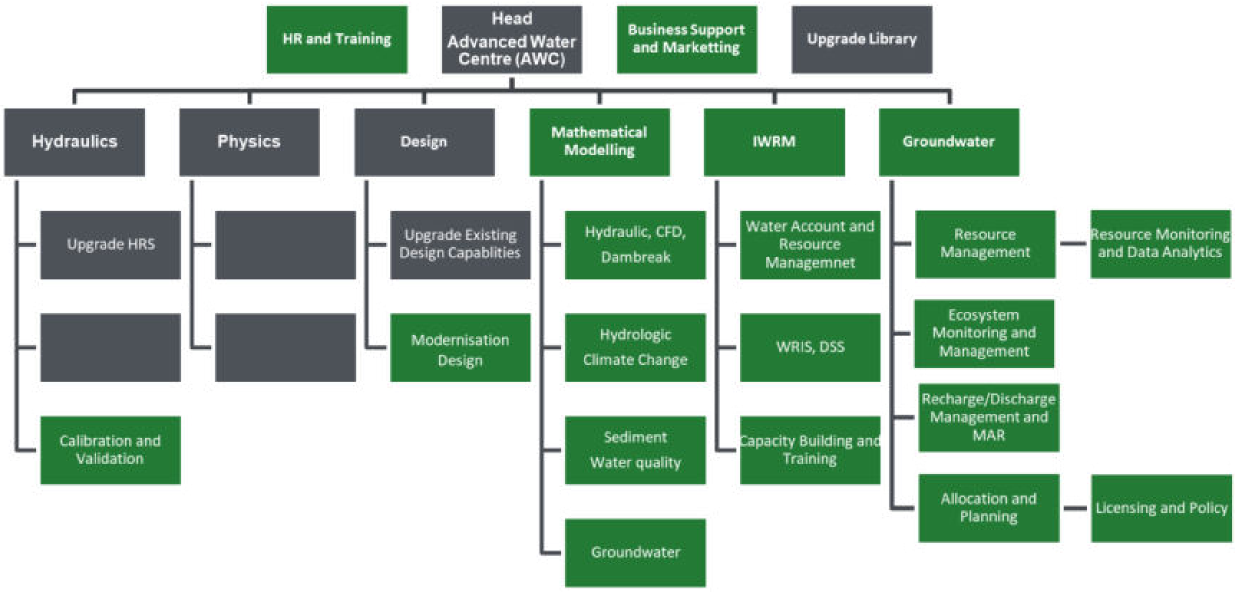
Business Model 3 (i.e. a hybrid model) would be well suited as it would be minimal disruption to the current IRI operation. It also provides the institute with adequate time to final collaboration partners and other interested parties such as investors, clients to establish.

8.6.6 AWC ORGANIZATIONAL STRUCTURE

The review found that

1. most of the existing IRI functions and offerings are relevant to the restructured PID and WRD
2. IRI needs modernizing and upgrading to international level
3. continued research and development and
4. continued support to IWRM

An organization structure is developed to address these findings and is shown in Figure 8-4.



Note: New units are shown as green Cells

Figure 8-4 : AWC Organization Structure

The new structure includes three new directorates for:

- Mathematical Modelling;
- Integrated Water Resources Management; and
- Groundwater.

Each of the new directorates will include a number of units specializing in specific areas. The new structure also includes a Business Support and Marketing Section and a Human Resources and Training Section.

8.6.7 NEXT STEPS

The following next steps are recommended:

1. Consultation with all current stakeholders and potential partners and clients
2. Develop draft business case
3. Agree on organization structure and functions
4. Finalize business case
5. Develop a realistic implementation plan
6. Seek an international partner
7. Seek funding
8. Implement upgradation plan
9. Set short-term, medium-term and long-term milestones and KPIs.

9 TRAINING AND CAPACITY BUILDING

9.1 GENERAL

This Section assesses the capacity constraints of existing PID staff and develops a plan to improve the capacity of PID staff for various water resources management functions.

Water sector management institutions have undergone several changes, such as existing departments expanded, and new departments formed. The emerging needs continue to increase with the new challenges and opportunities. On the other hand, introduction of information technology, new tools such as remote sensing and GIS and decision support systems have increased efficiency and cost effectiveness. A tradeoff should exist between expansion and modernization. Responsiveness, quality of services and economic efficiency should be the ultimate target. But achieving the target will require continued commitment and long-term transformation processes.

This deliverable will result in an agreed capacity building plan owned and implemented by the Punjab Irrigation Department (PID).

9.2 EXISTING SITUATION ASSESSMENT

Presently, PID is governed through the "Estacode" Rules and Regulations that apply to Government Employees. As a result, the scope for staff development is limited, with not much emphasis on continuing education, training, and other interventions required to continuously enhance employee performance. Merit is not the main consideration and mostly promotions depend on seniority and other considerations resulting in low morale and below standard performance.

SMEC with the assistance of the Asian Development Bank (ADB) has recommended PID employ a robust human resource system whereby employees will get every opportunity to enhance their skills and knowledge in the newly transformed Water Resource Department (WRD).

The new institutionalization and Transition of PID into a WRD places a heavy demand on the performance of the existing staff and will require extensive training, continuous education and other interventions.

