PCRWR

2023

PCRWR PROFILE

Pakistan Council of Research in Water Resource (PCRWR)

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PCRWR's Vision

Make Pakistan water secure while preserving the ecosystem

PCRWR's Mission

Find solutions to key water resource issues through action and adaptive research in collaboration with the stakeholders

1 Introduction

1.1 Water Resources of Pakistan

Pakistan has one of the largest irrigation systems in the world comprising three major reservoirs with a design capacity of about 20 billion cubic meters (BCM), 23 barrages, head works and siphons, 45 main irrigation canals commanding an area of about 17 million hectares (Mha). Irrigated agriculture is the backbone of the economy of the country where about 93% of the available water resources are consumed. Moreover, irrigation is used to meet about 90% food and fibre requirements. It is one of the largest sectors of the economy accounting for around 20% country's gross domestic product (GDP).

The total geographical area of Pakistan is about 80 Mha, of which about 17 Mha is irrigated whereas, dryland farming is practiced on 12 Mha. The average annual rainfall ranges from less than 100 mm in the South and Southwest to over 1,000 mm in the North and Northeast. Over 70% of this rainfall occurs in the Monsoon season (July to September). The combined contribution of rainfall runoff and snowmelt contributes towards 85% of total annual surface inflows during these months. The dryland contributes less than 10% of the total agricultural production of the country as crops in these areas depend completely on rainfall for their water needs. This contribution may further reduce if the rainfall is untimely and insufficient.

Water resources challenges are of diverse nature that include; development of resources, utilization and governance. Natural distribution of water resource availability per annum demands maximum storage during monsoon; to avoid flooding, combat scarcity over the year and regulate flow downstream Kotri barrage. Therefore, Pakistan's major storages were constructed in the 1960's; Tarbela, Mangla and Chashma reservoirs have remained integral for national water security. Effectiveness of these storages is challenged by high rate of sedimentation (0.25 BCM/year). Continuous storage loss necessitates for the construction of new reservoirs. The initiation of new projects for the construction of multipurpose dams is an encouraging start. However, given the population growth rate of Pakistan, water resources development has to be supplemented with other initiatives, i.e. promoting the water use efficiency and effective governance.

In addition to damming the major rivers, there is a need to explore the efficient utilization of hill torrent potential of Pakistan, equalling 22 BCM annually. Moreover, there is a potential to enhance the irrigation system efficiency, which is currently running at 40%. There is also a need to make wise choices for cropping pattern to enhance water productivity. Choice of high delta crops is never deflected by the reduction in canal water availability as farmers tend to use groundwater as supplementary source of irrigation. As a consequence, groundwater table is rapidly declining in almost all canal commands. Over irrigation along with heavy dose of fertilizer has accelerated waterlogging and secondary salinization. While over irrigation in agriculture is degrading the health of land and water system, the disposal of drainage effluents (about 12 BCM) into surface water bodies is destroying the health of whole ecosystem. In this regard, wastewater can be a high-water resource potential, if treated and re-used properly.

Poor governance of water has a resonating impact on water resources use and availability in Pakistan. Low efficiency of water use in agriculture, domestic and industrial sectors and conflict among stakeholders are ultimate results of a weak water governance system. In order to actualize the effects of resources development and efficiency enhancement, proper water governance is imperative. Therefore, the water resource management should be equipped with efficient monitoring mechanism, equitable water pricing across the sectoral uses, groundwater regulatory framework and agro-ecological zoning.

In view of the aforementioned water resource management challenges, Pakistan Council of Research in Water Resources (PCRWR) has remained instrumental in resolving these issues. In accordance with the mandate given to it by the Act of Parliament 2007, PCRWR has made land mark achievements in the area of water resources research.

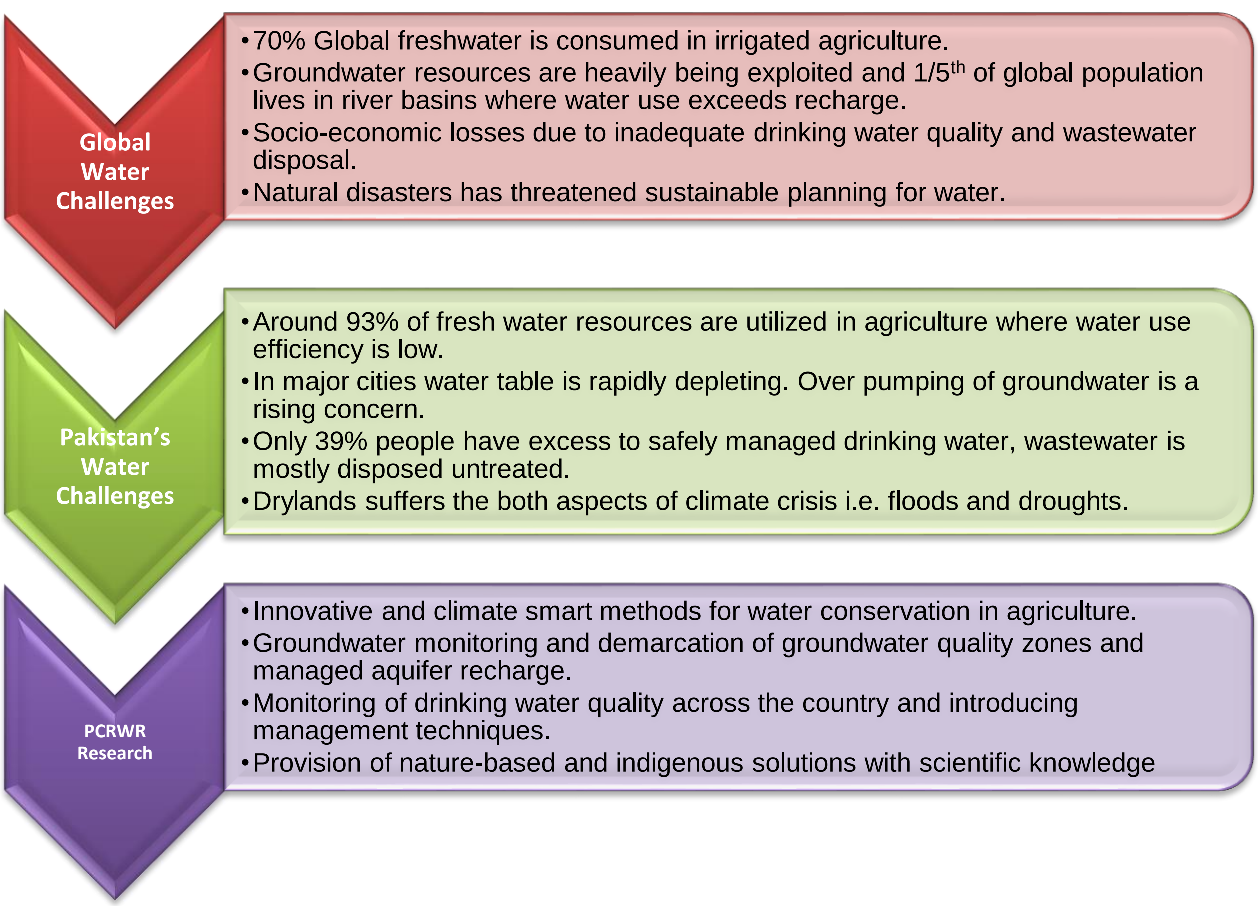


Figure 1: PCRWR's contributions in the context of national and global water issues

1.2 About PCRWR

PCRWR is an apex research body of Ministry of Water Resources and is the only organization in water sector at federal level. It is mandated to conduct, organize, coordinate and promote research on all aspects of water resources including irrigation (surface and groundwater), drainage, soil reclamation, drinking water, rainwater harvesting, etc. With its headquarters at Islamabad, it has eight Regional Offices located at Lahore, Karachi, Quetta, Bahawalpur, Peshawar, Tandojam, Gilgit and Muzaffarabad besides having 24 water quality testing laboratories and seven research and demonstration farms across the country.

The Council was established in 1964, under a resolution and named as Irrigation, Drainage and Flood Control Research Council (IDFCRC) under the Ministry of Natural Resources. Later it was renamed as Pakistan Council of Research in Water Resources in 1985 under the administrative control of Ministry of Science and Technology. In 2007, it was given the status of a corporate body through an Act of Parliament. In March, 2022, PCRWR was brought under the administrative control of Ministry of Water Resources through the decision of the Federal Cabinet. Ever since its inception, the organization has determined its research and development activities according to the mandate provided to it. Its research and development activities are either financed by Federal Government or by international donors as well as research agencies. The patronage from Government of Pakistan and knowledge support from international partners has resulted into the emergence of PCRWR as the most vibrant organization on water-related issues.

The Council is governed by a Board of Governors while Chairman, PCRWR is the Chief Executive. The Chairman is supported by the Secretary, Director Generals, Directors and other professionals. The total strength of the Council consists over 500 employees including; specialized staff (engineers, scientists, technicians, sub-engineers), administrative and management staff (administration, finance, coordination).

1.3 Research Infrastructure

The Council has particularly carried out activities especially in the field of water quality monitoring and assessment of surface, groundwater resources, water supply schemes and waste water at national scale, land and water conservation to enhance agricultural water productivity and last but not least, water security and livelihood improvement for the population living in the remote and vulnerable to natural disaster districts of Pakistan. In order to perform these activities at national scales, it maintains necessary infrastructure at important locations to address the region-specific water-related issues as shown in Figure 2:

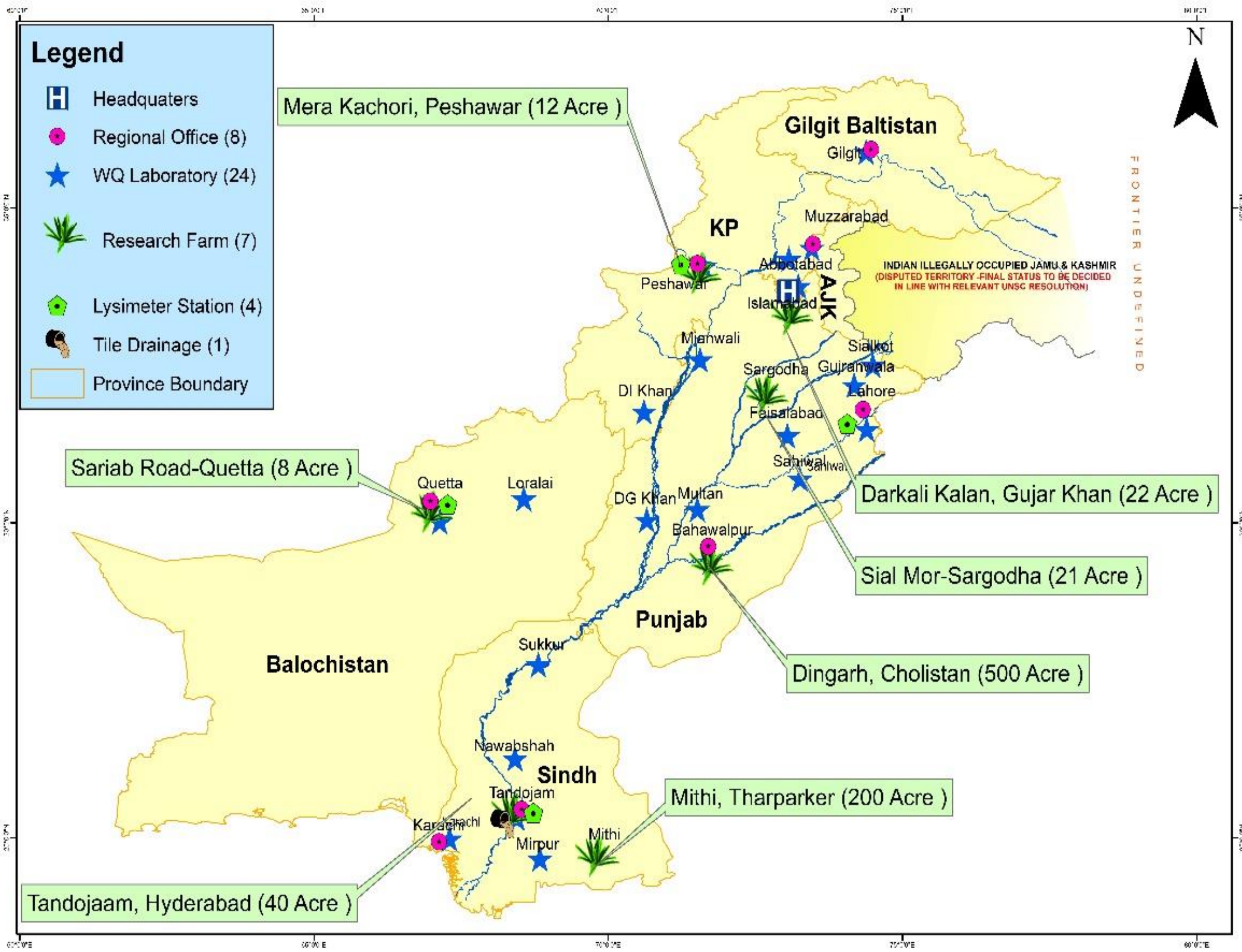
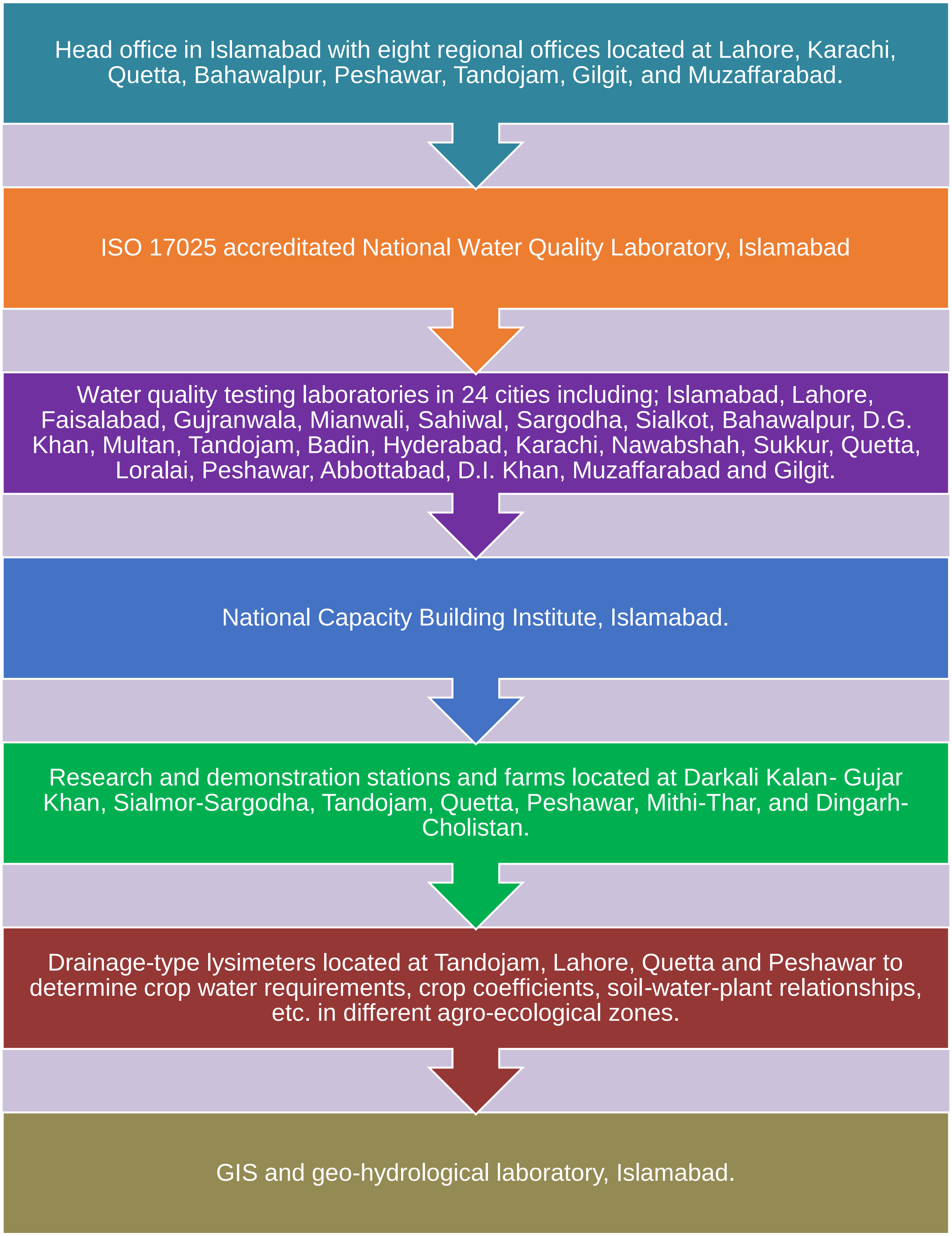


