Title: The Decision Support System for Integrated Water Resources Management in the Citarum River Basin

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Abstract - The water resources of the rivers systems in the Citarum River Basin (CRB) are critical to social and economic development of the country. They are essential for urban and industrial development particularly in Jakarta and Bandung areas, the capital city of Indonesia and West Java Province respectively, the cities among highest population density of the country. The system serves water for multiple uses, agricultural production through major irrigation systems, DMI water supplies, hydropower generation, and fisheries. While the water resources of the CRB are relatively abundant, competition for these resources has increased significantly over the past 20 years leading to a situation of acute water stress and water conflict in some places.

The CRB has unique system, which optimizes the unregulated local rivers in adjacent area combined with regulated resources through Citarum Cascade Reservoirs that formed into one hydrological boundary. In the system, there exist various institutions with their tasks and functions to fill up fragments of integrated water resources management (IWRM). In order to put into practice the IWRM in the basin, a decision support system has been applied to support the decision makers to make effective and responsive decisions towards water governance, particularly in water allocation and reservoirs operation, water quality management, flood early warning system, and water resources infrastructure management including dam monitoring.

Decision support system for Integrated Citarum Water Resources Management is a supporting system that managing assumptions, alternatives and opinions in making a decision which there are complex situations. The DSS comprises of not only collecting, validating, archiving, managing, and disseminating water resources data, but also models and other analytical tools, to come up with what if scenarios.

Since there are many institutions involved, development of framework for sharing of information, operation and management of the DSS is the crucial point of development, including integration, rationalization and harmonization data and information from various agencies. Capacity building of agencies, stakeholders, DSS operators and users is the main theme for its sustainability of operation and maintenance of the DSS. By application of the DSS, it can integrate information from different institutions and the mechanism in making decision particularly for water utilization can be conducted more effectively and responsively.

Keywords - Integrated water resources management, decision support system, capacity development

Introduction – The water resources of the rivers systems in the Citarum River Basin (CRB) are critical to social and economic development of the country. They are essential for urban and industrial development particularly in Jakarta and Bandung areas, the capital city of Indonesia and West Java Province respectively, the cities among highest population density of the country. The system serves water for multiple uses, agricultural production through major irrigation systems, DMI water supplies, hydropower generation, and fisheries. While the water resources of the CRB are relatively abundant, competition for these resources has increased significantly over the past 20 years leading to a situation of acute water stress and water conflict in some places. Rapid urbanization has significantly increased the exposure to flood risk. Environmental degradation has reached a level that compromises public health and livelihoods, particularly for the urban and rural poor, and incurs additional economic and financial cost related to the source of bulk water supply and its treatment.

The adoption of integrated Water Resources Management (IWRM) principles and sustainability of the water Resource was emphasized in the 2004 Water Law. The Water Law introduce the concept of management within the boundaries of a river basin and reflect the principles of decentralization and development of authority to local levels as promoted by the program of regional autonomy. In Citarum River Basin while management of water resource on a daily basis is supposed to be designed to local entities, the burden of policy formulation and management guidance will rest with a central agency. A Roadmap (Strategic investment plan) has been prepared for basin-wide IWRM based on a vision of basin stakeholder for Government and community working together for clean, healthy, and productive catchment and rivers bringing sustainable benefits to all people of the Citarum River Basin.

Information sharing is a basic principle IWRM planning and data, information, and decision support are key components to the roadmap for IWRM in the CRB. This includes collecting, validating, archiving, managing and disseminating relevant data covering surface and groundwater quantity and quality, as well as other natural resource data such as soils, geology, land cover and ecosystems, including such socioeconomic data as population, poverty and land use. This is information can be used to research catchment processes and demography; developing new technologies for water conservation and environmental protection, and developing and implementing decision-support tools. Including geographic information systems, hydrologic and hydraulic models and other analytical tools.