9.3 REVIEW OF PID'S HUMAN RESOURCES POLICIES

Currently PID follows the following documents as HR policy manuals:

a) Estacode 2015 Establishment Division (Federal Government)
b) Punjab Estacode – Regulations/O&M Wing (Provincial Government)

Both the above documents have been inherited from the British Rule in India and have been amended from time to time. These documents specifically cater to the requirements of the Federal and Provincial governments where employees are recruited through competitive written exams for the Central Superior Services (CSS) for the Federal Government and Provincial Civil Services (PCS) for the Provinces. Typically, bureaucratic procedures are followed where employees are promoted based on seniority and not merit. Other considerations are likes and dislikes of the supervising officer and the relationship with the supervisor. A lot of personal bias goes into the Annual Confidential Reports (ACRs).

In order for the WRD to be effective, the Department needs to obtain certain exemptions from the Punjab Government for formulating its own HR Policies and Procedures to operate under a new organization structure of WRD. It would be beyond the capacity of PID to achieve the goals and objectives of a WRD working as a purely Government department. Even in Karachi in the province of Sindh they have an independent and autonomous setup under the Provincial Government, known as "Karachi Water Board". PID should consider autonomy on those lines and may need

ADB to intervene and discuss this with the relevant authorities in the Provincial Government. PID will need legal support to move this issue with the concerned authorities in the Punjab Government.

9.4 EXISTING CAPACITY AGAINST JOB DESCRIPTION

Existing Job Descriptions provide only a very brief list of the duties at a very generic level and are not tailored to the requirements of each job. A review of the Job listing reveals that it does not specify any skills required to perform the job, except Minimum Academic Qualifications.

9.5 PID CAPACITY BUILDING FRAMEWORK & TRAINING PLAN

A comprehensive TNA (Training Needs Analysis) Survey Instrument was developed after input was obtained from Technical Experts that was discussed with PID also. After their concurrence, the TNA Survey Instrument was handed to PID at their request for comment.

Needs Assessment is the process of identify and evaluating the needs of stakeholders in regard to specific technical assistance to better perform their roles. A need has been described as a gap between a current situation and a desired result. The identification of needs is the process during which "problems" of stakeholders are determined and possible solutions are suggested in order to enable and enhance their capacities to put in practice the ability to apply knowledge and understand the know-how to complete tasks and solve problems, involving internal or external resources and the use of tools, materials, and instruments.

The TNA has focused on the future and what should be done rather than what has been done in the past. The necessary steps followed for a TNA are listed below:

- Performance of Gap Analysis to identify the current and desired skills, available knowledge and abilities of respondents.
- Training programs detailed.

9.5.1 TRAINING MAIN OBJECTIVES

The PID is expected to acquire improved capacity in:

- Water resource planning and management;
- Development research and operational management;
- Management of irrigation and drainage;
- Water related disaster management;
- Management of River ecosystem;
- Groundwater management; and
- Marginal quality water management

9.5.2 PERFORMANCE AND GAP ANALYSIS

9.5.2.1 STAKEHOLDERS

Water users and farmer's organizations and relevant ministerial entities at government level in selected areas are stakeholders, however, the scope of this report is focused on the staff of the Punjab Irrigation Department.

9.5.2.2 SITUATION ANALYSIS

An individual questionnaire was applied for the TNA. The Questionnaire was developed with inputs from our Technical Experts. The questionnaire survey was chosen as an efficient way to gather data from a potentially large number of respondents and to provide easy-to-analyses data.

The primary data in this work were collected through the questionnaire filled by PID Engineers as interviews and group discussions were not possible due to COVID 19 Pandemic travel restrictions where visits to Lahore were not possible. Only one survey instrument was sent to PID for obtaining responses.

Based on the data received we have been able to develop a preliminary Capacity Building and Training Plan.

9.5.2.3 JOB RESPONSIBILITY

a. Maintenance and Operation of Instrument
b. Procurement of Instrumentation (DCIRP)
c. Inspection of Barrages to evaluate:
    i. Working of SCADA Instrument
    ii. Electrical System
    iii. Preparation of reports to identify any problems.
    iv. Hydraulic structures of irrigation
    v. Safety of Hydraulic Structures
d. Inspection of Pre-flood and Post-flood condition
e. Identify faulty structures and prepare Report
f. Geological Investigation of Floods
g. Visiting Dams and Barrages for determining their performance.
h. Arrange and follow up the opening of control valves (internal irrigation schedule).

9.5.2.4 CURRENT PERFORMANCE LEVEL

Through their responses to the survey instrument, they identified lack of knowledge and difficulties in implementing their tasks pointed out the following gaps: -

a. Safe operation procedures.
b. When and how to conduct regular maintenance and where to go.
c. Estimate the needs of operation requirements and spare parts and its availability.
d. Steps to conduct daily routine maintenance.

9.5.2.5 KNOWLEDGE AND SKILLS SHOULD BE ACQUIRED

The respondents identified improvement areas in the current irrigation operation including the need for full understanding of the components and their functions relating to:

a. Irrigation and Drainage systems
b. Ground water management
c. Integrated water resources management
d. River Basin Planning and Management
e. Steps for safe operations
f. Daily routine maintenance
g. Preliminary diagnosis of maintenance malfunctions
h. Activating the role of PID in conducting irrigation scheduling.