Figure 2: Geographical presence of PCRWR across the country

The major specialized research infrastructure is given in the below flow chart.


Head office in Islamabad with eight regional offices located at Lahore, Karachi, Quetta, Bahawalpur, Peshawar, Tandojam, Gilgit, and Muzaffarabad.
ISO 17025 accreditated National Water Quality Laboratory, Islamabad
Water quality testing laboratories in 24 cities including; Islamabad, Lahore, Faisalabad, Gujranwala, Mianwali, Sahiwal, Sargodha, Sialkot, Bahawalpur, D.G. Khan, Multan, Tandojam, Badin, Hyderabad, Karachi, Nawabshah, Sukkur, Quetta, Loralai, Peshawar, Abbottabad, D.I. Khan, Muzaffarabad and Gilgit.
National Capacity Building Institute, Islamabad.
Research and demonstration stations and farms located at Darkali Kalan- Gujar Khan, Sialmor-Sargodha, Tandojam, Quetta, Peshawar, Mithi-Thar, and Dingarh-Cholistan.
Drainage-type lysimeters located at Tandojam, Lahore, Quetta and Peshawar to determine crop water requirements, crop coefficients, soil-water-plant relationships, etc. in different agro-ecological zones.
GIS and geo-hydrological laboratory, Islamabad.

1.4 Fuctions of PCRWR

The Council's functions mainly focus on research, policy recommendations, design and development of technologies, water quality monitoring, capacity building of officers from other federal and provincial government departments by developing coordination with national and international research and development organizations. Detailed functions assigned to PCRWR as per its mandate are shown in Figure 3.

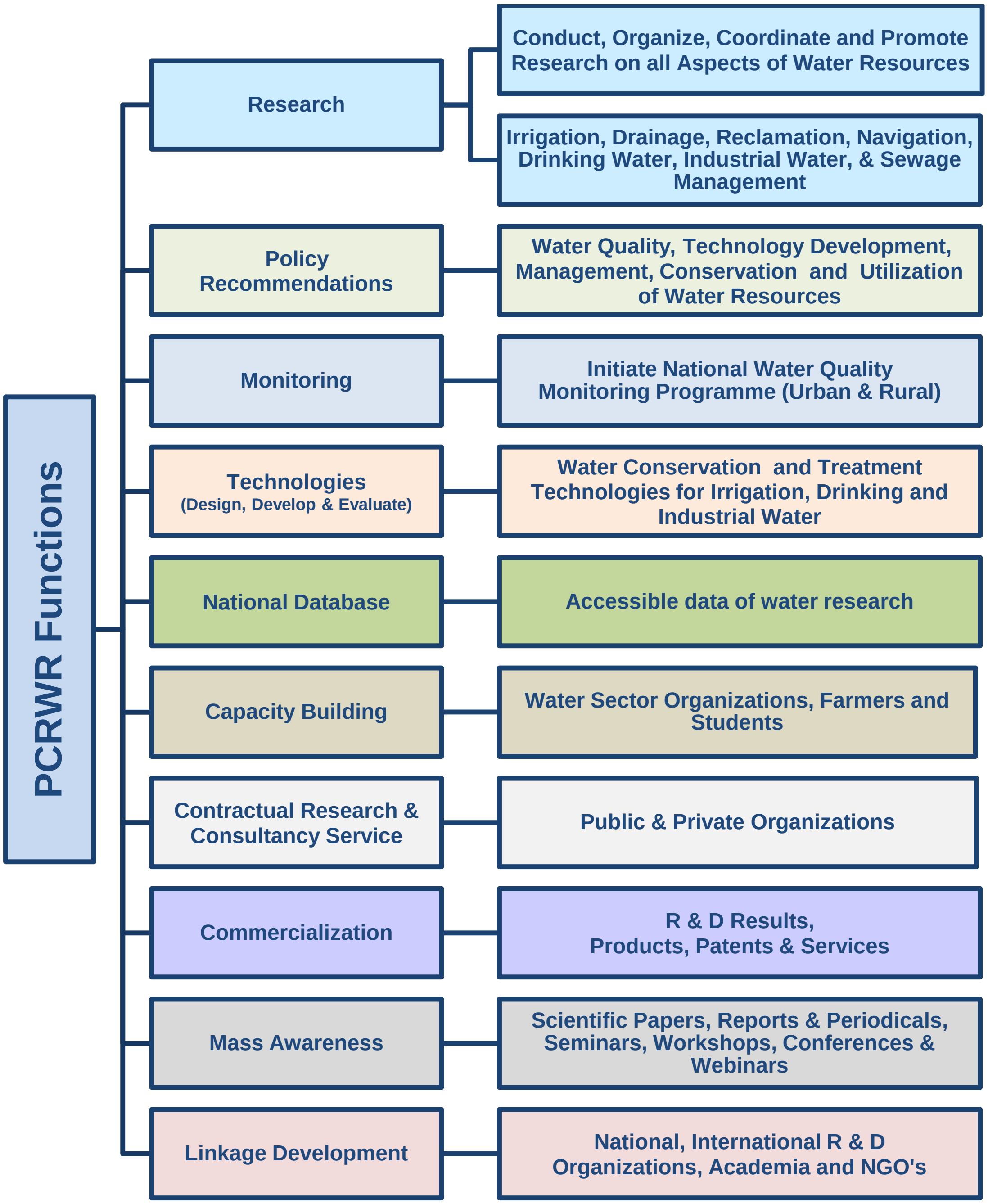


Figure 3: Functions of PCRWR

1.5 Focused Research Areas

PCRWR has a wide mandate to focus on various aspects of water resources. The focused research areas in the preview of the Council vary according to the prevailing water resources issues, priorities set by the National and Provincial government policies and international commitments of the government. However, the focused research areas are given in Figure 4.

Figure 4: Focused research areas of PCRWR

Water Resource Management: Pakistan has one of the largest contiguous irrigation systems in the world where more than 93% of water is used in agriculture. This is the area where maximum losses occur. For example, more than 60% of the water is lost during conveyance and application in the fields mainly due to the poor maintenance of the irrigation system and conventional irrigation methods. Hence, practices small saving in the agriculture sector may transform into a huge water saving at national level. Therefore, PCRWR's major research focus is on agricultural water management.

Water Management in Drylands: Out of 30 million hectares of cultivable land, dryland agriculture is practiced on about 12 Mha which is 40% of the total cultivable land. In these regions livelihood is totally dependent on rainfall. Pakistan's maximum investment has been on achieving water security focusing on irrigated agriculture for its crucial linkages to the nation's food security.

Rainfall is the sole source of water for humans and livestock in drylands. The groundwater is either not available or if available, is saline and mostly not usable. Rainwater harvesting is the principal source of survival in these areas. In deserts, rainwater is stored in natural depressions, locally called *tobas*, and in underground dug wells called *kunds*. These structures have remained very useful in sustaining livelihood in the desert areas playing a pivotal role in the population rise. If such *tobas* are dried up due to the absence of rainfall and the surrounding land also overgrazed, communities tend to migrate along with their herds. In the Cholistan desert there is 0.3 million human population whereas animal heads are around 2.0 million. Similarly, in the Thar desert, the human population is 1.6 million whereas their animal heads are about 5 million. Therefore, there is a need to develop water resources (rainwater ponds) close to their hamlets and also develop rangelands for their livestock.

In certain dry areas, rainwater is also harvested in the form of small ponds. Likewise, major urban areas of Pakistan need to be connected which suffer from urban flooding during the rainfall period. Due to the expansion in population, unregulated groundwater abstraction has nearly diminished groundwater in some districts, such as; Quetta, Islamabad, Rawalpindi and Lahore. In this regard, there is a need to manage the rainwater during the monsoon period in urban areas and transform urban flood potential into a useful resource through managed aquifer recharge.

Water Quality: Access to safe drinking water is the basic human right. Pakistan Vision 2025 and UN Sustainable Development Goals (SDG's) 2030 impose obligations on Pakistan towards achieving its water and sanitation goals. Drinking water is also placed as priority No. 1 in the approved National Water Policy 2018. One of the major components of maintaining water quality is the monitoring of the drinking water sources, because the surface and groundwater quality have direct impact on human health. It is ironically said that if you cannot measure a thing, you cannot manage it.

1.6 Partnerships and Collaboration

In line with its mandate to conduct and promote research, PCRWR has developed linkages with international and national collaborators. Moreover, given its wide scope of research, it is imperative to develop linkages with collaborators for the dissemination of research. The Council also derives its research funding and capacity-building opportunities of its professionals from such partnerships.

The Council does not conduct research in isolation rather in partnership with national organizations, think tanks, national/international universities, provincial government departments, international organizations, industry, and most importantly the communities. This linkage is in fact diverse in nature. It includes policy makers, development partners, implementing agencies, academia and beneficiaries of research (Figure 5). Prominent and most recent research collaborators of PCRWR are the following:

International Collaborations

- UN Agencies - UNICEF, WHO, UNESCO, FAO, UNU, UNHABITAT
- Australian Centre for International Agricultural Research (ACIAR)
- International Centre for Integrated Mountain Development (ICIMOD)
- University of Washington, USA
- The Asian Disaster Preparedness Centre (ADPC)
- United Nations University-Institute of Water, Environment and Health
- International Water Management Institute (IWMI)
- International Centre for Agricultural Research in Dry Areas (ICARDA)
- Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
- International Union for Conservation of Nature (IUCN)
- World Wide Fund for Nature (WWF)
- The Asia Foundation
- The WaterAid
- The World Bank

National Collaborations

- Federal Flood Commission (FFC)
- Indus River System Authority (IRSA)
- Provincial Irrigation and On-Farm Water Management Departments
- Water and Power Development Authority (WAPDA)
- Water Supply Agencies (WASA, PHED, CDA, TMA)

- Pakistan Meteorological Department (PMD)
- Universities (NUST, COMSATS, RIPHAH, MUET, FJWU, BUITEMS, Centre of Excellence in Water Resource Engineering, Lahore, etc.)
- Global Change Impact Studies Centre (GCISC), Ministry of Climate Change
- Agha Khan University Hospital, Karachi
- Provincial Agriculture Department
- Federal Water Management Cell
- Pakistan Agricultural Research Council (PARC)
- NGOs.