Key Issues and Challenges – The main issues of Decision Support System for IWRM in Citarum river basin are : (1) The water resources information on the hydrological, hydro meteorological, and hydro-geological information, water resources and water resources infrastructure, water resources policies, water resources technology, the social economic and cultural activities of the community related to the waters sources of concern. The water resources data and information management is spread among public institutions and managed by various institutions base on their legal mandates. (2) Design of gateway information technology infrastructure, which has interoperability capacity, for collaborating and sharing information from different protocols provided by various water resources data management centers. (3) sustainability of budget resources and staffing system, (4) Level of human resources skill-set, especially managerial and technical skill.
The challenges are :
- since there are many institutions involved, development of framework for sharing of information, operation and management of the DSS is the crucial point of development,

including integration, rationalization and harmonization data and information from various agencies.
- Capacity building of agencies, stakeholders, DSS operators and users is the main theme for its sustainability of operation and maintenance of the DSS. By application of the DSS, it can integrate information from different institutions and the mechanism in making decision particularly for water utilization can be conducted more effectively and responsively.
- DSS of PJT II is proved to be useful and needed in managing water resources.
- Require to conduct further system development (water resources infrastructure, model and scenario, integrated reservoir operation, etc).
- Addition of automatic precipitation station to integrate with hydrometric stations.
- Development of model and scenarios
- Data catalogue, custodian, sharing information and accessibility which related to water resource among institutions

Opportunities - Citarum River Basin System

Citarum integrated river basin located in the north plain of West Java Province, Java Island of Indonesian archipelagoes, covering area of about 12,000 km2. Its consist of (12) rivers traversing the area from south to north terminating to Java Sea (figure 1).

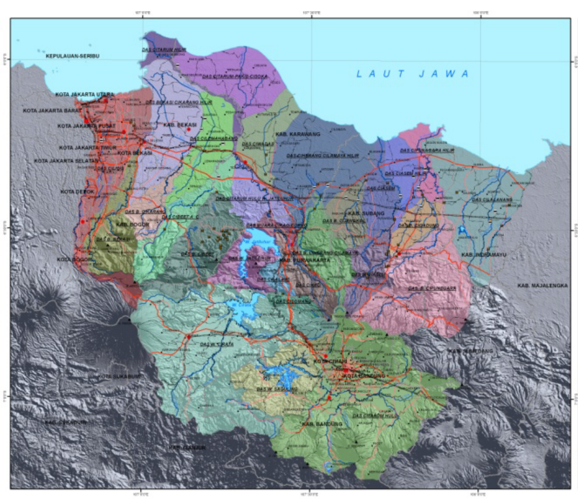


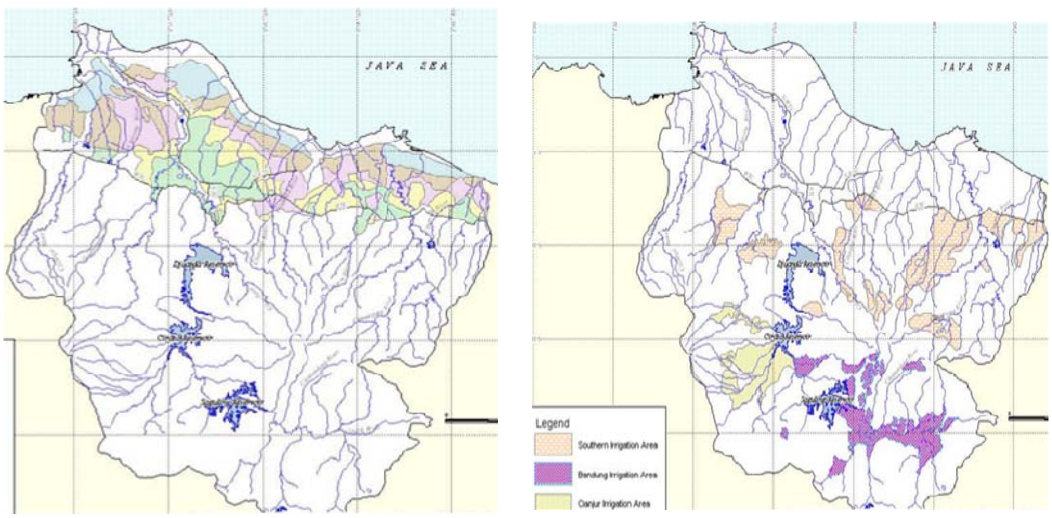
Figure 1.Citarum and Inter-connected Basins

Water potential in the Citarum river basin approximately 12.95 billion m^3 annually. However, by using the existing hydraulic infrastructures it's only 7.65 billion m^3 could be regulated to supply agricultural mainly for irrigation, besides for domestic, municipality and industries and the rest is still wasted to the sea. From 7.65 billion m^3 regulated water, about 5.50 Billion m^3 is used to supply agricultural mainly for irrigation (87%), besides for domestic water supply (6%), municipality (0,3%), domestic and industries (2%) (figure 1).

