Climate Informed Decision Making in Water Sector of Pakistan

Technical Inputs to Decision Support System.

Produced under the project Climate Adaptation and Resilience for South Asia, funded by the World Bank and co-implemented with the Asian Disaster Preparedness Center.

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Enabling Environment of Climate Resilience Policies and Investments in South Asia

Climate Adaptation and Resilience for South Asia

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Final Report
Review of Climate Informed Decision Making in Water Sector of Pakistan

Project	**Climate Adaptation and Resilience for South Asia (CARE) Project**
Sector	Water
Activity	Recommendations and Technical Inputs to Decision Support System for Climate Informed Decision Making in Water Sector of Pakistan
Activity Code	
Deliverable	Report on Recommendations and Technical Input to DSS
Country	Pakistan
Rev. No.	1
Date	2nd June, 2022
Changes	Revision 4
Submitted by	**Sana E Sakina, Water Expert Pak.**
Verified by	
Approved by	

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Abbreviations

DSS	Decision support system
FFC	Federal Flood Commission
HF	High Frequency
IWRM	Integrated Water Resource Management
IRSA	Indus River Systems Authority
ODM	Observation Data Model
PMD	Pakistan Meteorological Department
PID	Provincial Irrigation Departments
RTU	Remote Terminal Unit
SID	Sindh Irrigation Department
SRP	Sindh Resilience Project
SWHP	Surface Water Hydrology Project
WAPDA	Water and Power Development Authority
WEAP	Water Evaluation and Planning
WSFM	Water System modeling framework
LEAP	Long Range Energy Alternatives Planning

1 Introduction

Pakistan is considered to be a water-stressed country (rapidly moving to water-deficit) and many of its regions are categorized as arid. Pakistan lies in an arid and semi-arid climate zone. Most of Sindh receives less than 140 millimetres of rainfall a year. Per capita water availability has declined rapidly since 1951 and is currently only 1050 cubic meters per capita, which puts Pakistan in the category of a high water-stress country (1). This calls for improved water resource utilization through efficient project design and execution, climate change adaptation, mitigation and resilience and developing preparedness for water safety and disaster risk reduction.

Concern has been growing in recent years regarding the potential impact of climate change on stressed water resources of Indus. Sindh was severely affected by the massive floods in 2010/11 and this event alerted attention to the vulnerability of water supply system to climatic extreme events. Any change in water flow in the Indus basin will have significant implications for food security in Pakistan given that 90 per cent of total agricultural production occurs on arable land supported by the Indus Basin Irrigation System. While the potential for climate change to jeopardize the Sindh government's efforts to increase its water, energy and food security has been acknowledged by the Government of Pakistan, remains uncertainty regarding the ways forward.

The concept of IWRM requires data on variety of issues, many of which include rapidly changing parameters and cannot be easily specified in advance like climate change impacts on water demands. A decision support system (DSS) can assist in the acquisition, management and use of such data sets. Currently the system in place with the Sindh government is traditional not encompassing additional capabilities beyond modelling framework. The department needs a more dynamic tool for real time data management and interactive framework for communication, sharing and dissemination of water related information to general public and related stakeholders.

The report is intended to assist the enhancement of existing data collection mechanism of Sindh Irrigation Department (SID) for better climate informed decision making in the water sector of Pakistan. The focus area remains the challenge for the development and implementation of DSS for Sindh. In 2000, the responsibility of managing and developing water resources at the province level was handed over to provincial governments by the Federal Government of Pakistan (2). The apportionment of waters of Indus river system to provinces however remains a federal responsibility. This context establishes the need to study the relevant stakeholders of water at federal level to an extent for thorough understanding of the system. The outcomes and insights attained by studying the water stakeholders from federal to provincial level provide a detailed analysis for Sindh. The outcomes of the study may help to determine the bottle neck to which solution can be proposed specific to the DSS development and implementation for a successful execution in the region.

2 Objective of the Study

The objectives of the study are

- to assess the existing situation and identify gaps/requirements after reviewing the existing data components and functionalities of DSS for water resources management primarily focused on the Sindh province,
- to provide technical inputs in the design of the components of DSS to integrate climate related information in water management in the Sindh Province, and
- to provide the recommendations for operationalization, capacity building and sustainability of the DSS for climate informed decision-making processes of water sector planning and development.