Pillars of Knowledge

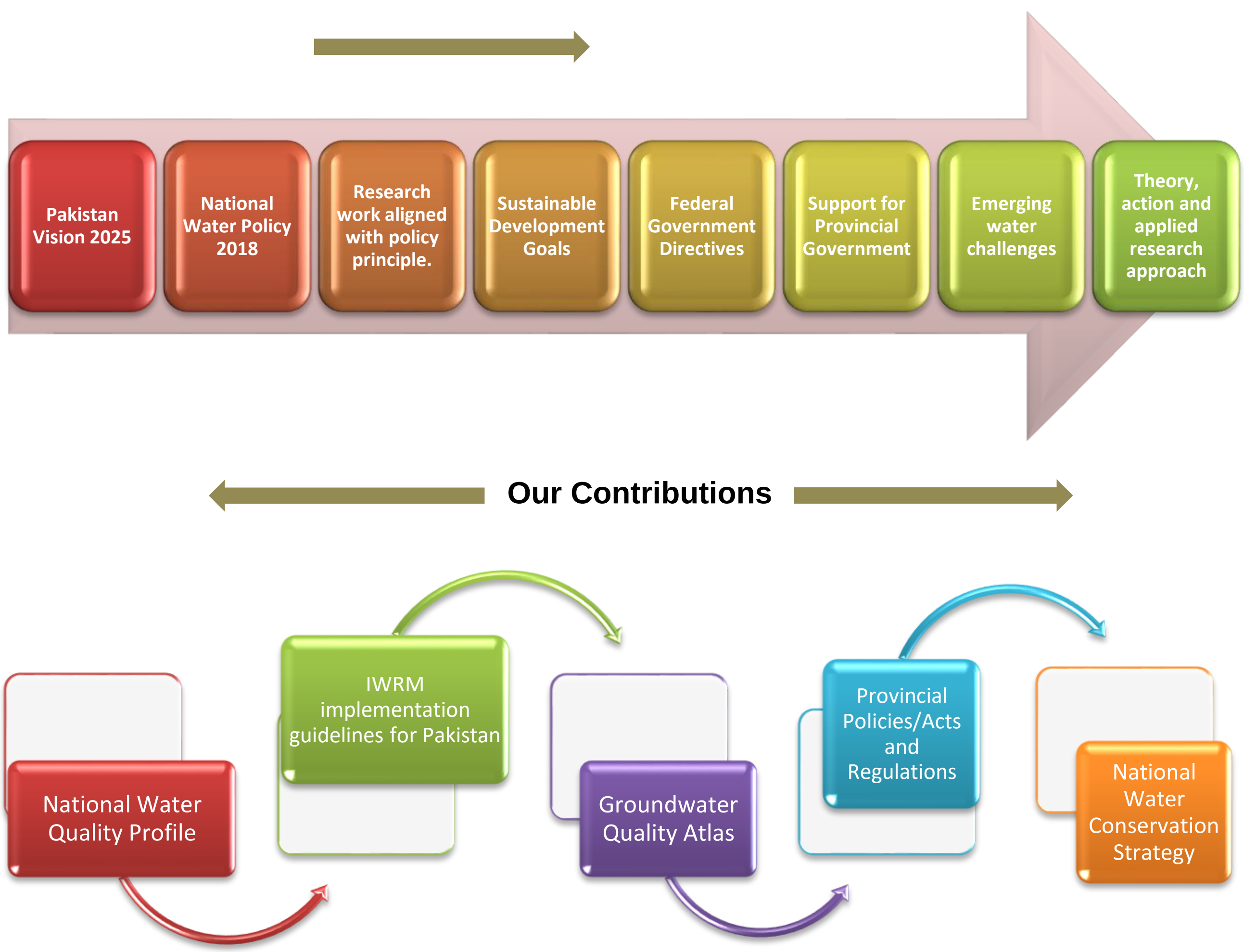


Figure 5: PCRWR's policy principles and contributions

Thematic Achievements

Water Resources Management

- Piloted Indus Telemetry System.
- Satellite Hydrology.

Agricultural Water Management

- Innovative on-farm water conservation and management.
- Irrigation advisory services and its customization.
- On-farm tile drainage.

Groundwater

- Groundwater investigation and mapping in the Indus plain aquifer.
- Real-time groundwater monitoring.
- Managed aquifer recharge.

Drylands Managements

- Rainwater harvesting in deserts.
- Leaky dam and artificial groundwater recharge in Balochistan.
- Nomination of Karezes of Balochistan at UNESCO's World Cultural Heritage.
- Saline agriculture.

Water Quality Management

- Assessment of Arsenic in groundwater.
- Technical Assessment and Survey of Water Supply Schemes.
- National Water Quality Profile.
- Bottled Water Quality Monitoring.
- National Capacity Building Institute.

1.7 Impact of Research

PCRWR is playing its role, as a leading water sector R&D organization through a well-established state of the art research and dissemination infrastructure. The knowledge generated by research-based activities is benefiting environment and society and sensitizing the stakeholders, policy and decision makers in right direction. Following are the few examples of its impactful research.

Forecasting the Future Water Scarcity	• PCRWR's report sensitized the stakeholders and accordingly, Supreme Court's decision to establish "Dam Fund" & initiation of 2 large dams
Drinking Water Quality Profiling	• Sensitized the nation about the issue of drinking water quality in early 2000 and subsequent launching of water quality initiatives by federal and provincial governments
Groundwater Quality Mapping	• Groundwater quality mapping by PCRWR has helped in developing provincial policies
Rainwater Harvesting in Desert	• Adoption of rainwater harvesting model of PCRWR by Cholistan Development Authority in Cholistan Desert
Quarterly Monitoring of Bottled Water Brands	• Quarterly monitoring of bottled water brands resulted in improved quality of bottled water in the country
Groundwater Recharge Techniques	• PCRWR's developed technique of inverted well is getting propagation in local government (CDA, RCCI). Judicial Water Commission in Lahore has ordered Punjab govt. to install recharge wells in public parks and buildings
Telemetry System	• To built the trust among provinces on flow measurements, PCRWR/IWMI have piloted Telemetry System on four canal commands of each province in collaboration with the provincial irrigation departments and IRSA. This system was extended to all 14 canals of Khyber Pakhtunkhwa.
Crop Water Requirment	• PCRWR is assissting the farmers in reducing inefficient water use.Through providing information about crop water requirment, PCRWR is providing this advisory service to around 20,000 farmers per week and in a process to take to over 100,000 farmers per week.

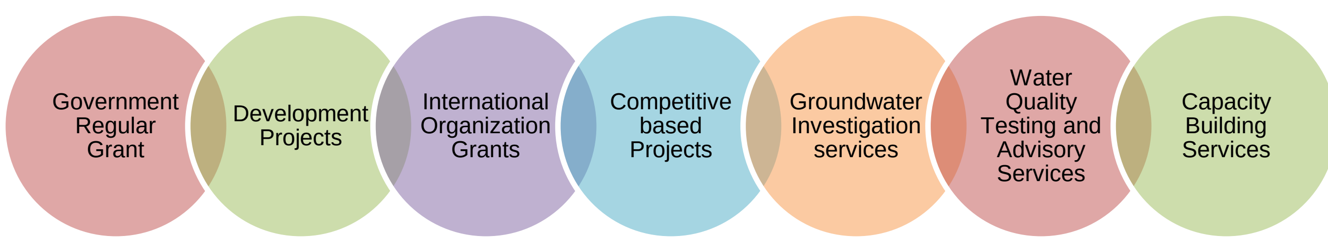
1.8 Dissemination of Research Findings

PCRWR is generating knowledge with public funding as well as in collaboration with its partners and transfer it to the relevant stakeholders for practical implementation. Dissemination of research findings is an important part of the research process, passing the benefits to other researchers, professional and the community. Research activities and findings are rarely considered complete until the results have been made widely available.

Following are the ways/means through which the Council is disseminating the knowledge generated.

1.9 Funding Sources

Major research activities of PCRWR are being executed by securing funding from partner organizations. Following are the main funding sources through which PCRWR is generating research knowledge for the benefit of the country.



2 Major Achievements

PCRWR has initiated projects of strategic nature starting from Gilgit-Baltistan to the Arabian sea. All of these research achievements are aligned with the mandate of the Council. These research projects are either implemented with the support of the Federal Government or collaborative research initiatives. As the mission statement indicate, the research within its three key research areas is targeted to resolve real-life water resources issues through simple solutions. Moreover, the Council cherishes the role of citizens, youth, and communities in bringing change in water resources management. The following section will provide a glimpse of PCRWR's key achievements.

2.1 Water Resource Management

2.1.1 Groundwater Investigation and Mapping of the Indus Plain Aquifer

Groundwater is an important resource for Pakistan. It meets about 60% of irrigation, 90% of drinking water, and almost 100% of industrial water requirements. Presently, there is no groundwater regulatory framework in the country. However, few provinces have enacted their water acts. To implement a groundwater regulatory framework, the knowledge of groundwater for the identification of hot/bright spots is very important. The Council has mapped the entire Indus basin, five districts of Khyber Pakhtunkhwa, and seven merged districts of tribal areas covering more than 24 Mha (Figure 6). The groundwater mapping has provided detailed information on fresh groundwater quality zones. This information will serve as a prerequisite for groundwater management and regulations which are also stressed in the National Water Policy 2018.

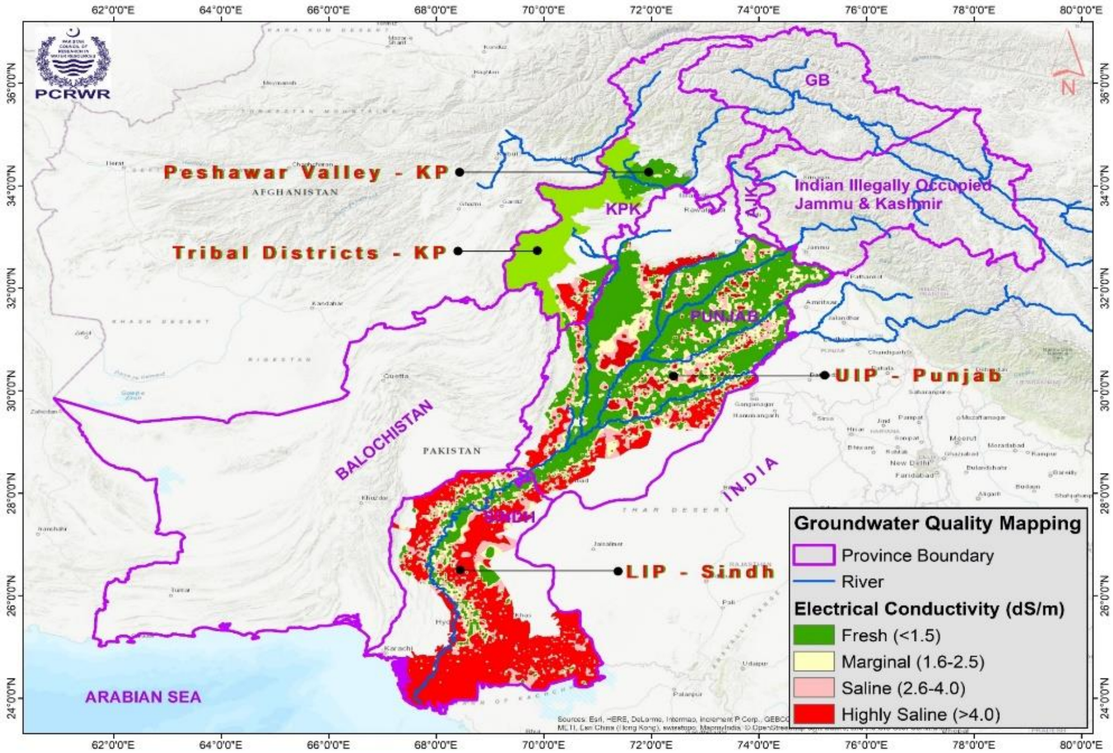


Figure 6: Groundwater quality map of upper and lower Indus plain (0-50 m depth)

2.1.2 Satellite-Based Groundwater Monitoring

Real-time groundwater monitoring is critical but, a cumbersome and long-term process. Gravity Recovery and Climate Experiment (GRACE) satellite provides data for effective groundwater resource management at the doab scale. PCRWR has developed the capacity to independently operationalize GRACE-based groundwater monitoring (Figure 7). It is also utilizing GRACE-FO data for gravity anomalies and tracking groundwater storage changes on monthly basis. PCRWR has developed this capacity with the partnership of the University of Washington, USA. Now, the Council is continuously monitoring storage changes in groundwater aquifer of Pakistan leading towards sustainable groundwater resource management.

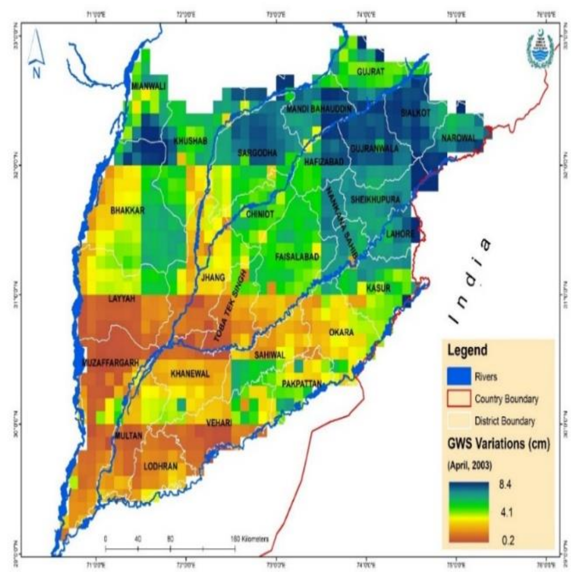


Figure 7: GRACE generated map of groundwater storage changes

2.1.3 Weekly Irrigation Advisory SMS Service

Irrigation scheduling is a complex process that requires hi-tech instrumentation and calculations which are not cost-effective and equally difficult to adopt at a basin scale. PCRWR's advisory message through SMS contains information that how much water is consumed by a particular crop during the previous week and how much irrigation is required during the coming week. This message also contains a weather forecast. PCRWR receives NASA satellite data on its server and after computing the lysimetric data of PCRWR with the satellite data, a text message in Urdu language is generated. This message is being sent to 20,000 farmers, however, the process of updating the server and broadening the scope of farmers to 100,000 is in process. The sequence of the procedure from data acquisition to sending of the text message is shown in Figure 8.