9.5.3 PROPOSED TRAINING PLAN/PROGRAMS:

Based on the Training Programs recommended by our Technical Experts and the survey instrument, they identified the following areas of Training (**Table 9-1**).

Table 9-1 : Areas of Training

SR. NO	MAIN AREAS OF TRAINING	TRAINING PROGRAMS
1	**Irrigation and Drainage**	1. Basics of Irrigation & Drainage 2. Modern Irrigation Systems & Design 3. Environmental Evaluation of Irrigation & Drainage Projects 4. Irrigation Works, Execution, Operation & Maintenance 5. Mechanization of Drainage system, Planning & Design 6. Canal Lining, Automation & Maintenance 7. Irrigation System and its application on Desert Soil 8. Maintenance of Open Channels. 9. Flow measurement and calibration 9. Drainage Maintenance, Silt and Weed Control 10. Non-Conventional Water Resources and their uses 11. Hill Torrent Irrigation and Flash Flood Conservation 12. Design and Construction of small Dams 13. WRMIS, Forecasting systems, Climate Change and Evaluation
2	**Ground Water Management**	1. Water Management at Different Levels 2. Water Organizations 3. Planning and Water Resources 4. Water Resources Information and Data Management 5. Water Resources and Regulation 6. Participation in Water Management 7. Water Resources and Financing parameters 8. Interpretation of results 9. Preparation of report 10. Groundwater Modelling and Management 11. Training Groundwater Monitoring and Data Analytics 11. Demand management 12. Supply management
3	**Integrated Water Resources Management**	1. IWRM Principles and Methods 2. Water Management at Different Levels 3. Water Organizations ns 4. Planning and Water Resources 5. Water Resources Information and Data Management 6. Water Resources and Regulation 7. Participation in Water Management 8. Water Resources and Financing parameters 9. Interpretation of re results

SR. NO	MAIN AREAS OF TRAINING	TRAINING PROGRAMS
		10. Preparation of report 11. Groundwater Management 12. Demand management 13. Supply management
4	**River Basin Management**	1. River Basin Profiling 2. Environmental Management Plans 3. Irrigation Water Management 4. Flood Risk Management 5. Hydrology 6. Water Supply 7. Water Laws 8. Hill Torrents/ Watershed Management 9. Remote Sensing and GIS for IWRM
5	**Miscellaneous**	1. Projects Management & Evaluation 2. Project Networking 3. Design and Analysis of Data 4. Strengthening Institutional Capacity Building for Water Sector 5. Group Work and Team Building 6. Computer Skills 7. Strategic Planning and Follow-up.

9.6 TRAINING PLAN PID CAPACITY BUILDING

9.6.1 TRAINING WORKSHOPS CONDUCTED

As a part of our commitments to capacity building and training we have delivered the following three training programs:

- Training of at least 10 PID staff in Groundwater Management – 2 September 2021
- Training of at least 10 PID staff in IWRM – 17 November 2021
- Training of 10 PID staff in River Basin Management – 17 Nov 2021.

9.6.2 GROUNDWATER MANAGEMENT TRAINING WORKSHOP

The first formal Training on Groundwater Management was conducted at Hotel Four Points Sheraton on Thursday 2 September 2021. The main presenters and topics are as shown in **Table 9-2**.

Table 9-2 : Groundwater Management Training Program

TIME	SUBJECT	PRESENTER
09:30	Opening remarks	Secretary PID, ADB
09:40	Introduction of the training workshop	PID Focal person / S. Yance / M. Manivasakan
09:50	Agricultural perspective/ remarks by Agriculture Department	Dr M. Javed, Director, PID
10:00 to 10:30	Introduction and interactive discussion on mapping the water table and water quality. *Aim: improved understanding of Identifying areas where water levels and water quality are declining*	M. N. Bhutta / J Punthakey
10:30 to 11:00	Sharing a 20-year experience on groundwater monitoring: challenges and opportunities *Aim: Understanding the existing monitoring network and improving data quality*	Director DLR, PID / M. N. Bhutta
11:00 to 11:30	*Coffee break and networking*	
11:30 to 12:00	Interactive discussion on critical areas of groundwater decline, main reasons, and possible management options *Aim: Participatory learning of co-groundwater management*	M. N. Bhutta / M. Javed
12:00 to 12:30	Panel discussion on participatory monitoring mechanisms Panelists: Director agricultural water management and Director WASA (water) *Aim: Direction setting for futuristic monitoring*	Facilitated by N. Arif (ex GM WAPDA) / M. Nadeem
12:30 to 13:00	What do we understand from groundwater balance/budget estimation? *Aim: Hands-on overview of approaches to water balance and sharing example of Water balance presented in Report*	M.N. Bhutta / S. Sarwar
13:00 to 14:00	*Lunch and prayer break*	
Session II		
14:00 to 15:00	Managed Aquifer Recharge (MAR): ♦ Concepts and examples ♦ Components and implementation requirements *Aim: Participatory learning and Improved understanding of Managed Aquifer Recharge*	J Punthakey / M.N. Bhutta Dilshad PCRWR/G.Z. Hassan PID
15:00 to 15:30	Panel discussion on farmers' and gender's perspective on groundwater use and management	Facilitated by M. Tariq from WWF
15:30 to 16:00	*Coffee break and networking*	
16:00 to 16:30	Groundwater modelling: What it can do and what it cannot do? *Aim: Improve basic understanding of groundwater flow amongst participants*	J. Punthakey / M.N. Bhutta / S. Sarwar
16:30 to 17:00	Feedback from participants and closing remarks	WASA/AAB-e-Pak (DG WASA or CEO Authority)