3 Stakeholders Mapping

To foster the culture of prevention through preparedness rather than reactive responses stakeholders mapping was done. The disasters linked to water, both floods and droughts are multi-dimensional owing to risks, uncertainties, constraints and conflicting objectives calling for a participatory approach towards better climate informed decision making addressing the broader socio-political issues. These concerns were qualitatively incorporated through tapping all major entities involved in management and decision making of water resources.
The participation of the stakeholders was a judicious approach. The relevant stakeholders were identified and their awareness was built on the issues under consideration enabling their participation through equitable and fair process. The table below includes list of water sector stakeholders in Pakistan, their roles and responsibilities and level of engagement.

Table 1 Stakeholders and their roles for water sector DSS

SN	Stakeholder	Roles and Responsibilities	Level of Engagement
1	Sind Irrigation Department	• Operation, maintenance, development & management of irrigation network • Flood control along River Indus and hill torrents • Rain Water Harvesting by construction of Small Dams and retention weirs • Operation, maintenance, development & management of surface drainage system and tube wells	High
2	Sindh Resilience Project	• Improve Infrastructure and System of Resilience • Improve institutional capacities, performance, and preparedness at key agencies responsible for managing disaster risk in Sindh • Contribute towards enhancing resilience to hydro-meteorological disasters including floods and drought through physical infrastructure investments	High
3	Indus River Systems Authority	• implementation of Water Apportionment Accord 1991 • implement IRSA act 1992 • Generates daily gauge and discharge data for all four provinces • Responsible for water allocation as per the accord for each province	Low
4	Pakistan Meteorological Department	• Hydro-meteorological services and flood forecasting • Weather forecasting services to public through electronic & print new media • Climatological data processing for scrutinizing, comparing and publishing	Medium

SN	Stakeholder	Roles and Responsibilities	Level of Engagement
		• Glacial Lakes Outburst flood warning	
5	Federal Flood Commission	• Preparation of Flood Protection Plan for the country • Scrutiny of flood control/protection schemes funded by Federal Government and prepared by Provincial Governments and Federal Agencies • Review of damage of flood protection works and review of plans for restoration and reconstruction works • Preparation of Research Programme for flood control and protection • Standardization of designs and specifications for flood protection works; • Recommendations regarding principles of regulation of reservoirs for flood control; • Evaluation and monitoring of progress of implementation of the National Flood Protection Plans	Low

4 Existing Decision Support System

4.1 Water Evaluation and Planning Model

One of the models for GIS based integrated water resources management is Water Evaluation and Planning (WEAP) model that integrate supply and demand at catchment scale. The model is only been studied for research purposes and has not been implemented for practical purposes by the Mehran University of Engineering and Technology Jamshoro Sindh. WEAP is a water centric system that uses Linear Programming (LP) approach. WEAP integrates the physical operation through coupling hydrologic sub-modules i.e., lumped rainfall-runoff model, ground water model and surface water quality model. This type of model is capable of integrating with Long Range Energy Alternatives Planning (LEAP) model.
The model has the following functionalities:

- Data repository for water
- Web portal for data dissemination
- WEAP helps for baseline scenario and growth scenario

WEAP Methodology
It demonstrates a specific water system, with its main supply and demand nodes and the links between them, both numerically and graphically. The allocation rule to each node is specified by the user based upon the preference for each node (3). This model gives the flexibility of changing the

priority for different nodes. The priority base will be decided upon the various climatic weather pattern and consumption requirement of the command area.
It includes:

Central Data Repository for Data Storage and Retrieval: Central data repository is designed as a relational database. Data model is based on the Observation Data Model (ODM). ODM is designed to store the point data, which keeps it in data values entity which are interconnected with other entities that store the ancillary information related to observations. The ODM is extended with entities of Target, Target description, Indicator and Indicator description.

Web Portal: The design of the web portal is based on the "4+1" model view. There are five views of the data portal, which are

- Use case view
- Logical view
- Process view
- Deployment view
- Data view.