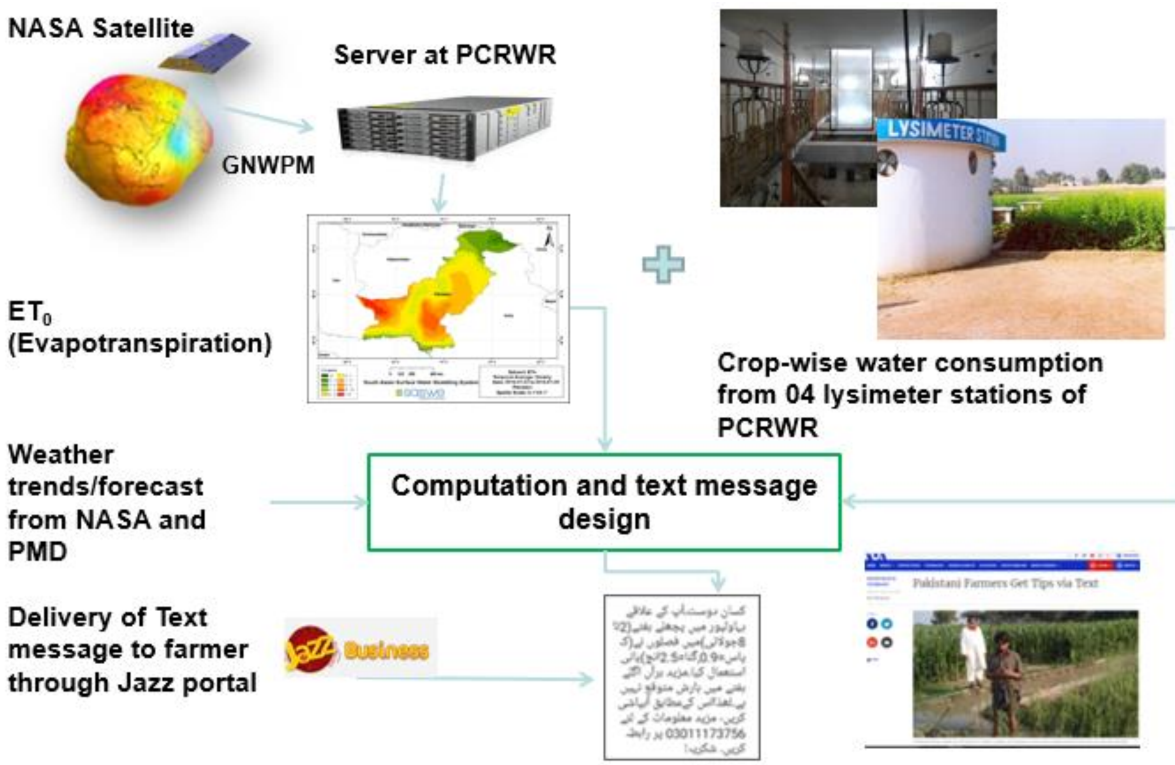


Figure 8: A flow diagram of text message formulation

2.1.4 Customization of Irrigation and Climate Advisory Service through Citizen Science

There are many barriers to the scalability of irrigation advisory services such as; contextualizing according to farmer's requirements and improving satellite observed values through real-time data. There is need to establish such robust systems that may provide a reliable agricultural water management advisory to farmers. In this regard, the farming community may serve as an important source of scientific data that can be used to upgrade the irrigation and climate advisories and empower farmers with knowledge during the process. In this regard, PCRWR implemented a pilot in three districts of Pakistan, Multan, Bahawalpur and Tando Allahyar involving farmers to record climate information such as; rainfall, temperature, humidity, wind speed and air pressure. In return farmers receive and validate irrigation and climate advisory messages. This pilot was implemented under Climate Innovation Challenge launched by the Asian Disaster Preparedness Centre (ADPC). It was regarded as one of the best among 530 innovative solutions proposed in this global competition. The data recorded by the farmers for the rainfall in the Bahawalpur district is shown in Figure 9.

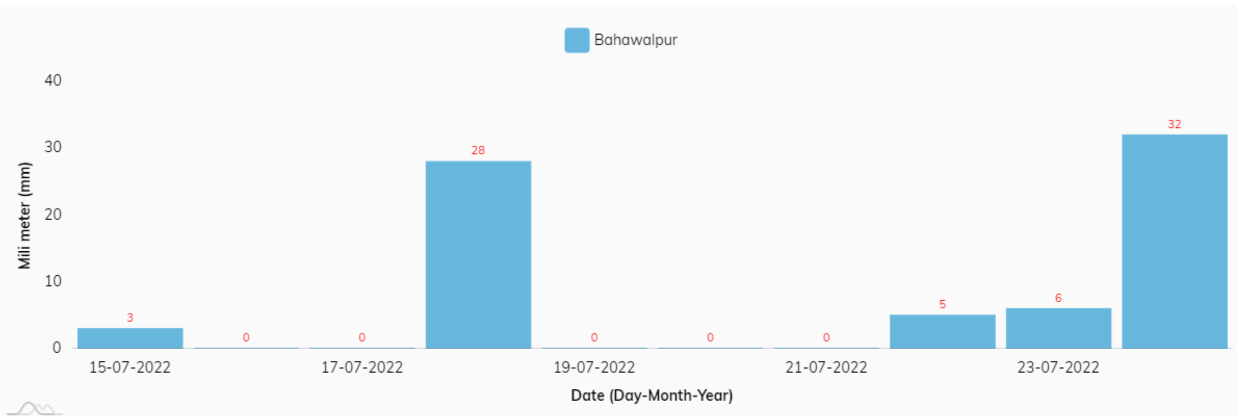


Figure 9: Rainfall data recorded by farmers during monsoon 2022 in Bahawalpur district, Punjab

2.1.5 Nomination of Karezes of Balochistan as World Cultural Heritage

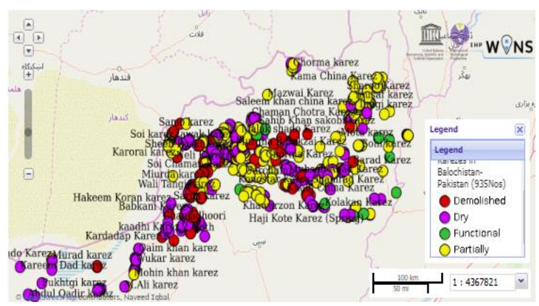


Figure 10: IHP-Wins Karez database

Karezes of Balochistan are pro-poor, sustainable and climate-smart system of water supply. It provides round the clock and round the year water supply through gravity to the whole ecosystem. However, presently these systems are threatened by rapid infrastructural development, and excessive abstraction of groundwater. These systems still possess the potential to be rejuvenated and provide water security to the livelihood of Balochistan people, as it has done in the past few centuries. PCRWR, with the support of the UNESCO-Pakistan office, has successfully got included Karezes of Balochistan in the tentative list for Declaration as World Cultural Heritage whereas formal dossier is in the preparation stage. To support this nomination, the Council has surveyed about 1200 Karezes in Northern Balochistan and developed first ever digital inventory (online available through IHP-Wins) as shown in Figure 10. This is first-ever effort made by PCRWR and UNESCO for geo-tagging and evaluating practical operational states of karez system, which exists in Balochistan province for centuries.

2.1.6 Determination of Crop Water Requirements

Crop water requirements (CWR) are specific to the climate and soil characteristics of a particular cropping zone. In this regard, one way to determine CWR is through lysimetric studies. The lysimeter installed at PCRWR research centre Tandojam is shown in Figure 11. The Council owns state of the art drainage-type lysimeters and has determined crop water requirements of major crops in Central Punjab and Sindh through lysimetric studies – to assist farmers in reducing inefficient water use. These crops include; cotton, wheat, rice, maize, maize-hybrid, sugarcane, chillies, rapeseed, mustard, banana, papaya, sunflower, and sesame.

Figure 11: Lysimeter Station at PCRWR, Tandojam

2.1.7 Indus Telemetry System

On the occasion of 25 years of Water Apportionment Accord-1991, PCRWR and IWMI jointly organized a series of dialogues in the provinces and the capital. One of the key findings of the dialogue was mistrust on flow measurements and reporting to IRSA by the provinces. To take-up this challenge, PCRWR/IWMI have piloted automated depth sensors on four canal commands of each province in collaboration with the provincial irrigation departments and IRSA, called Indus Telemetry System. The information from the Indus Telemetry is available through the internet at any location. One of the effective methods to disseminate Indus Telemetry data is through digital display screens. Display screens have been installed at key government offices. The flow data is transmitted and displayed remotely in PCRWR Headquarter, IRSA Headquarter, Government of Khyber Pakhtunkhwa Irrigation Department (North) Office. In addition to flow data of canals, three more datasets have been displayed at PCRWR Headquarters Islamabad (Figure 12). The real time data displayed on the screens consist of the following sets;

1) Monitoring of Canal Flows
2) Groundwater Monitoring
3) Weather Data
4) 7-Day Weather Forecast

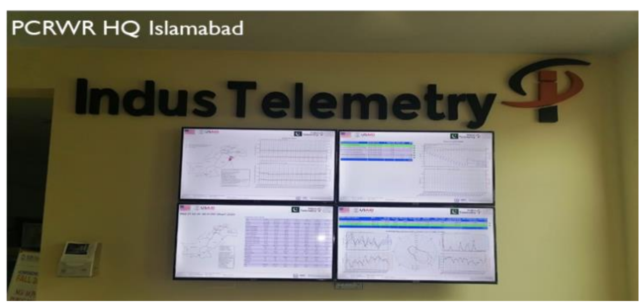
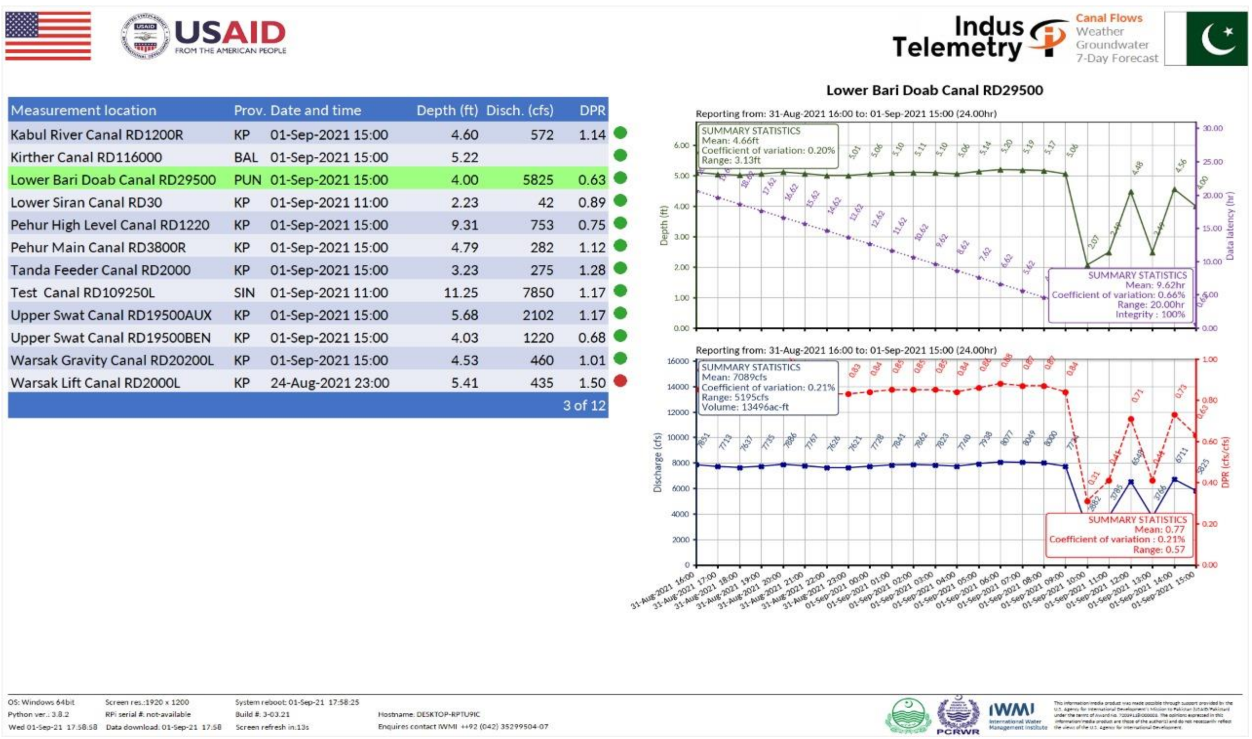


Figure 12: Indus Telemetry Visual interface at PCRWR Headquarter, Islamabad

2.1.8 Monitoring of Canal Flows

PCRWR/IWMI have installed telemetry system on 12 tier-1 canals in Khyber Pakhtunkhwa (KP) and one canal in each of three provinces (Punjab, Sindh and Balochistan). Canal flow is continuously measured by on site telemetric instruments. The onsite instrument (data logger/ computer) has been programmed to send data thrice per day. Once the data is received at the server, the data is post-processed using additional canal parameters such as; elevations, rating curves etc. to estimate the discharge and the Design Performance Ratio (DPR). The Indus Telemetry has addressed most of the technological challenges in setting up a flow monitoring system in the main canals of the IBIS. The datasets displayed through telemetry system is depicted in Figure 13.