9.6.2.1 PARTICIPANTS

A total of 53 participants attended the training workshop comprising of nominations from the following organizations:

SMEC/EGC (including organizers)	15
PID	12
UET (University of Engineering and Technology	5
WWF Pakistan	3
WASA, Lahore	2
WAPDA	3
NESPAK	4
Others including Reps from Farmers and Female community	9
TOTAL	**53**

9.6.2.2 MAIN PRESENTATIONS

The following presentations were made during the workshop:

1. Introduction and interactive discussion on mapping the water table and water quality. Sharing a 20-year experience on groundwater monitoring: challenges and opportunities	Dr. M. Nawaz Bhutta / J Punthakey
2. Interactive discussion on critical areas of groundwater decline, main reasons, and possible management options	Dr. M. Nawaz Bhutta
3. What do we understand from groundwater balance/budget estimation?	Dr. M. Nawaz Bhutta / Dr. Saleem Sarwar
4. Managed Aquifer Recharge (MAR): Concepts and examples	J Punthakey / M.N. Bhutta G.Z. Hassan / J. Punthakey / Design Engineer or Muneeb Tariq
5. Managed Aquifer Recharge (MAR): Components and implementation requirements	M.N. Bhutta /J Punthakey / G.Z. Hassan / Design Engineer or Muneeb Tariq

9.6.2.3 CONCLUSION & PARTICIPANTS EVALUATION

Overall, the training sessions went very well marked by very knowledgeable presentations by the trainers and enthusiastic participation of the trainees and participants.

The participants evaluated the entire training at 3.9 on a scale of 5.

9.6.3 IWRM AND RIVER BASIN MANAGEMENT TRAINING WORKSHOP

The Second formal Training was on Integrated Water Resources Management (IWRM) and River Basin Planning (RBP), conducted at Hotel Four Points Sheraton on Thursday 17 November 2021. The main presenters and topics are as shown in **Table 9-3**.

Table 9-3 : IWRM and RBP Training Program

SR. NO.	ACTIVITY	TIME	PRESENTER
Session I			
1.	Recitation from Holy Quran	10:00 AM	
2.	Opening Remarks	10:05 AM	Clive Lyle
3.	Introduction of the Training Workshop	10:15 AM	Dr Saleem Sarwar
4.	IWRM – Basic Concepts	10:30 AM	Dr. Nadeem
5.	International examples of aspects of IWRM	11:10 AM	Clive Lyle
6.	Discussion / QA Session	11:25 AM	Dr Nadeem / Clive Lyle
7.	Tea / Coffee Break (20 Mins)	11:45 AM	
8.	River Basin Planning – Insights on relevant international experiences and directions for the Punjab Indus River Basin Management	12:15 AM	Clive Lyle
9.	Sectoral Water Demands and Climate Change	12:30 PM	Dr. Saleem
10.	Discussion / QA Session	1:00 PM	Dr Nadeem / Clive Lyle
11.	Lunch and Prayer Break (60 Mins)	1:30 PM	
Session II			
12.	Water Quality Management in Punjab River basins	2:30 PM	Farzad Dadgiri
13.	Q/A Session	3:00 PM	Farzad Dadgiri
14.	Summing up	3:30 PM	Clive Lyle
15.	Feedback from participants and closing remarks	4:00 PM	Dr Muhammad Javed (Director SPRU)
16.	Tea Break	4:15 PM	
17.	End of the Workshop	4:30 PM	

9.6.3.1 PARTICIPANTS

The workshop was only conducted for PID and no other organization was formally invited. The PID Participants were invited on behalf of SPRU-PID for the training which included technical personnel from irrigation secretariat, site and other offices of Irrigation Department. At the outset the senior attendees of PID were expecting that this workshop was based on the work done by the consultants of CDTA Project. It was explained to them this particular training is a part of our commitment to train and build capacity of PID staff on issues covering IWRM and RBM.

A total of 36 persons participated in the workshop as follows:

PID	17
Trainers (SMEC)	7
Organizers (SMEC/EGC)	10 (including organizers)
Individual invitees	2
Total	**36**

9.6.3.2 MAIN PRESENTATIONS

The following presentations were made by Trainers:

1. Basic Concepts of IWRM by Dr Mohammed Nadeem
2. International examples of aspects of IWRM - By Clive Lyle
3. River Basin Planning – Insights on relevant international experiences and directions for the Punjab Indus River Basin Management by Clive Lyle
4. Sectoral Water Demands and Climate Change by Dr Saleem Sarwar
5. Water Quality Management in Punjab River basins by Farzad Dadgiri.

9.6.3.3 CONCLUSION

Overall the training sessions went very well as acknowledged by Dr. Javed representing the participants from PID.

9.6.4 ON-THE-JOB TRAINING

Due to COVID 19 pandemic limited On-the-job Training was provided by CDTA National Experts. However, every effort was put in place to provide on-the-job training to PID nominated candidates. A list of the programs, the trainers and participants are provided in **Appendix B** of this report.