Use case view is visible to all the stakeholders; this is general website that is visible to all audience. Logical view is specific to designers, who are responsible for functional requirements of the website. Process view is visible to integrators, integrators handle non-functional requirement of the website. Programmers use deployment view that is for the software requirement that include describing the modules and sub-systems of the application. Architecturally, significant persistent elements in the data model are described in the data view, which is handled by database administrators.

Node-Link system model: The canal off take points, reservoirs demand sites are conceptualized by nodes. The nodes after being linked with lines called node-links which demonstrate the offtake structures like river diversions, canals and pipelines.

WEAP Conceptual Elements

The main conceptual elements are:

Demand sites: The demand site shows water user relying on the distribution. In the current scenario the barrage command area of the Guddu, Sukkur and Kotri will be used a modelling unit. Demand will be calculated at canal command area, and then lumped.

Rivers, diversions, and river nodes: Rivers and diversions are represented by reach element connected between the river nodes. Diversions like link canals and other contributing tributaries can be connected to the river.

Withdrawal: Point when water is directly removed signified at each barrage in the lower Indus considered in the system.

Diversions: In diversion nodes, water is diverted from the river to another river or canal.

Reservoirs: Reservoir nodes represent the reservoir sites on the river. All small dams represent the reservoir nodes. These nodes are applied such that the water can be released directly to the downstream nodes and to the demand sites.

Flow requirements: Flow requirement nodes represent minimum flow requirement for in-stream flow for river or at the diversion nodes to control the outflow from reservoir.

Stream flow gauges: Gauges represent actual measurement stations and are installed on the downstream of barrages and reservoirs to compare model outputs with observed measurements.

Priorities of water allocations: Priorities are user-defined for the model and include demand priorities and supply preferences. Priorities range from 1 to 99; 1 is the highest priority, and 99, the lowest.

4.2 Data Collection Mechanism at Sindh Irrigation Department

The Sindh irrigation department has a formalized way of collecting the discharges at the control points established that include the 3 main barrages of Guddu, Sukkur and Kotri in the region and their off-taking canals. The method of collection of data however is manual. The daily readings are recorded only for the parameters of u/s and d/s discharge data. The daily discharge sheet is circulated from IRSA that follows the Indus channel from upstream in Sakurdu to downstream entry in the province of Sindh. The discharge data for the Barrages and main canals is noted manually by the Baildar designated on the location for this purpose manually. There are no proper gauges install for data collection mechanism at the control sites usually bars are used to determine the depth. This data is then communicated to the SID office which communicates the same to the IRSA to issue daily water data nationally.

There is no proper mechanism for standardization of the data. The data collection cell at SID uses the Arc GIS for data management. The software operates with specialists-analytics, containing of analysis, modelling and imaging spatial geographical data, originated from connection of mathematics, informatics and geography, which are intended for creating, visualization and analysis of data, located on the Earth surface. However the data system is not accessible publically.

5 Lessons Learnt from the Desk Review Process

The desk review was an integral component of the assignment. The available list of documentation as mentioned in the desk review report was collected and synthesized by which the context of water governance was obtained. The following are the key learnings from the desk review.

- All water entities branch from the Ministry of water Resources. Thus the integral position necessitates the designation of a focal person for smooth progress.
- Provincial governments in Pakistan are responsible for water and related matters.
- The daily discharge data is published by the PIDs and PMD generates relevant weather information on web portals.
- The main stakeholders of the water allocation and availability information currently are the government bodies.
- The advisory issued for the flood warning doesn't usually give ample time to make satisfactory mitigation measures for protection against the damages.
- Major portion of population residing in the rural communities is deprived of education system that necessitates the use of local language .to successfully run an awareness campaign on water stress in the region.

- Urbanization and population growth are driving water competition between different users and sectors and contributing to, deteriorating water quality and extensive decline of groundwater table.
- There is no shared portal for real time sharing of weather and water situations inter department and there is need to strengthen platform to make the departmental documentation more accessible for research and development purposes.