Measurement location	Prov.	Date and time	Depth (ft)	Disch. (cfs)	DPR
Kabul River Canal RD1200R	KP	01-Sep-2021 15:00	4.60	572	1.14
Kirther Canal RD116000	BAL	01-Sep-2021 15:00	5.22		
Lower Bari Doab Canal RD29500	PUN	01-Sep-2021 15:00	4.00	5825	0.63
Lower Siran Canal RD30	KP	01-Sep-2021 11:00	2.23	42	0.89
Pehur High Level Canal RD1220	KP	01-Sep-2021 15:00	9.31	753	0.75
Pehur Main Canal RD3800R	KP	01-Sep-2021 15:00	4.79	282	1.12
Tanda Feeder Canal RD2000	KP	01-Sep-2021 15:00	3.23	275	1.28
Test Canal RD109250L	SIN	01-Sep-2021 11:00	11.25	7850	1.17
Upper Swat Canal RD19500AUX	KP	01-Sep-2021 15:00	5.68	2102	1.17
Upper Swat Canal RD19500BEN	KP	01-Sep-2021 15:00	4.03	1220	0.68
Warsak Gravity Canal RD20200L	KP	01-Sep-2021 15:00	4.53	460	1.01
Warsak Lift Canal RD2000L	KP	24-Aug-2021 23:00	5.41	435	1.50
					3 of 12

Figure 13: Canal discharge data – Indus Telemetry

2.1.9 Groundwater Monitoring

The changes in flow regime can be determined from the observed changes in aquifer water levels. Monitoring groundwater abstraction and aquifer water levels thus provides key information for groundwater resource management. In this context, PCRWR has installed more than 100 multi-level observation wells in six districts (Sialkot, Narowal, Gujranwala, Sheikhupura, Lahore and Kasur) along the eastern border since 2019 and is monitoring water-table depth biannually. Additionally, 10 CTD divers have also been installed with the support of IWMI, Pakistan for real time monitoring of spatio-temporal changes. The CTD-Diver is a data logger for long-term uninterrupted, real-time groundwater level monitoring using a pressure sensor when submerged at a fixed level in the groundwater. The CTD diver is programmable to record data at desired frequency (PCRWR/ IWMI programmed it to record the data once a day). Datasets generated through the system are shown in Figure 14:

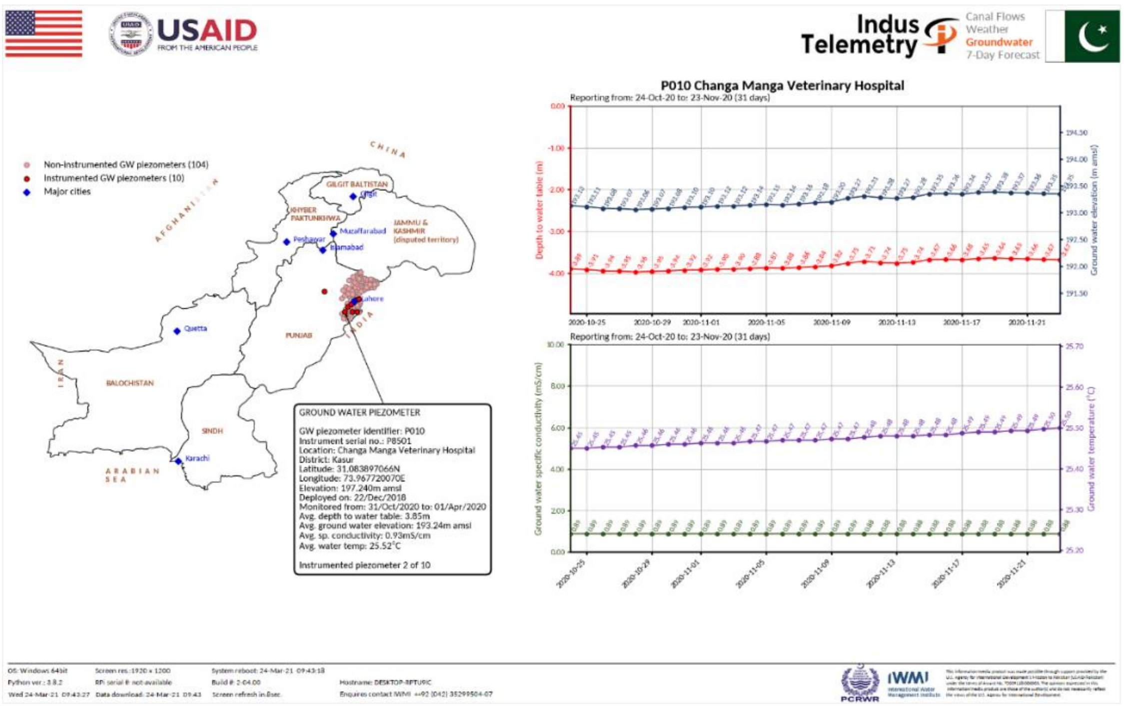


Figure 14: Groundwater monitoring data-Indus Telemetry

2.1.10 Weather Data

The Weather data such as precipitation, humidity, temperature, and wind speed is tremendously important to agriculture and infrastructure planning, demand forecast, and supply chain management. Weather data from automated weather stations installed at PCRWR's R&D farm, Sargodha and lysimeter station, Lahore is being displayed on screen installed in Head Office PCRWR Islamabad. An automated weather station typically consists of a weather-proof enclosure containing the data logger, rechargeable battery and telemetry. The meteorological sensors (solar radiation & humidity), telemetry external antenna, a solar panel and wind turbine mounted upon a mast. It records temperatures (maximum, minimum & average), relative humidity, wind speed & direction and solar radiation hourly. It also calculates the reference evapotranspiration (ET_0) by itself. This data is being used in determination of crop water requirement and irrigation scheduling. Datasets generated through the system are shown in Figure 15.

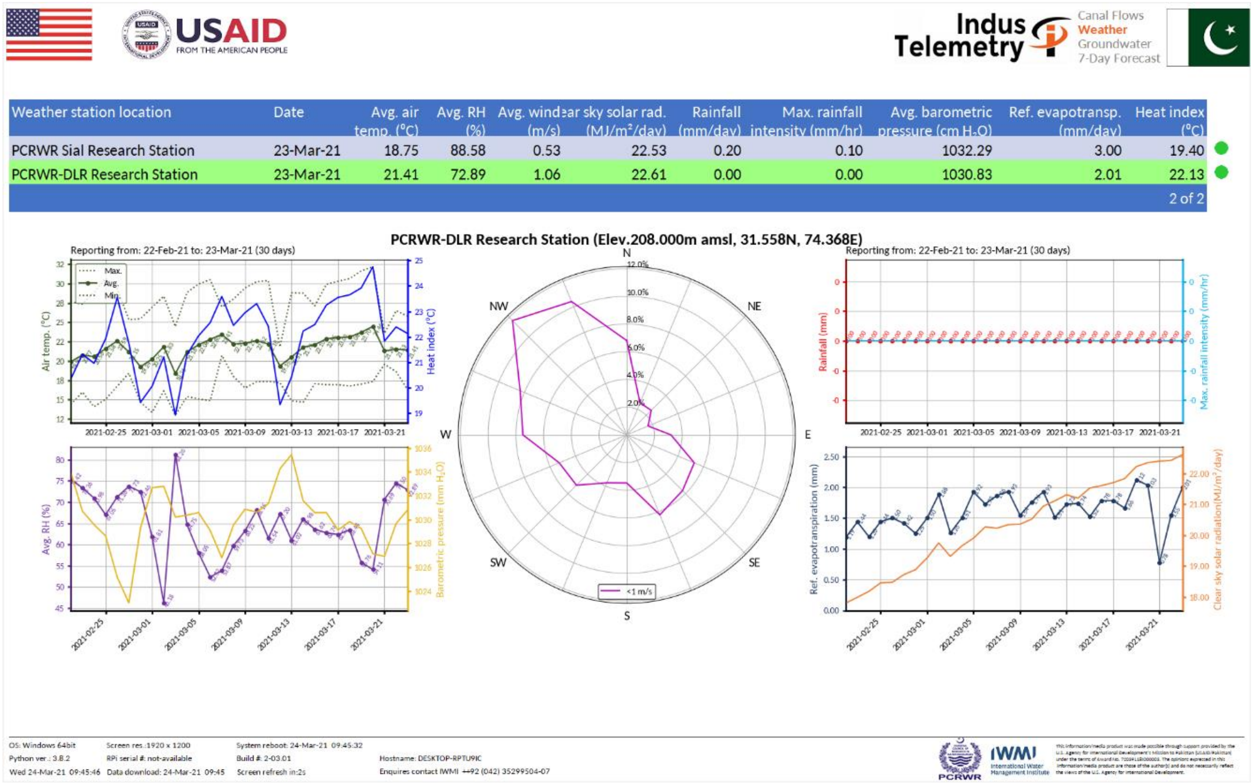
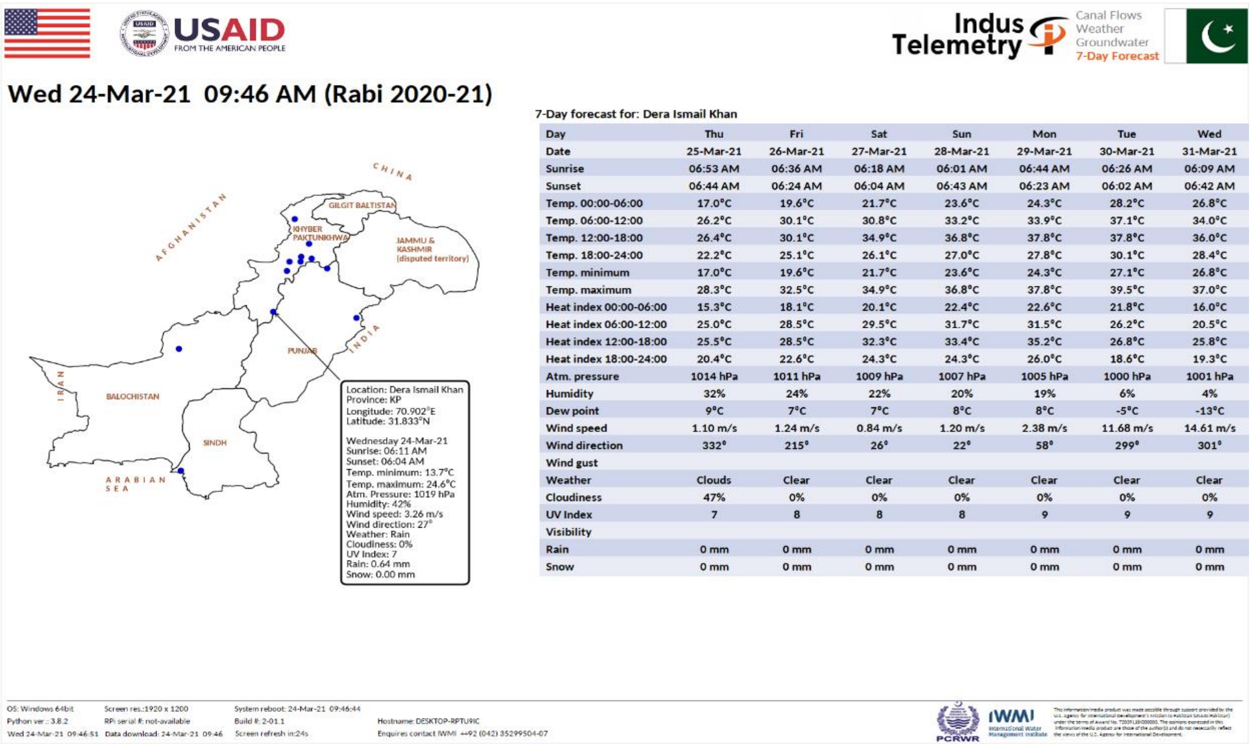


Figure 15: Automatic Weather Station Data - Indus Telemetry

2.1.11 7-Day Weather Forecast

Weather forecasting is the application of science and technology to predict the future state of the atmosphere of a particular location. Weather forecasts are made by collecting the current state of the atmosphere (particularly the temperature, humidity and wind) and using understanding of atmospheric processes to determine how the atmosphere evolves in the future. However, due to the chaotic nature of the atmosphere and incomplete understanding of the processes, forecasts become less accurate as the range of the forecast increases. Keeping in view the accuracy of forecast and requirement of irrigated agriculture, PCRWR/ IWMI have chosen seven days forecast by acquiring the weather forecast data from Global Forecast System (GFS). The GFS is a National Centres for Environmental Prediction (NCEP) weather forecast model that generates data for dozens of atmospheric and land-soil variables, including temperatures, winds, precipitation, soil moisture, and atmospheric ozone concentration. It provides weather forecast data for whole country, system extracts the desired parameters of key locations through post processing of the GFS data. These key locations can be seen as blue dots on the map of Pakistan at left hand side of the screen (7-day weather forecast). Also a pop-up window below the Pakistan map is on display which is connected to a blue dot (a particular location) with a line, this pop-up window keeps on switching between 12 key locations (i.e. Chitral, Mingora, Mardan, Peshawar, Nowshera, Kohat, Swabi, Islamabad, Dera Ismail Khan, Lahore, Quetta and Karachi) after every 20 seconds and displays the information (i.e. location address, province name, location coordinates, date, sunrise, sunset time, min/max temperature, atmospheric pressure, humidity, wind speed & direction, weather condition, cloudiness, UV Index, rainfall and snow). While on the other side of screen tabular data displays the 7-day forecast of the above-mentioned parameters (Figure 16).



Day	Thu	Fri	Sat	Sun	Mon	Tue	Wed
Date	25-Mar-21	26-Mar-21	27-Mar-21	28-Mar-21	29-Mar-21	30-Mar-21	31-Mar-21
Sunrise	06:53 AM	06:36 AM	06:18 AM	06:01 AM	06:44 AM	06:26 AM	06:09 AM
Sunset	06:44 AM	06:24 AM	06:04 AM	06:43 AM	06:23 AM	06:02 AM	06:42 AM
Temp. 00:00-06:00	17.0°C	19.6°C	21.7°C	23.6°C	24.3°C	28.2°C	26.8°C
Temp. 06:00-12:00	26.2°C	30.1°C	30.8°C	33.2°C	33.9°C	37.1°C	34.0°C
Temp. 12:00-18:00	26.4°C	30.1°C	34.9°C	36.8°C	37.8°C	37.8°C	36.0°C
Temp. 18:00-24:00	22.2°C	25.1°C	26.1°C	27.0°C	27.8°C	30.1°C	28.4°C
Temp. minimum	17.0°C	19.6°C	21.7°C	23.6°C	24.3°C	27.1°C	26.8°C
Temp. maximum	28.3°C	32.5°C	34.9°C	36.8°C	37.8°C	39.5°C	37.0°C
Heat index 00:00-06:00	15.3°C	18.1°C	20.1°C	22.4°C	22.6°C	21.8°C	16.0°C
Heat index 06:00-12:00	25.0°C	28.5°C	29.5°C	31.7°C	31.5°C	26.2°C	20.5°C
Heat index 12:00-18:00	25.5°C	28.5°C	32.3°C	33.4°C	35.2°C	26.8°C	25.8°C
Heat index 18:00-24:00	20.4°C	22.6°C	24.3°C	24.3°C	26.0°C	18.6°C	19.3°C
Atm. pressure	1014 hPa	1011 hPa	1009 hPa	1007 hPa	1005 hPa	1000 hPa	1001 hPa
Humidity	32%	24%	22%	20%	19%	6%	4%
Dew point	9°C	7°C	7°C	8°C	8°C	-5°C	-13°C
Wind speed	1.10 m/s	1.24 m/s	0.84 m/s	1.20 m/s	2.38 m/s	11.68 m/s	14.61 m/s
Wind direction	332°	215°	26°	22°	58°	299°	301°
Wind gust							
Weather	Clouds	Clear	Clear	Clear	Clear	Clear	Clear
Cloudiness	47%	0%	0%	0%	0%	0%	0%
UV Index	7	8	8	8	9	9	9
Visibility							
Rain	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
Snow	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm

Figure 16: 7-day a weather forecast – Indus Telemetry

2.1.12 Development of On-farm Tile Drainage System in Sindh

Waterlogging is a huge menace for the farmers in Sindh. This issue has claimed vast patches of fertile land. In some areas providing artificial drainage is the only option to reclaim the affected lands. PCRWR is pioneer in initiating horizontal on-farm tile drainage system with state-of-the-art machinery to control waterlogging and salinity (Figure-17). Over 1000 ha of agricultural land in Sindh has been reclaimed.