9.6.5 SEMINARS ON SPECIAL TOPICS

During the CDTA implementation process a number of seminars on special topics was also organized after discussions with PID.

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Appendix A COMMENTS ON INTERNAL FRAU TOR

The FRAU Terms of Reference (TOR) is as follows:

TOR'S

- Development of province based run time flood monitoring and management system
- To forecast Time and volume of a specific flood peak likely to pass at a specific location
- Issuance and Dissemination of Flood Forecasting Report on Daily Basis during Flood Season (15th June to 15th October).
- Identification of villages likely to be inundated for a specific range of Flood in rivers of Punjab.
- Mapping and dissemination of inundation maps to relevant field officers for better decision making and flood fighting (Concerned XENs & Deputy Commissioners)
- Extraction of flood path and identification of areas/villages under risk of breach of Canal or Flood Bund.
- Collection of all relevant data for assessment of the risk that is to be imposed by the flood
- Storm Monitoring and Extraction of Rain Fall Hazardous Zones in River Catchments.

The following comments might be formulated with respect to the capacity building and related on-the-job training of FRAU cell team in 2021.

Comment 1: Development of province-based run time flood monitoring and flood management system

Consultants' comments: there is only one Province involved across the Punjab river basin under study. A flood monitoring & management cell may be created in each provincial administration office, which works daily with the FRAU cell in monitoring the water levels and discharges in the river inside their provincial jurisdiction. These data serve as input to the FRAU Hec-Ras mathematical modelling for flood forecasting and early warning system. The provincial flood monitoring & management cell should be capable to act adequately in case of an upcoming event of extreme flooding in their own province. They should be able to take the necessary preparatory works to do prevention, mitigation, rescue and aftermath recovery activities, in conjunction with the other services under the same provincial administration office. With time progressing over years, this provincial flood monitoring and management cell will become more performing and successful.

Important features for the on-job-training sessions:

- Lead time for flood propagation from the location of flood peak creation/RD position along the river upstream down to the river stretch under the provincial jurisdiction (expressed in hours);
- FRAU cell will run the mathematical modelling and convey the results on the expected highest water level and corresponding discharge to the provincial cell team; the geographical extent of expected flooding, i.e., flood plain submergence in water depth and flow velocities, should also be communicated, along with the related mapping products (by email and/or WhatsApp applications, social media and/or www website/internet site;
- The provincial cell team should consist of civil and/or hydraulic engineers and hydrologists who will assess the received data and mapping products and do its interpretation, for internal reporting to higher provincial authorities and then to the wider public in the Province (early warning, triggering other services to get prepared, disaster management, etc.);

- The provincial cell team should be charged with hydrometry and topographical terrain survey, e.g., the local river cross sections; the presence of obstacles, encroachments etc. are also included in this survey;
- The main stem rivers in the Punjab are expected not to behave as a high energy river with high rates of erosion and sedimentation; it is therefore expected that the morphological modelling of the riverbed will probably not be required;
- The mathematical model Hec-Ras should contain all water control and water management structures across the entire river basin of the Punjab, including features of the catchment areas/sub-areas, e.g., land-use, spatial plan etc.

Comment 2: To forecast time and volume of a specific flood peak likely to pass at a specific location

Consultants' comments: this issue has been addressed/integrated under pointer 1 here above. In this forecasting task, the role of the Hec-Ras model is predominant and decisive, along with its mapping product. As a matter of fact, existing statistics can be used to simulate many flood peak events and then select which ones are specific. A higher return period (e.g., from 10 years going higher to 1000 years) will yield a larger specific flood peak. The times series may be selected over the past 20 or 30 years for the simulations on Hec-Ras model. The propagation of the flood hydrograph from one RD in the main river down to the following RD in the same stem of the river can be also simulated and computed with the same mathematical modelling software Hec-Ras (alternatively the Muskingum Routing model can be used as well; this computational approach models the flow of water in natural and man-made open channels using the Muskingum method to route the flow. The Muskingum Routing calculates the discharge within a river or channel reach given the inflow hydrograph at the upstream end. The unit is based on the continuity equation and the Muskingum storage relationship. Cross section details are not required and only the Muskingum parameters k and x are specified. Both parameters are fixed. A minimum of two Muskingum Routing sections are required for each end of the river or channel reach. Intermediate discharge points can be specified by using additional Muskingum Routing nodes). The river hydrographs in the Punjab may show a multi-modal peak event implying that a speedy dispatch is required by the FRAU cell team to react, day and night. Moreover, the base time may be short, e.g., some hours only or less than half a day prompting the same sense of emergency and urgency by the FRAU cell team.

Comment 3: Issuance and dissemination of flood forecasting report on daily basis during flood season from 15 June to 15 October, each year again.

Consultants' comments: this task constitutes the core business of the FRAU cell, which will cater for the need in forecasting of all stakeholders. Daily flood forecasting data, mapping/infographic/sketches products and the related narrative/explanatory notes can be short or long. Different stakeholders need different forecasting bulletins (specifics), messaging and notes. Various formats and outlooks of the daily reports can be developed together in the capacity building sessions and related on-the-job training sessions. The basic standard hydraulic, hydrological, weather etc. forecasting will be communicated daily to the provincial flood monitoring and management cell. This report is complete and comprehensive and integrated.