6 Key Findings from Stakeholders Consultations

KIIs and FGDs were held with the relevant water stakeholders and the idea of implementation of DSS was discussed in the context of the climatic impacts, on the variability of available water for domestic consumption, irrigation, flood, drought patterns, population growth, and maintenance of existing water reservoirs and planning of new resources.

The matter of implementation of DSS was discussed and the views regarding the utility of the activity were obtained. While on one hand the usefulness of the system was acknowledged on the other hand the probability for the success of the activity was frowned upon. Similar activity resulted in failure in past under Federal Flood Commission (FFC) due to the static nature of the developed system and inability of technical man power to operate. Since the Integrated Water Resource Management (IWRM) is a complex domain it is very important to implement the activity in the Sindh while keeping in mind the need to expand the system at national level by replicating in other provinces in future. At present all departments are functioning individually. Sindh Resilience Project (SRP) under one of its components is working on the similar activity in the region, DSS is still under development and there is no such system in implementation that can provide real time, precise climate information and water data and can study the past trends to forecast for future scenario.

Key findings of user need assessment are given below:

Table 2: Key Findings from Key Informant's Interviews

SN	Stakeholder Consulted	Key Findings
1.	Indus River Systems Authority (IRSA)	Indus River Systems Authority (IRSA) doesn't directly monitor any control stations and primarily relies on data received from Pakistan Meteorological Department (PMD) and Provincial Irrigation Departments (PIDs). The mode of receiving data is through SMS and hard copy data. IRSA receives information from PMD of seasonal snow cover thickness in rabbi season to predict water availability for Kharif. The data for temperature max, min and snow cover is received from PMD seasonally to predict the trend. IRSA receives PID data every 24 hours from provincial irrigation offices which is the mean of 6 hourly data. Currently a decision support system CCIRO is under construction for IRSA with Aus. Aid. The details to which are yet confidential. The advisory on daily water distribution is shared with all provincial and federal stakeholders. The daily water report is also published online that includes upstream and downstream discharges of three major barrages of Sindh namely Guddu, Sukkur and Kotri[1].

[1] http://pakirsa.gov.pk/DailyData.aspx

SN	Stakeholder Consulted	Key Findings
2.	Pakistan Meteorological Department (PMD)	PMD provide service for Weather, climate and seismic data recording, generation and dissemination services, Flood forecast and warning services, Numerical weather prediction, Climate change scenarios for Pakistan (AR4, AR5) on resolution of 25 km and 50 km, Seasonal forecast, Drought monitoring and warning services[2]. PMD possesses a system for rainfall and other meteorological observations across the country. Currently PMD has weather radars at around seven sites. Flood Forecasting Division of Pakistan Meteorological Department located at Jail Road, Lahore collects and reviews all the hydro-meteorological data and issues flood forecasts. Surface Water Hydrology Project (SWHP) of WAPDA records rainfall and river flow in the upper catchment of rivers. This is sent to reservoir operating agencies and PMD via High Frequency (HF) radio network of WAPDA. The Hydrology and Research Directorate of WAPDA operates gauges of rainfall and river stage under its telemetry system. Thus through its telecommunication system, provides data during flood season to PMD for flood forecasts
3.	Sindh irrigation Department	The data recording is carried out with the help of water levels in the canal. To record water levels, staff gauges have been installed at every head regulator, cross regulator, bridges and along the canal at regular intervals management of water in the context of availability and allocation was department's prime concern. There is no method to use the water data available with the department to proactively mitigate the water induced disasters or forecasting and early warning system. However, Sindh being on the lower side of the flood gets better preparatory time. The high flood peaks in lower indus have increased pressures on protective bunds on all the three barrages i.e. Guddu, Sukkur and Kotri in Sindh province. Information management tools improving the current data management can help the department perform more efficiently

[2] https://www.pmd.gov.pk/en/services.php

SN	Stakeholder Consulted	Key Findings
4.	Sindh Resilience Project	SRP is working in the province with the objectives of strengthening Sindh's capacity to manage natural disasters. A subcomponent of SRP is supporting the Sindh Irrigation Department (SID) to implement of non-structural measures to enhance IWRM by implementing DSS. The geographical mapping available is for main rivers and canals, the GIS mapping that is available with the SRP can be further utilized and enhanced to increase the detailing of the available information. The DSS being developed is taking into account the U/S and D/S discharges, the data recorded is manual.