Figure 17: Laying of tile drainage in Sindh

2.2 Water Management in Drylands

2.2.1 Rainwater Harvesting in Desert Areas

In drylands, drinking water is not available in sufficient quantities for human as well as livestock. The main sources of water in these areas are rainwater and to some extent groundwater where fresh water is available. The rainwater is collected in natural depressions or man-made ponds locally called 'Tobas' during rainy season. This water is being used for drinking, domestic, livestock, wildlife etc. However, water collected in these Tobas is usually muddy and full of impurities.

PCRWR has established a network of about 110 rainwater harvesting ponds in the Cholistan desert (110 reservoirs with 4-million-gallon capacity each). This technique is also adopted and replicated by Cholistan Development Authority. As an immediate socio-economic benefit, forced migration due to drought has been stopped. The location map of the ponds installed across the Cholistan desert is given in Figure 18, while Figure 19 shows a herd of animals drinking water from these ponds.

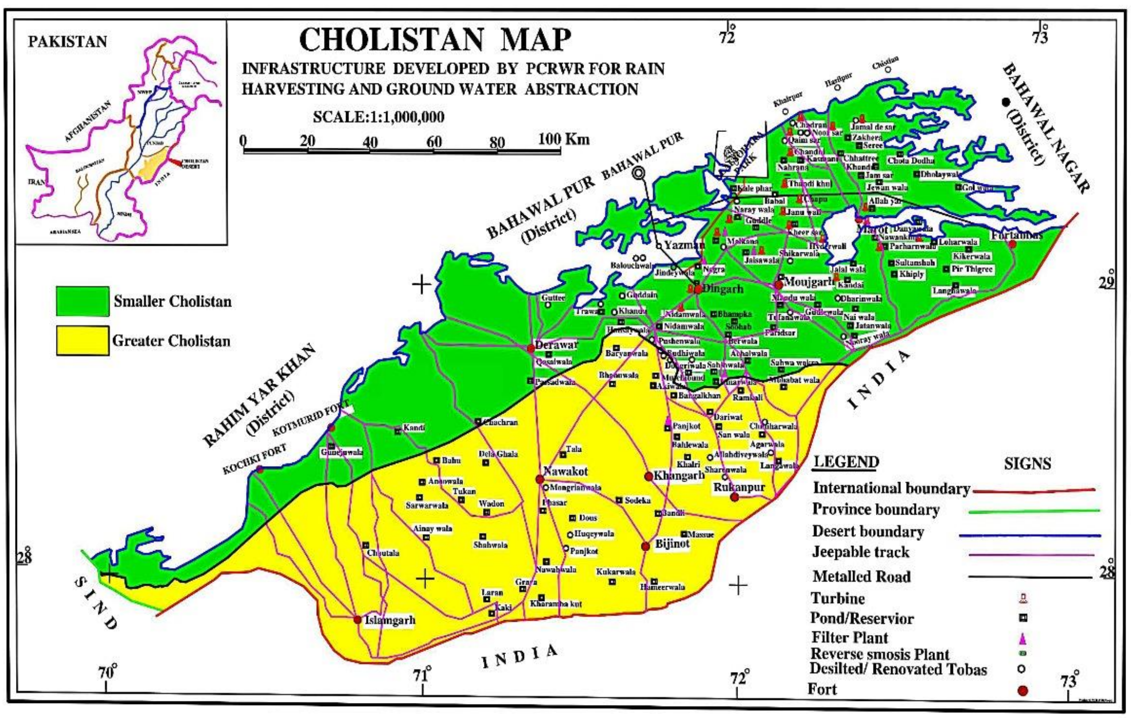


Figure 18: Network of rainwater ponds in Cholistan Desert

Figure 19: Animal drinking water from a PCRWR's constructed pond in Cholistan

2.2.2 Leaky Dam and Artificial Groundwater Recharge in Balochistan

Balochistan relies predominantly on groundwater for meeting its requirements. However, this precious resource is depleting rapidly at almost 3 m per year. If groundwater abstraction continues at the same rate, the water table would reach a level where abstraction would not be possible. This requires creating a balance between groundwater abstraction and recharge. PCRWR has introduced the concepts of leaky dams and inverted wells (Figure 20) for groundwater recharge as an alternative to conventional "Delay Action Dams". Moreover, a possible solution is to preserve the scarce yet significant rainfall events and divert it to groundwater, preventing the situation of flash floods and recharging the mother wells of Karez water systems. In this regard, construction of leaky dams/gabion structures in cascade approach helps slow down the storm runoff and inverted well technology captures this low velocity water and help recharge the aquifer.

Figure 20: Leaky dam structure in Balochistan (left) and Inverted well (right)

2.2.3 Rainwater Harvesting for Managed Aquifer Recharge

Metropolitan cities of Pakistan are increasingly facing episodes of urban flooding. Various cities have recently witnessed worse forms of urban flooding during monsoons. Consequently, not only the urban infrastructure is vulnerable to flash floods generated in the urban areas but it also causes damage to innocent lives. In this regard, PCRWR has developed a model for rainwater harvesting in urban areas of Lahore and successfully demonstrated it in key locations around the city, such as PCRWR's regional office in Lahore, STEDEC office building and Jilani Park, Lahore. PCRWR's idea of rainwater harvesting for managed aquifer recharge gained interest from the Planning Commission of Pakistan and Capital Development Authority. As a result, CDA in partnership with PCRWR is constructing 100 recharge sites in Islamabad. Some of these sites are also equipped with real time monitoring systems to determine the quantity and quality of recharged water. Moreover, in collaboration with IWMI and WaterAid, PCRWR has developed a model site at Kachnar Park, Islamabad for demonstrating rainwater harvesting and artificial recharge (Figure 21). This is the first ever fully instrumented groundwater recharge model site, where rainfall, groundwater recharge and its impact on local aquifer in terms of water table and quality is being monitored in real-time through various instruments. As a result, during 2022-23, 54 million gallons of rainwater has been recharged into groundwater aquifer of Islamabad.

Figure 21: Managed aquifer recharge – PCRWR, IWMI and WaterAid

2.3 Water Quality

2.3.1 National Water Quality Profile

Monitoring of drinking water quality is a first step towards its management. The Council started a nationwide water quality monitoring program in 2002 focusing on 24 major cities of the country. Now this has become a regular program of the Council. This program monitors the water quality throughout the country and releases its report after every five years. The national-level water quality monitoring carried out in 29 major cities of Pakistan in 2020 revealed that 39% of the population has access to safe drinking water. The comparison of unsafe water quality samples reveals that in Gilgit 100% samples are found to be unsafe, followed by Sindh (85%), AJ&K (70%), Punjab (51%), Balochistan (45%) and Khyber Pakhtunkhwa (57%).

The decade-long water quality monitoring study's findings are given in Figures 22 and 23. During 2002 -2020, only 19% improvement in safe drinking water supply has been observed (on an average 1% per year). If this situation continues, Pakistan would not be able to meet its national and international obligations within the stipulated time.

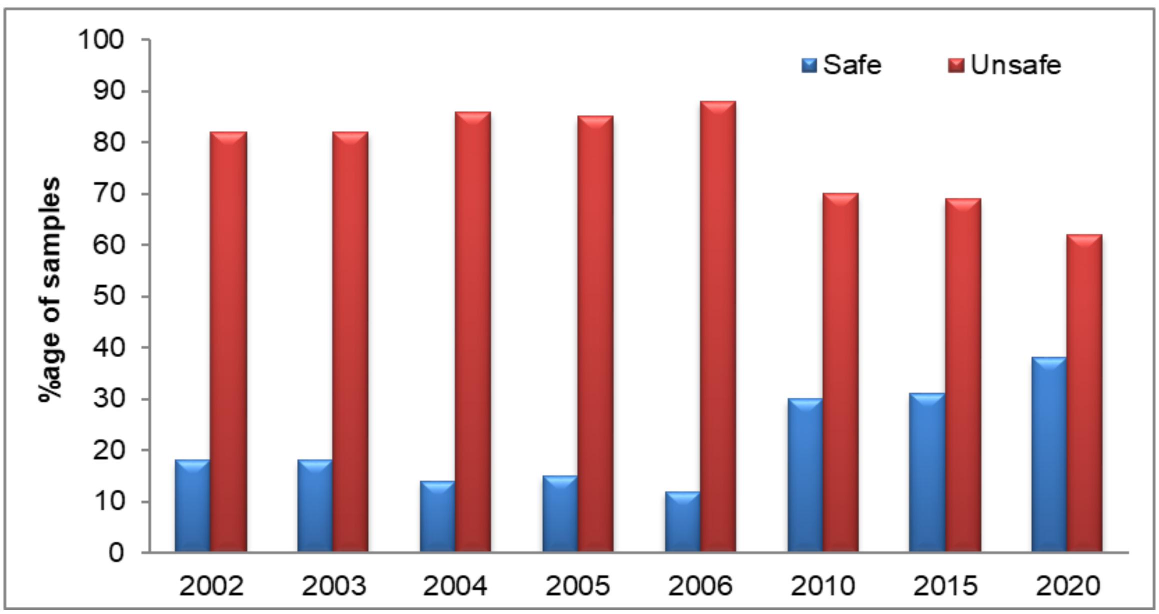


Figure 22: Overall water quality status of Pakistan

Overall analysis of 29 cities has identified 11 major water quality problems in drinking water sources of Pakistan i.e. microbiological (41%), TDS (14%), Iron (14%), Hardness (10 %), Turbidity (9%), Chlorides (8%), Arsenic (5%), Nitrates (4%), Fluoride (4%), and pH (1%).

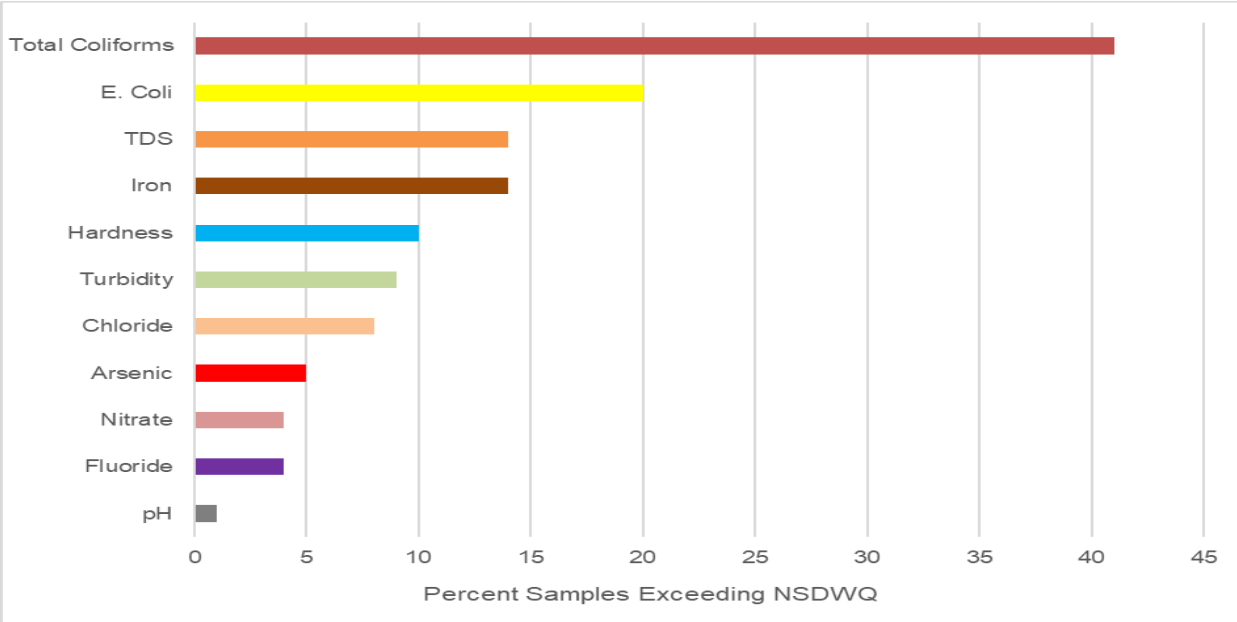


Figure 23: Major prevailing contaminants in the country

The outcome of this program helps raise awareness in the country regarding the issue of water quality. It acts as a guideline for the federal, provincial and local governments to take necessary steps towards improvement in this sector. Following this, the respective provincial and local bodies government undertook a number of initiatives. However, most of the initiatives could not yield the desired results mainly due to: project approach focusing mostly on infrastructure development, installation of decentralized plants (mostly reverse osmosis), lack of ownership for O&M, lack of professional capacity to address the issue and more importantly lack of service delivery concept.

2.3.2 Monitoring of Bottled Water Brands

Drinking water quality is deteriorating continually due to biological contamination from human waste, chemical pollutants from industries and agricultural inputs. The poor quality of drinking water has forced a large section of citizens to buy bottled water. As a consequence of this, a mushroom growth of bottled water industry in the country has been witnessed during the last few years. However, many of the mineral water companies were found selling contaminated water. To monitor and improve the quality of bottled water, the government of Pakistan had designated the task for quarterly monitoring of bottled/mineral water brands to PCRWR in 2005. Since then, PCRWR is continuously monitoring the commercially available bottled water brands from all over the country. Figure 24 shows the status of quality of bottled water since 2006 on quarterly basis.