FRAU cell gives advice how, what can be issued by the provincial cell to the higher authorities, wider provincial public/stakeholders, sister agencies, provincial services etc. This is proposed to avoid the crafting and issuance of wrong information. Generally, the wider public and higher (political) authorities are not interested in statistics, hydraulics, hydrology, mapping, graphics and weather. These stakeholders need simple messages in a kind of journalistic language (not politicized or academic textbook language). The provincial cell will then ensure the further issuance and dissemination down the line, to reach the fishermen, remote human settlements in the flood plains, etc. (no involvement of FRAU cell here). Use can be made of SMS message, WhatsApp message, local FM radio broadcasting, local newspapers, www websites etc. Methods may be developed to enhance the public awareness activities and approaches, in particular the local interest groups directly affected by flood and drought hazards and risks (attributes of risk values and its related site location).

Comment 4: Identification of villages likely to be inundated for a specific range of floods in the rivers of Punjab.

Consultants' comments: this ToR task relates to an exercise across the entire river basin, whether the area is inhabited or not. Affluent rivers usually runoff faster than the main stem river reaches. This implies that the propagation time of the flood wave is also different. The water velocities and the duration of inundation are also different, whether it happens on a wide or narrow river corridors/flood plains/highwater beds. Where human settlements are present in the flood plains, economic damage may occur. The economist of the FRAU cell may look into this damage economics. The hydraulic structure engineer of the FRAU cell may establish the flooding mechanisms and its damaging impacts and locations of damage. This exercise can be repeated and simulated for a specific range of floods, for instance a flood event with a return period of 5, 10, 25, 50 and 100 years. For every RD of the affluent river and the main stem river, the corresponding water levels and discharges and geographical/areal/spatial extent can be calculated. The differences between a value of low return period and a high return period will be calculated so that the incremental damage costs can be computed. A series of return periods and damage costs can be tabulated, for discussion and decision-making with higher authorities. Rough guidelines can then be formulated what/where/when/how flood risk mitigation measures can be defined and shared with all stakeholders (e.g., green rivers, flood deflection structures, eco-based wetlands etc.).

Comment 5: Mapping and dissemination of inundation maps to relevant field officers for better decision-making and flood fighting (concerned XENs & Deputy Commissioners)

Consultants' comments: this task emanates from the above ToR tasks and activities, especially the sub-activities related to mapping and its dissemination to the field officers under the PID Management organization. Hence, it is a more internal organization and communication matter.

As this internal sharing of data and maps deals should cater for better decision-making and flood-fighting on the ground, the inundation maps are primordial, predominant and crucial.

This requires mapping products of top quality standards: Hec-Ras simulations may be executed in 2D mode; spatial attributes for assessing the flood hazards and risks should be gathered by field officer and input into the 2D modelling work, using a detailed DEM data base of good quality; flood risks of riverine area should be distinguished from flood risk of pluvial area; selection of an agreed base year for the modelling; all primary and secondary infrastructures must be adequately modelled; ribbon development of settlements along highways and roads must also be mapped (affecting the pluvial flood risks); growth trends/aggravation of flood risks on the spatial plan map, to facilitate the flood risks estimates; area with shallow inundation depth can be separated from area with deep inundation depth, along with its respective flooding duration time (urban growth affects the hazard component of flood risk); testing the outcome to shifting flood frequencies/return periods; selection of proxy indicators for future climate change induced changes in river discharges (trend changes and amplified extreme weather events change the natural hazard profile in many areas across the river basin); distinguishing sub-basin areas with notable differences in precipitation (areas with/without a disproportionate increase of future susceptibility to floods for riverine and pluvial flooding cases/rainfall-induced flooding; drainage characteristics of watersheds; differences in topography and geomorphology are to be documented; etc.

The set of features must be as complete as possible, as the outcome of the mathematical modelling will be shared to higher authorities such as Deputy Commissioner. The mapping and dissemination will be issued during the rainy and flood season, but also e.g., on monthly frequency during the dry season (drought management purpose etc.).

Comment 6: Extraction of flood path and identification of areas/villages under risk of breach of Canal or Flood Bund.

Consultants' comments: this task is intimately related to the PID department in charge of barrages and irrigation, i.e., the PMO Barrages. All existing data of infrastructures are well known and well documented at the PMO Barrages

agency. These data will be input into the Hec-Ras model for simulation purposes. An overview will be established of all these infrastructure assets and compiled in a separate working document for internal use only.

As to the flow path, this can be derived from the DEM data base, supported with satellite images of a given workable scale, e.g., scale 1:50,000.

The simulation scenarios will be designed as to match with the set of frequencies/return period here above, aiming to support the identification of hazard and risks sources on the ground. As the XEN's are very well familiar with managing the flood-fighting activities and the breaches of Canals and Flood Bunds, their close involvement and proactive cooperation are indispensable to accomplish this ToR task. As stated here above, simulations will be run for a specific range of floods, for instance a flood event with a return period of 5, 10, 25, 50 and 100 years. For every RD of the affluent river and the main stem river, the corresponding water levels and discharges are calculated from these simulations.

Comment 7: Collection of all relevant data for assessment of the risk that is to be imposed by the flood.