Table 3: Key Findings from Focused Group Discussions

SN	Stakeholder Consulted	Key Findings
1.	Sindh irrigation Department	SID's main functions include; river survey and hydrological data, operation and maintenance of barrages, operation and maintenance of canals, distribution of water, flood protection works, drainage schemes, land reclamation, construction of small dams, irrigation research, administration of canal and drainage works and assessment of water charges. Currently the data collection system is primarily manual and has no integration of climatic information. The water utilization and allocation decisions are taken however a DSS system in place can back the decision making with scientific data and can assist in better climate informed decision making.

SN	Stakeholder Consulted	Key Findings
2.	Sindh Resilience Project	Salient interventions pf DSS activity of SRP include the establishment of a Decision Support System for the Department, evaluation of flood embankments, river morphology studies, and floodplain mapping SRP is working in the province with the objectives of strengthening Sindh's capacity to manage natural disasters. A subcomponent of SRP is supporting the Sindh Irrigation Department (SID) to implement of non-structural measures to enhance IWRM by implementing DSS. The current DSS under development is only focused on the flood related damages and any initiatives related to drought management and climate-based decision making is not included. The responsiveness to the distribution system can be improved.
3	Indus River System Authority	The prime focus of the activities of the department is on the apportionment of water to the provinces there is currently no measure in place for IWRM. The department receives the data from all provincial irrigation departments. The Water induced disaster management including forecasting and early warning system is not the area of focus of IRSA A web based DSS that has integrated information on water allocation and climate data points can assist IRSA in better future apportion and allocation of water. A web-based data base system and analytical tools for data visualization is an area of improvement in the current system.

SN	Stakeholder Consulted	Key Findings
4	Pakistan Metrological Department	The PMD is primarily concerned with weather data collection however the wing of Flood Forecasting Division (FFD), is the specialized unit of PMD and plays a pivotal role in the Flood Forecasting & issuance of Warnings to concerned quarters. The access to the climate and hydrological data is through both manual and digitized system depending on the location of observatory the data parameter. Data is then analysed to produce weather /flood forecasts & warnings and disseminated to various Federal/Provincial organizations and electronic/print media through various means and also uploaded on FFD Website. Data sharing is a sensitive matter and PMD does not give access to any agency to the climate/weather data. A limited targeted access, at departmental level, can be given after due process and necessary approvals.
	Federal Flood Commission	FFC is the federal coordinating body for implementation of Normal/ Emergent Flood Program. The department issues the flood forecasts based on the information received from PMD during moon soon, the parameter include rainfall primarily. The dissemination of data/ flood warnings is primarily for the specialized departments. A DSS was previously developed for FFC under WCAP project that is not currently in use due to its static nature.

7 Technical Inputs to DSS

7.1 Need Assessment

In order to formulate a reliable tool for IWRM it is important to first define the type of decisions that need to be taken as a result of implementation of DSS. The credibility of the DSS can be ensured by DSS formulation and testing. The pre - assessment of the intervention must go through the following steps:

- **Problem Identification:** It is important to identify the issues, environmental problems that the system needs to address.
- **Problem Review**: Identify the key data input required and available, process and expected out puts
- **DSS Development:** Develop the DSS fulfilling the requirements, populate with data, calibrate and validate analytical models using acceptable performance indicator criteria
- **DSS Outputs:** Generate the output in the form of tables, graphs, maps, report etc.

Table 3 below presents the needs that are identified after the consultation with the prime stakeholder (SID). Each key issue can be characterized by a performance objective that will lead to management decisions.

Table 3: Key Issues and Performance Objectives

SN	Key Issues	Performance Objective
1	Water Allocation to respective channels based on the command area utility, Identification of water stressed areas towards which load can be shifted in flood situation	Water Use efficiency
2	Responsiveness of the distribution system	Quality of distribution/Framer Satisfaction
3	Environmental Impact of irrigation decisions	Quality of Soil
4	Flood and drought management	Saving lives, properties and infrastructure

7.2 Specific Parameters and Data Inputs

The pillar on which a decision support system functions is the data input. Specific data points available at the national level on which the system would be operating and serving the issues of the concerned department are presented in Table 4 below. SID has a robust system for measurement of u/s and d/s discharges at mega hydraulic structures and canal feeders in the Sindh region.