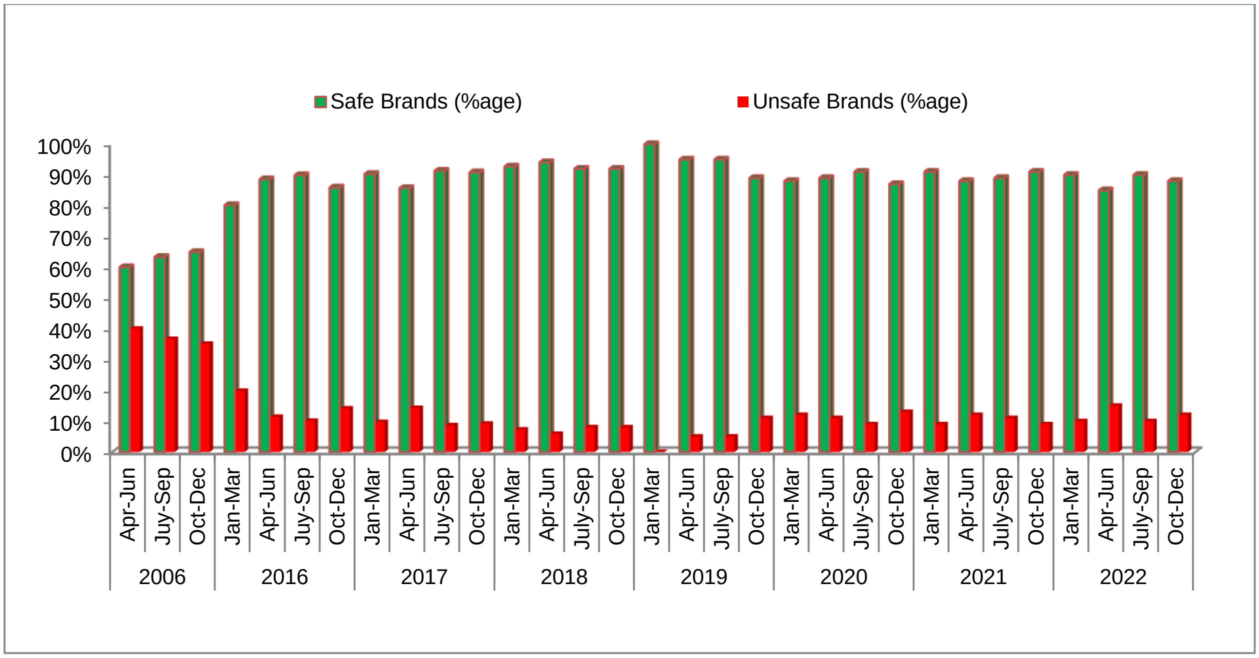


Figure 24: Report of quarterly monitoring of bottled water brands, 2006-2022

In 2006, about 40-50% bottled water brands were found selling contaminated water. However, through continuous water quality monitoring and publicizing results in print and electronic media, an improvement in their quality was observed. Accordingly, the most recent report shows that only 10-20% bottled water brands are found to be contaminated.

2.3.3 Assessment of Arsenic in Groundwater (61 districts of Punjab and Sindh)

Arsenic (As) contamination in groundwater continues to increase in many districts of Pakistan. The main sources of human exposure to arsenic are through arsenic contaminated water or food. Arsenic exposure has reported to be associated with an increased risk of cancer and non-cancer health effects depending on the duration of exposure. Considering the adverse effects of inorganic arsenic on human health in two provinces of Pakistan, PCRWR initiated project entitled “Arsenic Monitoring and Mitigation in Pakistan”

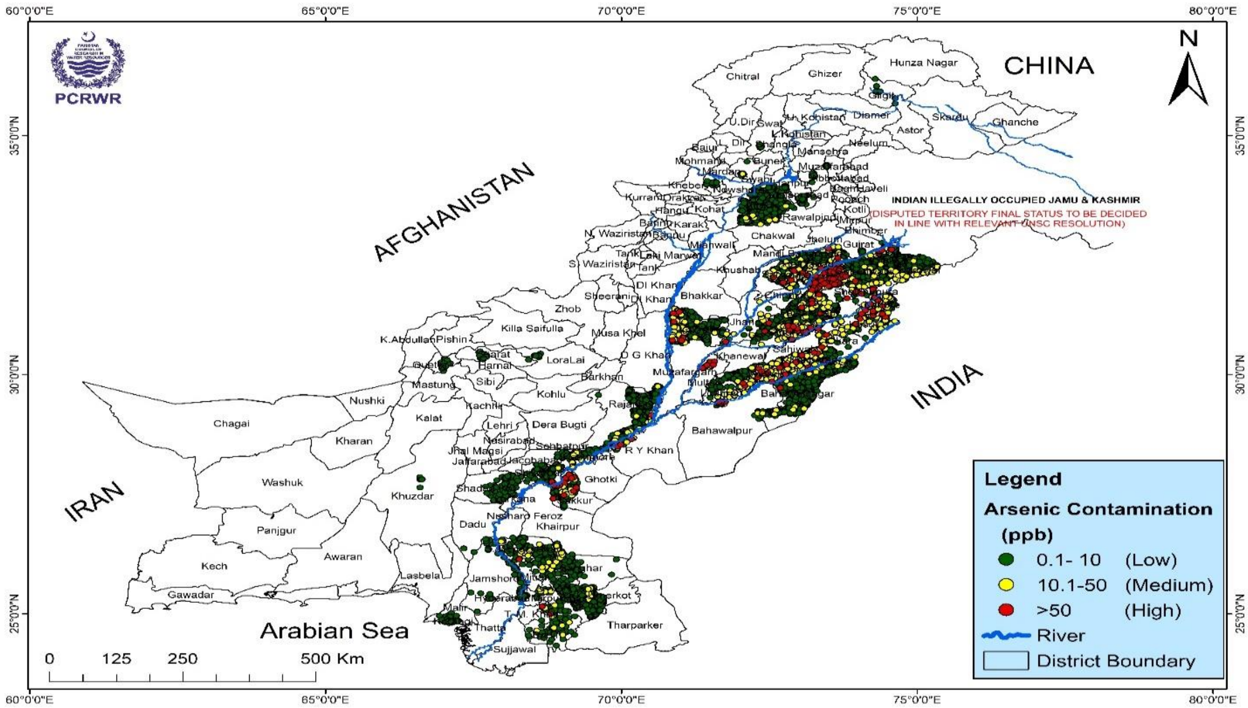


Figure 25: Spatial distribution of arsenic contamination in groundwater

This largest national survey during (2005-2014), PCRWR has assessed about 34,000 water sources in 61 districts of Pakistan including 34 districts of Punjab and 27 districts of Sindh. According to the survey, 15% of the assessed water sources were unsafe due to excessive arsenic mainly along the Indus River system.

Critical analysis of available data on prevalence of arsenic reveals that arsenic contamination is predominant in the Indus plain. All those districts identified as high in arsenic contamination (Multan, Bahawalpur, Rahim Yar Khan, Lahore and Kasur in Punjab province, and Khairpur and Dadu in Sindh province) are located along the Indus River and its tributaries. Figure 25 shows the spatial variation of arsenic contamination across the surveyed provinces.

2.3.4 Technical Assessment Survey of Water Supply Schemes

Realizing the importance of providing safe drinking water to the people, the Government of Pakistan launched the Provision of Safe Drinking Water Project in 2006. One of the major components of this project was the technical assessment survey of water supply schemes. The main aim of this survey was to ensure the provision of safe drinking water to the urban and rural population of the country through monitoring the water quality and identifying the problems related to existing water supply schemes. The assessment was carried out to; i) identify problems that existed in the water supply schemes, ii) analyse reasons of the inability of the schemes to deliver safe drinking water to the communities, iii) types of pollution found in surface and groundwater which are being used as sources of these schemes, and iv) recommend prevention and remedial measures to ensure the delivery of safe drinking water to the communities. The survey was carried out from 2007 to 2011 and more than 10,000 water supply schemes were surveyed. The findings revealed that out of 7,311 functional water supply schemes only 23% in urban areas and 14% in rural areas were supplying safe drinking water to the communities (Table 1).

Table 1: Survey results of water supply schemes (2007-2011)

Province	Districts Surveyed	Water Supply Schemes reported by Provinces	Surveyed Water Supply Schemes			Functional	Samples Safe for Drinking (%age)	
			Total	Urban	Rural		Urban	Rural
Punjab	33	4,100	3,883	746	3,137	2,725	17	23
Sindh	22	1,300	1,247	123	1,124	529	5	5
Khyber Pakhtunkhwa	16	3,000	2,203	474	1,729	1,710	63	26
Balochistan	14	1,600	1,034	480	554	968	20	13
GB/AJ&K/ FATA	10	2,000	1,794	18	1,776	1,379	8	2
Total	95	12,000	10,161	1,841	8,320	7,311	23	14

Figure 26: Some glimpses of inefficient water supply schemes

The major issues identified were; lack of institutional capacity to manage, operate and maintain the water supply schemes, non-existence of treatment facilities, lack of public awareness about safe drinking water, financially unviable schemes due to transfer to community-based organizations, improper design of water supply schemes, unprotected water sources and water supply lines are operating beyond their service life (Figure 26).

2.3.5 National Capacity Building Institute (NCBI)

For human resource development, capacity building training of the professionals is a key component. Capacity building can increase the efficiency and effectiveness of organizations and individuals. It helps them to identify their strengths and weaknesses and develop strategies to improve their performance. This can lead to improved service delivery, better decision-making, and increased productivity.

Figure 27: National Capacity Building Institute of Pakistan

PCRWR has established National Capacity building institute with the financial support of the Korean Government through a grant-in-aid project (Figure 27). This institute has been established not only to enhance the capacity of water professionals from federal and provincial stakeholder organization but also to develop future water professionals in youth through initiating different capacity building and dissemination programs with the collaboration of partner organizations in water quality and water resource management. In this context first-ever three-year Diploma of Associate Engineering (Advance Water Quality) is being initiated. The competency-based diploma course is accredited by National Vocational and Technical Training Commission (NAVTTC). Recently two courses (Water Quality Testing Technicians & Wastewater Treatment Technician) of 6-month diploma have been initiated under Kamyab Jawan Program of Government of Pakistan. The curriculum of these courses is 20% applied theoretical concepts and 80% practical demonstration of these concepts. Three batches of these diploma courses with 25 trainees in each batch has been completed so far.

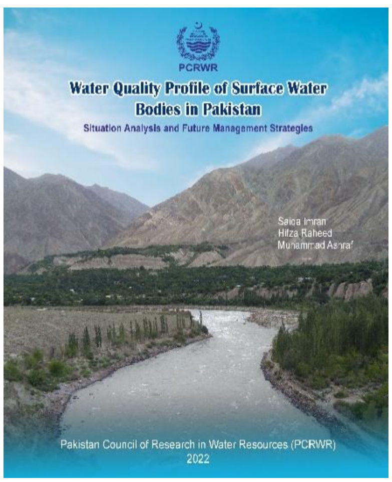
3 Some Recent Publications

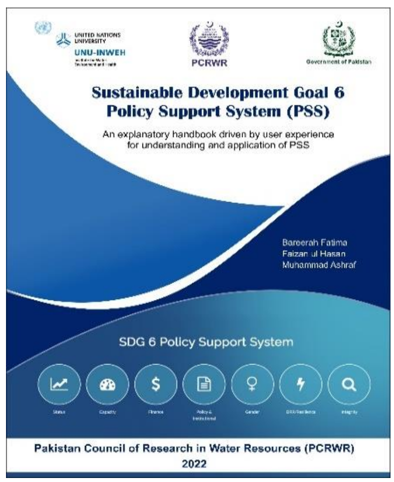
After generating knowledge, the Council disseminates it through various means including seminars, workshops, trainings, videos, Facebook, WhatsApp, website, YouTube channel, brochures, newsletters, annual reports and research publications (articles and reports). It continuously strives to provide the outcomes of its research in the form of knowledge products for dissemination to the stakeholders. Some of the recent publications are presented below. The hard copies of these reports can be obtained from PCRWR Offices and soft copies can be accessed online through PCRWR's website at:

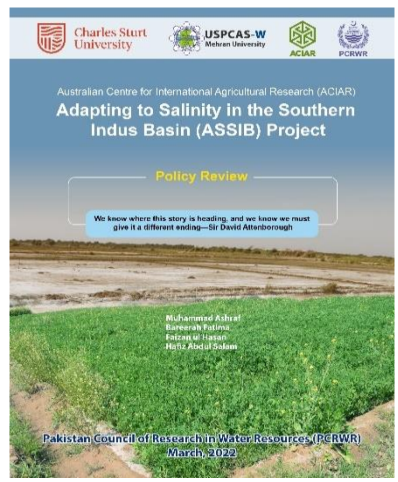
Water Management Reports: https://pcrwr.gov.pk/water-management-reports/

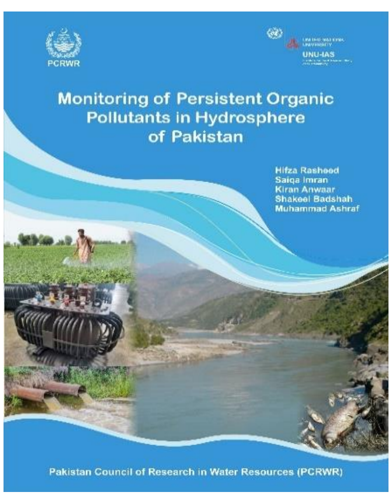
Water Quality Reports: https://pcrwr.gov.pk/water-quality-reports/

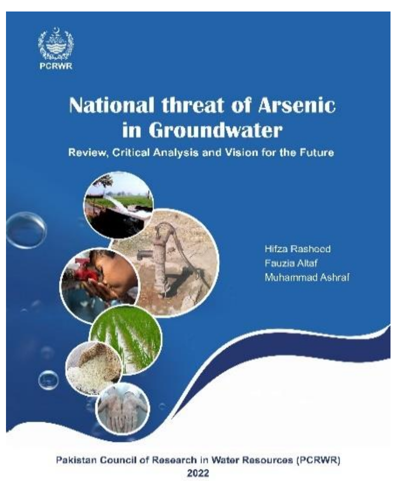
Research Articles: https://pcrwr.gov.pk/articles/