Consultants' comments: this task is considered a routine occupation of FRAU every day; past floods and past flood damage are supposed to be well known and well documented; the economist, member of the FRAU cell team, may help to establish the damage costs expressed in PKR; the hydrologist, member of the FRAU cell team may help to establish the estimated frequencies/return periods of the past floods. A correlation may then be sought for between return period/risks/frequencies and economic damage cost. To assess the past risks, the related river water levels and the corresponding river discharges are also needed, to a high level of reliability.

As to the theoretical future flood events, a set of return periods will be selected for the purpose of Hec-Ras model simulations runs. Rating curves are scarce and may be acquired through fresh hydrometric measurements in the river, e.g., tasked to the XEN's concerned.

The risk is defined as frequency/return period multiplied by economic damage in PKR, for instance a flood event with a return period of 5, 10, 25, 50 and 100 years. A graphic representation can then be made between economic damage in PKR and the corresponding frequencies, for the data of past floods and for the newly simulated data together. This is the final graph to assess the flood risks in decision-making, strategy and policy plans by higher authorities.

Given the need to find the best strategy to mitigate flood hazards and flood risks in the future, the above graph is then used to test the effects of each strategy against the end goals as laid down in the Action Plan to achieve the objectives of the Water Policy and Water Act 2019.

Options will be studied such as the green rivers and detention/deflection of flood waters, in view of sustaining the local ecology, wetlands etc.

Finally, it is important to note that the cooperation with other third party governmental and non-governmental entities shall be established through a kind of MoU, so that the collection of data is institutionalized. A yearly national seminar may be held with all external data and map providers and other stakeholders too to show how their data are being used by FRAU cell team. This gathering will certainly strengthen the confidence among all stakeholders.

Comment 8: Storm monitoring and extraction of rainfall hazardous zones in river catchments.

Consultants' comments: this task is related to pollutions entering the river water and surface water resources in general. Local rainfall causes local pluvial flooding which when surpassing a certain threshold can grow to a genuine rivulet flow that enters the main stem river/affluent. Data on urbanization and industrial estates are required to execute this ToR task. The ADB donor agency prescribed which pollutants are relevant to study. Moreover, Pakistan laws may dictate also how to proceed in this matter. The Hec-Ras model in possession by the FRAU cell team may not contain the coupled software for modelling the transmission of dissolved matters from a catchment down to the main stem river reach. This part of the modelling work is most difficult, hence many schematization and simplification of such a model will be required due to the short duration of this study Project.

A mapping overview will be established per sub-basin/sub-catchment to know where rain gauges are missing. A high density of rain gauges is decisive, as per the World Meteorological Agency guidelines (Geneve, Switzerland).

The sub-catchments can then be classified as follows:

Green catchments: catchments where there are no pollutants entering the main stem river.

Orange catchments: catchments where pollutants are entering the main stem river, WITHOUT endangering the existing biodiversity and the water/land resources.

Red catchments: catchments where pollutants pose a high risk for human and ecosystem; these environmental hotspots must be mitigated through the mitigation measures. Wastewater issues may be tackled by involving the related polluting sources/point sources/other ministries. Solid waste may be mitigated at the source also, with the help of the relevant third-party stakeholders.

Some proposals for on-the-job training of FRAU cell staff

Given the need to proceed to a full-fledged mode of genuine FRM-oriented tasks and activities, the following basic in-house training is proposed:

- Training on the set-up of a computational framework FRM, whereby both the economic damage data and the flood/drought frequency data are being used in combination to ascribe risk values to sub-basins, pointing toward the River Basin Planning linkages.
- Training on the typology of mapping products to break down the Punjab river basin into sub-basins or main water infrastructures along with the respective risk values.
- Training on the effectiveness of Flood and Drought Risk Management solutions, structural and non-structural ones, for time-bound scenarios dictated by the Punjab Water Policy 2018.

Appendix B PID NOMINATIONS FOR ON-THE-JOB-TRAINING

EXPERTS	ASSIGNMENTS	NOMINATED PID STAFF FOR ON-THE-JOB TRAININGS	CONTACT INFORMATION
River Basin Planning / IWRM			
Mr. Clive Lyle **Dr. Mohammed Nadeem** IWRM: Ongoing till End Aug 2021 RBM: Ongoing till Mid May 2021 **Supporting Experts:** 1. Hydrologist / Climate Change Expert 2. Drainage expert 3. Irrigation Management Experts 4. Flood Management Experts	Prepare a River Basin Plan by • Reviewing current administrative and management boundaries by different water management departments and relevant levels of government. • Superimpose the boundaries on the hydrological boundaries of the basin. • Prepare stakeholder assessment, prepare and undertake key stakeholder participation • Assess DSS tools used by PID and other Departments for River Basin Planning and Management • Plan for Environmental Management • Assessment of Government Stakeholders in River Basin Management in Punjab • Data Gap Analysis • Scheduling of River Basin Management Plan	Mr. Aleem Ullah Khan Deputy Director Monitoring & Evaluation, (SPRU)	P: 042-99214828 M: - E: pmomegaprojects@gmail.com
		Mr. Shahid Habib Deputy Director Environment, (SPRU)	P: 042-99214830 M: 0321-4600-718 E: shahid.semu@gmail.com
		Ms. Qandeel Zahra Deputy Director Water Informatics (SPRU)	P: 042-99214830 M: 0323-4886-172 E: ddirrigation13@gmail.com
		Mr. Waqas Karim Awan, Senior GIS Specialist, (DSS)	P: 042-99213595 M: 0300-4203-742 E: Waqas_gis@hotmail.com
		Mr. Zia-ur-Rehman Assistant Director (Monitoring), (PMIU)	042-99214827
		Saleem Akhtar Junior Research Officer, IRI	P: 042-99212096 M: 0345-4393-483 E: raisaleem43@gmail.com
		Mr. M. Kamran, DSS PMIU	M: 0304-4564-408 M: 0343-5990-501 E: kamran.pmiu@gmail.com