Table 4: Currently Available National Data for DSS

SN	Parameter	Mode of observation	Time step of data collection	Time lag of data being available	Spatial scale	Data Source
1	U/S Discharge	Manual	Daily	24 Hours	Stations	SID
2	D/S Discharge	Manual	Daily	24 Hours	Stations	SID
3	Q max	Manual	Yearly	-	Stations	SID
4	Q min	Manual	Yearly	-	Stations	SID
5	Inflow	Manual	Daily	4 Hours	Barrage control points	SID
6	outflow	Manual	Daily	4 Hours	Barrage control points	SID
7	Air Temperature (Max, Min, Grass Min)	Manual	Daily	30-45 Min	station	PMD

8	Humidity	Manual	3 Hrs	30-45 Min	station	PMD
9	Rain/Fall Precipitation	Manual	Hourly	30-45 Min	station	PMD
10	Sunshine	Manual	Daily	Monthly	station	PMD
11	Evapotranspiration	Manual	Daily twice	Monthly	station	PMD
12	Snow Cover Thickness	Manual	Daily Seasonal	Daily	station	PMD
13	Water Scheduling & Allocation	Manual	Daily	-	-	IRSA
14	Number of tributary canals left /right	-	-	-	-	SID
15	Infrastructure's Dimensions for Barrage and canals	-	-	-	-	SID
16	Sedimentation Rate	-	-	-	-	SID
17	Barrage Gate opening /operation of irrigation structures	-	-	-	-	SID
18	River Bed Level	-	-	-	-	SID
19	River Runoff	-	-	-	-	SID

7.3 Key Components of Decision Support System

The DSS should be designed to meet the needs of different types of users, integrate diverse priorities, visualize and compare a variety of scenarios and support collaborative as well as independent actions. The users of DSS may be the public, the decision-makers and the technical staffs. The main user of DSS will be the Sindh Irrigation Department (SID). Among other relevant stakeholders, PMD may provide an efficient early warning system to generate advisory for lower Indus and share data. The potential users through an open data bank can incorporate the data for research purposes; incorporate the climate indicators in the planning process for a dynamic risk assessment tool for floods and droughts. Clarity on the common goals for water management as well as the objectives, roles and responsibilities of the overall engagement processes is crucial to create collaboration with all stakeholders. The DSS can contribute to the formulation of river basin plans at the watershed level, awareness-raising, risk mapping, auditing, service delivery, as well as performance monitoring.

The DSS functionality for the public (general, specific community, interested stakeholders) needs to include:

- Interactive map viewer that allows non-technical users to easily explore and overlay multiple datasets, query, zoom, pan and print maps online,

- Library of scenarios that allow users to quickly and easily compare potential scenarios that show the impact of various policy decisions or investments, and
- Visuals that tell a story and make the case.

While decision-makers (agency leaders, elected officials) need all the same easy and accessible functionality required by a public audience, they also need:

- High resolution data and downscaled analyses that can support investment decisions,
- Project profiling features that allow uploading or tracing proposed project boundaries and receiving a site specific "profile report", and
- Executive storytelling, which supports the creation of information-rich presentation tools and visuals to enable executives to "make the case."

For technical staffs (scientific, academic and agency), the DSS should be integrative that allows for easy compatibility with other in-house tools and datasets, including the ability to download the results of analyses and overlay them with data and planning results from other departments. It should also allow uploading high resolution data and incorporating into online maps and analyses, and downloading regional and national data for use with in-house GIS systems.

The DSS for water resources management may consist of three main components as follows.

I. **Data management module**
II. **Water System modeling framework (WSMF)**
III. **User interface**.

The DSS itself isn't a model. It is a data and model integration system. The steps that are generally taken while using the DSS are data collection, data transformation, running models, analysis and action. Figure 1 below presents the flow diagram of different steps in DSS.