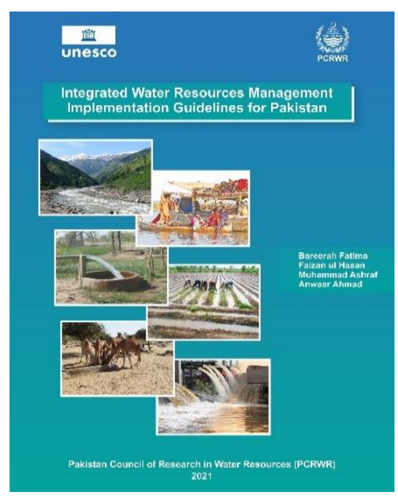


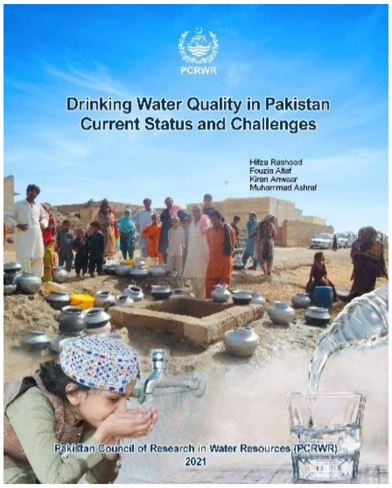


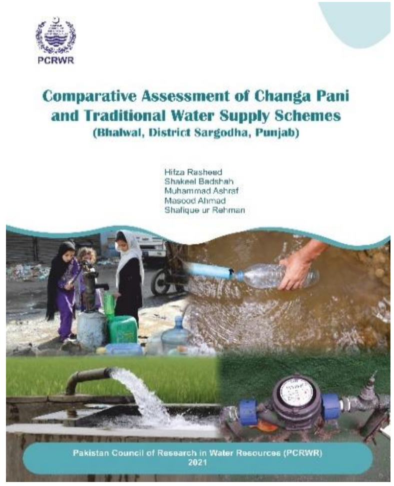









PCRWR
Drinking Water Quality in Pakistan
Current Status and Challenges
Hifza Rasheed
Fouzia Altaf
Kiran Anwaar
Muhammad Ashraf
Pakistan Council of Research in Water Resources (PCRWR)
2021


PCRWR
Comparative Assessment of Changa Pani
and Traditional Water Supply Schemes
(Bhalwal, District Sargodha, Punjab)
Hifza Rasheed
Shakeel Badshah
Muhammad Ashraf
Masood Ahmad
Shafique ur Rehman
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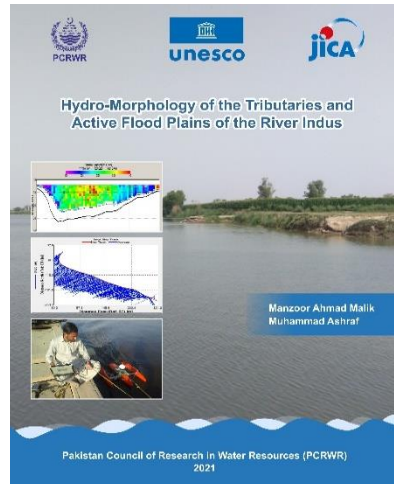
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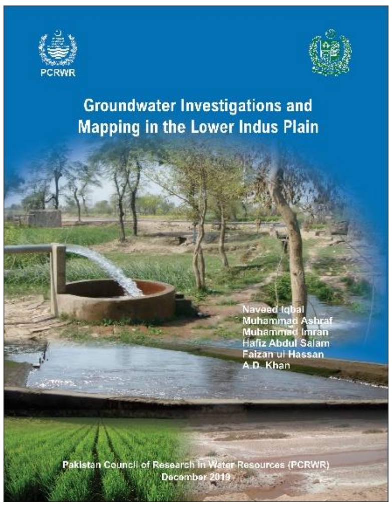
JICA
Hydro-Morphology of the Tributaries and
Active Flood Plains of the River Indus
Manzoor Ahmad Malik
Muhammad Ashraf
Pakistan Council of Research in Water Resources (PCRWR)
2021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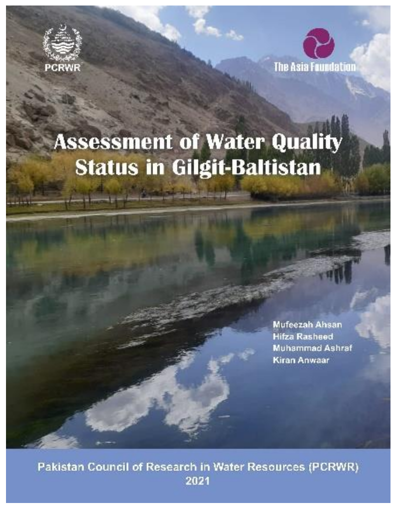
Groundwater Investigations and
Mapping in the Lower Indus Plain
Naveed Iqbal
Muhammad Ashraf
Muhammad Imran
Hafiz Abdul Salam
Faizan ul Hassan
A.D. Khan
Pakistan Council of Research in Water Resources (PCRWR)
December 2019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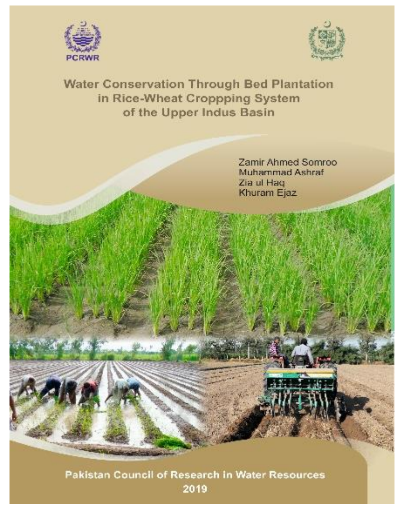
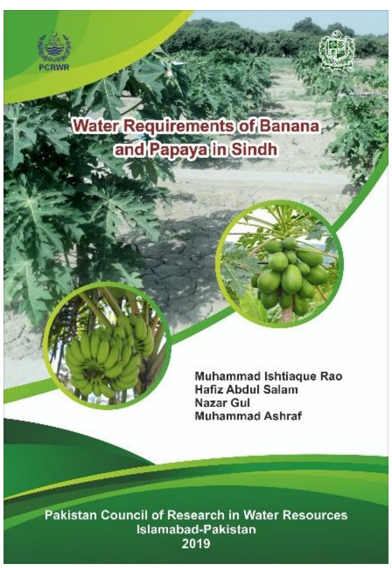
The Asia Foundation
Assessment of Water Quality
Status in Gilgit-Baltistan
Mufeezah Ahsan
Hifza Rasheed
Muhammad Ashraf
Kiran Anwaar
Pakistan Council of Research in Water Resources (PCRWR)
2021


PCRWR
Water Conservation Through Bed Plantation
in Rice-Wheat Croppping System
of the Upper Indus Basin
Zamir Ahmed Somroo
Muhammad Ashraf
Zia ul Haq
Khuram Ejaz
Pakistan Council of Research in Water Resources
2019


PCRWR
Water Requirements of Banana
and Papaya in Sindh
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Hafiz Abdul Salam
Nazar Gul
Muhammad Ashraf
Pakistan Council of Research in Water Resources
Islamabad-Pakistan
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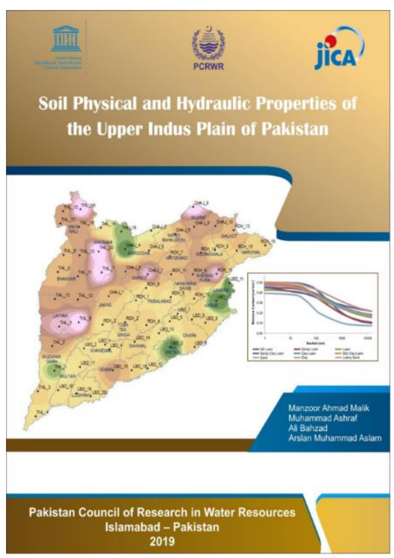
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the Upper Indus Plain of Pakistan
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Muhammad Ashraf
Ali Bahzad
Arslan Muhammad Aslam
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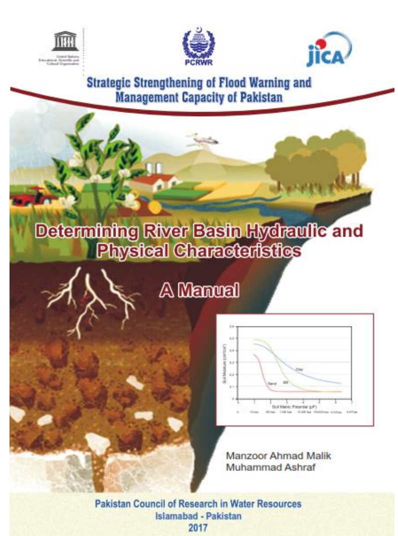
2019


PCRWR
JICA
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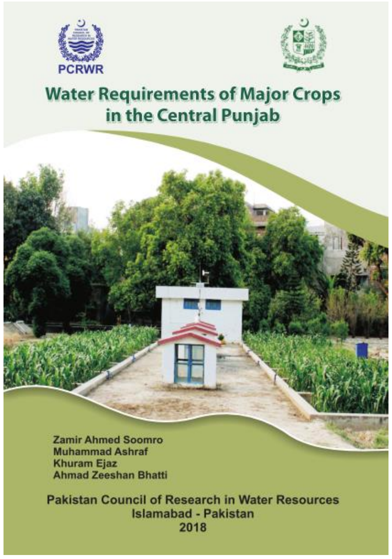
Determining River Basin Hydraulic and
Physical Characteristics
A Manual
Manzoor Ahmad Malik
Muhammad Ashraf
Pakistan Council of Research in Water Resources
Islamabad - Pakistan
2017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Muhammad Ashraf
Khuram Ejaz
Ahmad Zeeshan Bhatti
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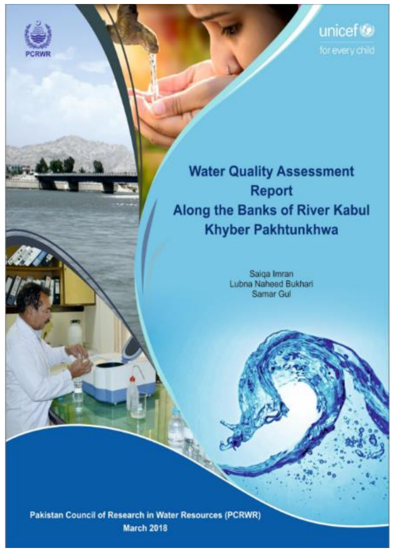
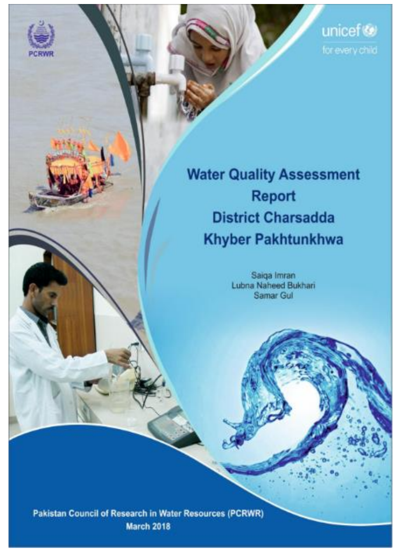
Islamabad - Pakistan
2018


PCRWR
unicef
for every child
Water Quality Assessment
Report
Along the Banks of River Kabul
Khyber Pakhtunkhwa
Saiqa Imran
Lubna Naheed Bukhari
Samar Gul
Pakistan Council of Research in Water Resources (PCRWR)
March 2018


PCRWR
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Khyber Pakhtunkhwa
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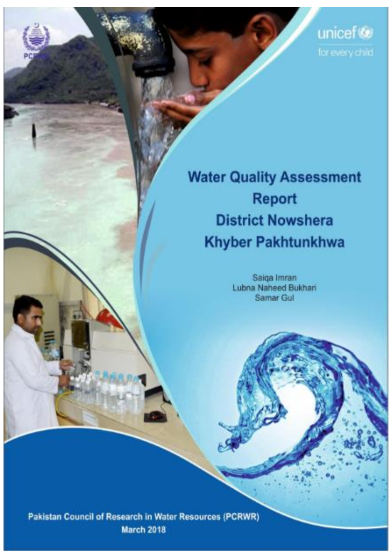
Pakistan Council of Research in Water Resources (PCRWR)
March 2018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Report
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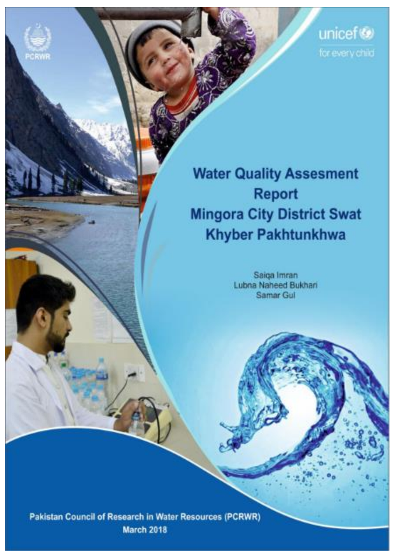
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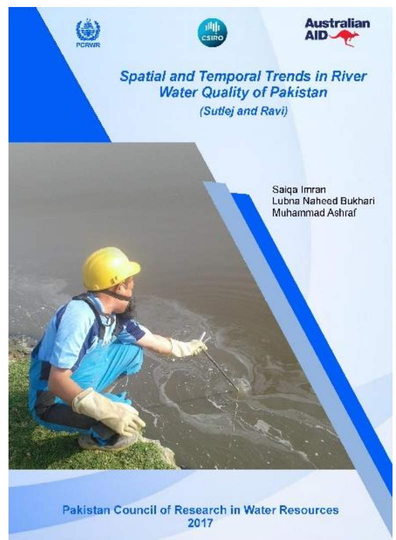
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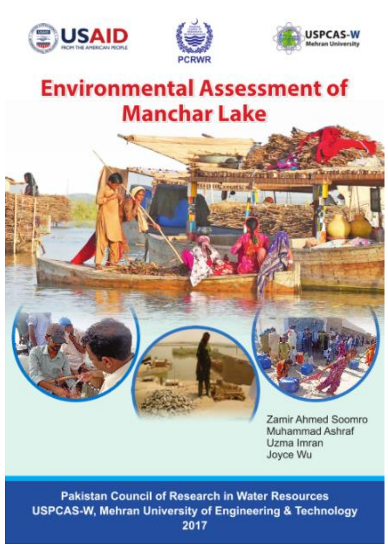
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