Parallel to the national economic development the water requirement especially for DMI is increasing accordingly. It is predicted that the regulated water in the basin is only able to cope with the demands up to the year of 2015. There for measures have to be taken to fulfill the demands of water beyond 2015 by constructing prospective dams in the basin. Besides, improving efficiency on water utilization especially water for irrigation which is almost 90% of the total utilization of water in the basin.

Citarum river is biggest one connected with four rivers to the West namely Cibeet, Cikarang, Bekasi and Ciliwung and four rivers to the East namely Ciherang, Cilamaya,Ciasem and Cipunegara by man made canals namely West Tarum Canal and East Tarum Canal respectively formed a unit by hydrological boundary of Citarum integrated basin of 12.000 km2. Three big reservoirs, in the upstream, Saguling, Cirata and Djuanda Reservoir regulates river run off and releases stable water flows to the curug barrage and diverted to the west Tarum Canal and east tarum canal by gravitation to the north. As mention before, the main aim of the Jatiluhur Multipurpose Project is to enhance the national staple food of rice through river water utilization in optimal way for certain irrigation area, especially during dry season. Before the project there were run off irrigation systems, in small, medium and large scale, supplied from local rivers traversing the area. During dry season normally the cropping intensity very low, due to low flow in the rivers and only a part of the systems could be irrigated.

After the construction of Djuanda Dam and reservoir the systems were integrated and become Jatiluhur Irrigation System. The water released from Djuanda Reservoir through turbines to generate electric power, besides through other means named hollow-jet valves and then flows to Citarum down-stream. About 8 (eight) km from the tail race, the water were diverted to the West and to the East and discharged into West Tarum Main Canal and East Tarum Main Canal respectively. Citarum through operation of Djuanda Reservoir became the water main source especially during dry season. In principle during wet season, 70% water requirement could be supplied by local resources and 30% from Djuanda Reservoir, while during the dry season, it only 30% of the requirement could be provided by local resources and the rest of 70% are supplied from the reservoir. Citarum Water System of 240,000 Ha were divided into 3 (three) service area namely West Irrigation System (57.000 ha), North Irrigation System (81.000 ha) and East Irrigation System (102.000 ha).



(a) (b)

Figure 2
Irrigation system in Citarum River Basin. (a) Jatiluhur North irrigation area. (b) Jatiluhur south irrigation area.

Downstream of Jatiluhur reservoir two weirs across the Citarum divert water into the three main canals: the West Tarum Canal (WTC), the East Tarum Canal (ETC), and the North Tarum Canal (NTC). The WTC and ETC tap the Citarum at Curug weir, while the NTC gets its water at Walahar weir (Figure 2). The WTC serves an area under irrigation of 45,000 ha at present. The canal also transports water for the drinking water treatment plants of Jakarta, the capital city of Indonesia. The ETC area comprises 90,250 ha and the NTC area is 78,850 ha in size. Thus the total irrigation area served under the Jatiluhur reservoir is 240,000 ha. It is the largest contiguous irrigation system in Indonesia and is a major rice production area. Irrigation water demand is the largest amount of water among the others (DMI), it is about 90% of total water utilization. Based on the Note of Jatiluhur Reservoir Water Management (Angoedi, 1960), in principle the total water demand in the downstream of the reservoir during Wet Season will be supplied 70% from local resources and 30% from the reservoir, while during Dry Season 30% from local resources and 70% from the reservoir. However, due to environmental change especially in the catchment area, the base flow in the rivers decreased tremendously low caused the availability of local water resources during Dry Season less than 30%. It is mean that more water should be released from the reservoir. Conversely, during Wet Season the peak flow of local water resources is increasing beyond conveyance capacity of the rivers caused flood in some area.

Jatiluhur irrigation system is divided into three sub system that are West Tarum Sub System (58,196 ha), North Tarum Sub System (87,426 ha), and East Tarum Sub System (96,234 ha). Supplying system of water from the reservoir for irrigation is performed by man-made canals, namely West Tarum Main Canal (WTC), North Tarum Main Canal (NTC) and East Tarum Main Canal (ETC) respectively with overall length about 250 km. From the main canal water is diverted to secondary systems then to tertiary systems and quarterly systems. Distance from the reservoir to the most far of paddy field is about 150 km and give delayed of water to reach the paddy field about one week. Since the irrigation area is very large, the crop pattern is divided into four groups with the interval of 15 days of each group successively. The first group of Wet Season planting starts in the first of October and the first group of Dry Season planting starts in the first of April. Water requirement for paddy per crop is 10,000 m^3 per ha, it is mean that for two crops per year is about 20,000 m^3 per ha. Considering of loses along the supply system, among others due to: evaporation, seepage of dikes, leakage of gates and structures, human interference, and operation loses, then the other 30% of water requirement should be added to the calculation of water supply. According to the experiences the largest loses of irrigation water is due to improper operations and those will increase considerably high amount of water.