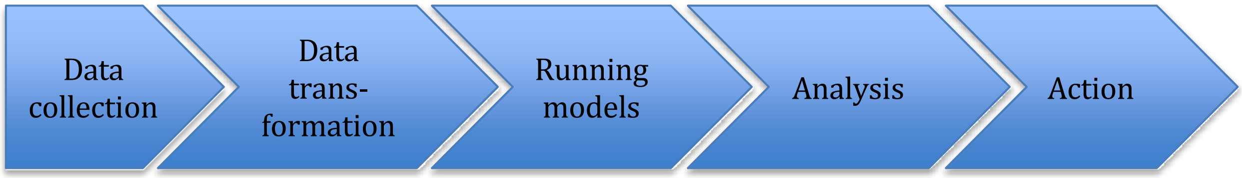

Figure 1 Flow diagram of different steps in DSS

I. Data management module

The data management module collects the weather, climate and hydrological data from ground based observation stations, radars, satellites and external forecasts. It also transforms data by merging, aggregating and interpolating to different temporal and spatial scales required for the analytical models. It should be programed for data review, quality checking, analysis and processing. The data repository must be centralized and open access to decision-makers, academics and researchers for related analysis of changing hydrologic conditions with changing climatic impacts.

II. Water system modeling framework

The Water System Modeling Framework (WSMF) consists of options for running the models and analyzing the results. It is the tool that is used for the water resources management in the river basins. The mathematical model chosen must be in compliance with the data sets and robust capable to analyze the complex data, and transforming it into useful information. The model will draw the outcomes in given set of conditions (inputs). The hydrologic/hydrodynamic analytical tools must be formulated keeping in mind the user requirements. The model adopted must be capable of multiple criteria examination for examining substitute plans, cost-benefit analysis and benefit sharing.

The WSMF must be an open modelling interface capable to access and apply mathematical models for required water management purposes e.g. general water resources management, flood management, drought management, climate change analysis, etc. WSMF must be enabled to store relevant model results and adaptable to new tools developed in future that can be plugged into the DSS. The implementation of adapters helps keep the system flexible.

The WSMF can include statistical models with a range of statistical functions, sensitivity analysis tools to gauge the impact of one parameter on other, forecasting models to make statements about the future or to predict floodplain flooding, levee overtopping, threshold crossing etc. in advance that will particularly aid in flood management and rerouting excess water to dry channels, optimization analysis to optimum utilization of resources etc.

III. User Interface

The user interface is the most important component for taking action. It is the user interface and the ease with which it can be adapted that determines the success of the entire system. The interface is used to showcase the outputs for the given inputs by the users. It is used to inform decision makers, send warnings and create flood/drought bulletins.

The user interface must be developed in layers and the access of information must be given differently to the people at different management level, decision making level and general public. The interface must be capable of displaying the result/reports, and compare the same data with the historical data saved in the form of text, tables and graphs depending on the requirement of the User. It should also be able to generate an evaluation report weekly or at a set frequency as desired by the department that demonstrates the volumes issued, difficulties in implementation, trends in variation of parameters, proposals for maintenance and achievements in implementation.

8 Operation and Sustainability of the System

Successful implementation of the DSS can only be done by devising a comprehensive operational model through which challenges can be dealt. The main operational challenges are errors in the observed data and lack of availability of historical data; this requires data cleaning mechanism to be put in place along with reduction of gauging errors. The precise observed data can ensure reliable forecasted data. Based on the estimated reservoir release and comparing it to the optimal and tolerance levels of the system, the DSS can evaluate access and rank the management options. The main operational areas that need to be looked into while putting a DSS in place are water related disaster management, water management at river basin/watershed level, transboundary water rights, resource allocation to channels and water storage works.

Thus, for the sustainable implementation of DSS, a robust system is required that can keep archives of real time data tested using the uncertainty analysis and future conditions (climate change), optimizing the measures based on multi-objective functions, using all the necessary constraints, considering the spatial distribution on the predefined integrated criteria—multi criteria analysis.