EXPERTS	ASSIGNMENTS	NOMINATED PID STAFF FOR ON-THE-JOB TRAININGS	CONTACT INFORMATION
Groundwater Management			
Dr. Jehangir F. Punthakey **Dr. Muhammad Nawaz Bhutta** Ongoing till End Sep 2021 **Supporting Experts:** 1. GIS Expert 2. Remote Sensing Expert 3. Drainage expert 4. Irrigation Management Experts 5. Hydrologist / Climate Change Expert	• Groundwater Analysis ○ Evaluate present practices of groundwater exploitation, use, management and monitoring and identify areas where groundwater levels are declining. • Analyze recharge and discharge to develop a water budgets for doabs/sub-basins in Punjab. • Estimate water productivity and suggest methods to increase water productivity. • Estimate water quantity and quality demand for future. • Impact of present groundwater pumping and use on groundwater table and quality • Institutions and Management Options ○ Develop guidelines and framework for quality checking and archiving useable groundwater data, and will recommend strategies for modernizing monitoring, which will be accompanied with recommendations for investment planning in data analytics • Provide an assessment of areas with high water tables where drainage dewatering may be required	Dr. Muhammad Javed, Director Social & Environment Mgmt. (SPRU)	P: 042-99214829 M: 0300-4250-856 E: drmj63@yahoo.com
		Mr. Zeeshan Ashraf Deputy Director Groundwater Management, (SPRU)	P: M: 0322-4153-448 E: zee.civil@gmail.com
		Ghulam Shabbir Senior Research Officer, IRI	P: 042-99212096 M: 0301-4339-592 E: shabirkhokhar43@gmail.com
		Adnan Hasson Senior Research Officer, IRI	P: 042-99213213 M: 0321-6801-068 E: adhassan@hotmail.com
		Saleem Akhtar Junior Research Officer, IRI	P: 042-99212096 M: 0345-4393-483 E: raisaleem43@gmail.com
		Faiz Raza Junior Research Officer, IRI	P: 042-99212096 M: 0321-7258-902 E: faizrazahassan@gmail.com
		Tariq Yameen, In-charge Groundwater Monitoring Cell, DLR	0321-4507245 0333-4380732
		Mr. Waqas Karim Awan, Senior GIS Specialist, (DSS)	P: 042-99213595 M: 0300-4203-742 E: Waqas_gis@hotmail.com

EXPERTS	ASSIGNMENTS	NOMINATED PID STAFF FOR ON-THE-JOB TRAININGS	CONTACT INFORMATION

	• Short to medium term plan for Groundwater management including aquifer recharge options in Punjab
	• Capacity Development and Training
	  ○ Existing capacity of different sections/departments involved in groundwater monitoring and management will be assessed
	  ○ Training of at least 10 Punjab Irrigation Department (PID) staff in groundwater management
	• Plan and design of two Pilot Projects for Managed Aquifer Recharge (MAR).		

EXPERTS	ASSIGNMENTS	NOMINATED PID STAFF FOR ON-THE-JOB TRAININGS	CONTACT INFORMATION
Water Resources Information System (WRIS)			
Mr. Abdul Musawwar Waqar Intermittent from Med Sep 2020 to End Sep 2021 **Supporting Experts:** 1. GIS Expert 2. Remote Sensing Specialist	A water resources information system (WRIS) will be designed and documented consistent with existing databases (WRMIS, RTFMS etc.) that will comprehensively support the data and information needs of the reformed PID as a water resources agency. Comprehensive design documents will be prepared to provide details of system architecture, design, guidelines and implementation strategies. The consultant will propose best design, based on the need to employ the most modern technologies in an economical way. The Consultant will conduct an in-depth study of the existing infrastructure and systems to propose the best solution for integrating existing systems to avoid wastage of resources and duplication of effort.	Dr. Muhammad Riaz, Chief Monitoring, (PMIU)	042-99213595 E: riazpmiu07@yahoo.com
		Mr. Zeeshan Ashraf Deputy Director Groundwater Management	P: M: 0322-4153-448 E: zee.civil@gmail.com
		Mr. Faisal Rasheed Executive Engineer Sahiwal	0335-7617600
		Mr. Mohib Ullah Ali Executive Engineer Khanki Headworks Division	0334-9565827
		Muhammad Noman Deputy Director GIS, (FRAU)	042-99214683
		Hafiz Hassan Assistant Director GIS, FRAU	042-99214683
		Mr. Waqas Karim Awan, Senior GIS Specialist, (DSS)	P: 042-99213595 M: 0300-4203-742 E: Waqas_gis@hotmail.com

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