., it is important to develop the human capacity with the collaboration of SID through training programs. To invest in a sustainable system it is important to set up a system that is flexible and can adopt on new input parameters as the future trends for forecasting may change.

9 Conclusions and Recommendations

9.1 Conclusions

The development of DSS for water sector of Sindh needs a close collaboration and updated technical sharing of activity progress of DSS being developed under SRP. The Mehran University has conducted a similar research for DSS development for Punjab and Sindh at a pilot scale. Currently, a study is also in progress for management of ground water resources. This should be put to use. The Sindh Irrigation Department (SID) only takes into account the stream discharge data at various points across the lower Indus. There is no mechanism that can relate the discharges to the climatic data that can be further extrapolated to forecast the trends in future. In order to develop a mechanism that can take into account the climatic factors and link them to the water availability for better climate informed decision making, the climatic information from the PMD and the river discharge data from the SID can both be linked together and the mode of data collection can be upgraded from manual to automatic for more reliable and precise data collection

Development of the DSS needs the establishment of a working group of the relevant stakeholders that need to be trained to equip them with the proper working knowledge. The DSS activity successfully implemented will help further to achieve success in vision water 2025, by which Pakistan should have adequate water available, through proper conservation and development. Water supplies should have equitably distributed and meet the needs of all users through an efficient management.

The management of water in the context of availability and allocation is the prime issue. Having an efficient water management will assist SID in identifying the peak flow in the channels hence their responses to flood and drought situations will improve that will in return improve the overall water management. This will also assist the SID to study the trend of water availability in the context of climatic changes and help them to take better strategic decisions for water reservoirs or small dam planning in future and help to Identify water conservation mechanisms to reduce water use because the water demand of Punjab and Sindh Provinces is increasing at a rate, which is more than the current entitlements and availability.

9.2 Recommendations

The following recommendations should be taken into consideration:

1. The Sindh Irrigation department requires a system that can focus on the allocation and availability of water to manage the available resources in an optimal manner and plan the future reservoirs accordingly.
2. As a next step to it the DSS in place can be extended for measures like, flood forecasting and early warning, reservoir operations, flood risk zoning, disaster management and other measures to mitigate flood damages.
3. A similar activity of DSS is under process by the SRP working on the water allocation management system and combining it with the DSS on flood by SRP will not formulate an extensive system but also will avoid duplication of work.
4. Sindh province is facing drought conditions, in order to minimize impacts of prolonged droughts, floods can be efficiently used by diverting excess flows to the areas of drought. A water management and allocation system can efficiently serve the purpose and help design possibilities of new flow paths/ capacity enhancement and extension of existing canals reaching drought affected areas.

5. Mechanism to bypass large flood discharge that can be diverted to lands in Sindh which can be developed as irrigated areas

6. Elevated efforts should be given to fill up the Institutional Gaps related to data. Data gaps impede understanding of past, ongoing and projected future changes. This can be addressed by strengthening existing lower network of Indus stream gauges.
7. Increase coordination and data sharing among provincial and federal departments through DSS web portal instead of manual notification.
8. Enhanced efforts for digitization and improved real-time data availability.
9. Improve forecasting mechanism to give reasonable reaction time for flashy streams
10. Capacity building & institutional strengthening of executing agencies.
11. Establish a centralized, open access data portal
12. To cater for larger uncertainties in precipitation projection and hydrological models through collaborate with SID and identify the points along the node points that lack the monitoring stations for data generation in main, branch and distribution channels and fill the critical hydro meteorological data gaps to improve the volume and quality of data available.
13. Climate changes can impact the monsoon rainfall patterns that can consequently lead to greater frequency and heavy floods thus it's important to integrate the precipitation data and forecast the patterns
14. Development of protocols for data quality, access and usage, such as quality control and quality assurance protocols. Data access and use protocols would also be established to ensure respect for intellectual property rights and existing copyrights.
15. Digitization and automatic gauge installation to ensure real time data availability.
16. Register departments to the data portal for data sharing. This can be used as an exemplary case to encourage departments nationally to share and manage data in an efficient manner.
17. Assist in standardization of the data in the database.
18. Extend the implemented model to include the upper Indus basin that needs to be implemented to answer the question of climate change.

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