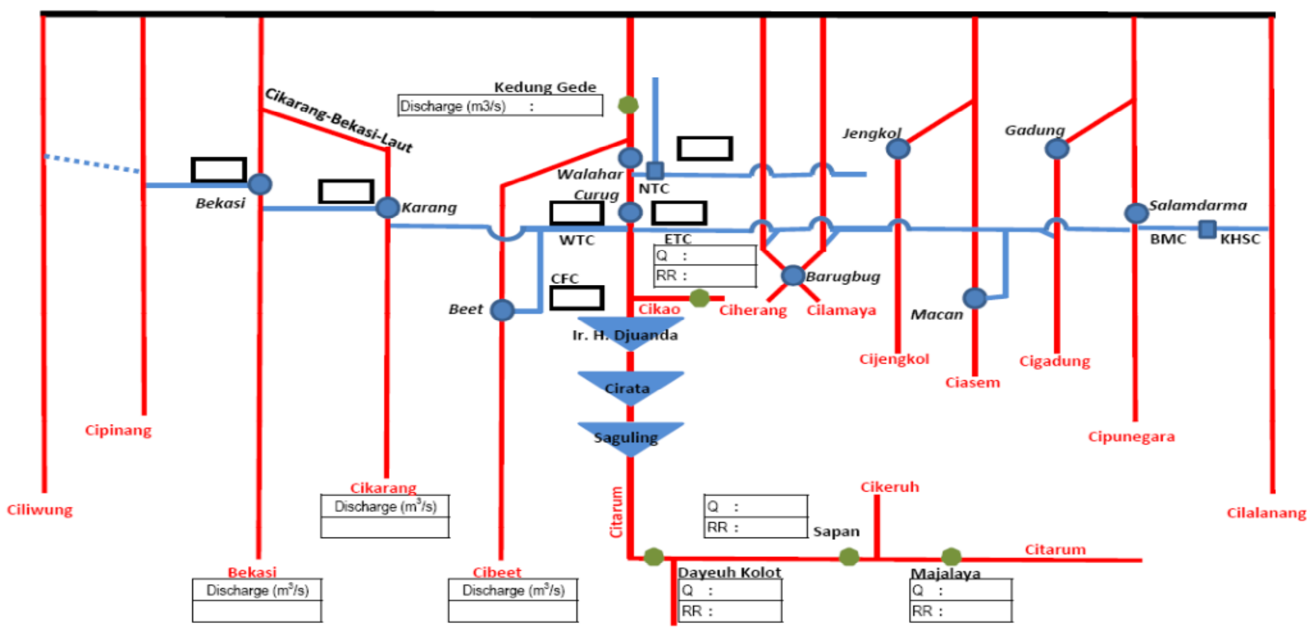


Figure 3. Scheme of configuration on water distribution.

Decision Support for Integrated Water Resources Management (IWRM)

1. Concept the DSS in Citarum

DSS is a system assisting executive on managing assumptions, alternatives and opinions to a or some decision makers in making a decision which there are complex situations.

The DSS is expected to serve as a standardized framework on which all current monitoring, modeling and conservation practices can be integrated and analyzed by the river basin manager. Its intended that the DSS be suitably comprehensive and will provide support to all river managers without need for future operation and expansion of the DSS to other Ci's river under local supervision.

The DSS to be developed will be a structured collection of databases including hydrological and spatial databases and analytical tools such as rainfall-runoff model, water allocation model and water quality models. The component of DSS be integrated and communicate directly with one another as follows :

a. GIS-Database will serve as a central database for data sharing throughout the whole basin.
b. Hydrological Database will store rainfall, water level, flow, ground water level and water quality.
c. Rainfall Runoff model will be used to predict stream flows for short, mid and long term periods
d. Water allocation Model will be used to analyses water resources allocation in the basin and adjacent basins
e. Water quality Models will be used to predict water quality for the rivers, canals, and reservoirs.

Other features of the DSS to be developed are the user interface, a database and model integration system and a communication module that will allow access to the data from the internet and sharing of information between agencies and stakeholders. An overview of the structure of the DSS is shown in figure 4. The DSS provides support for data collection, processing, analysis, decision making and implementation.

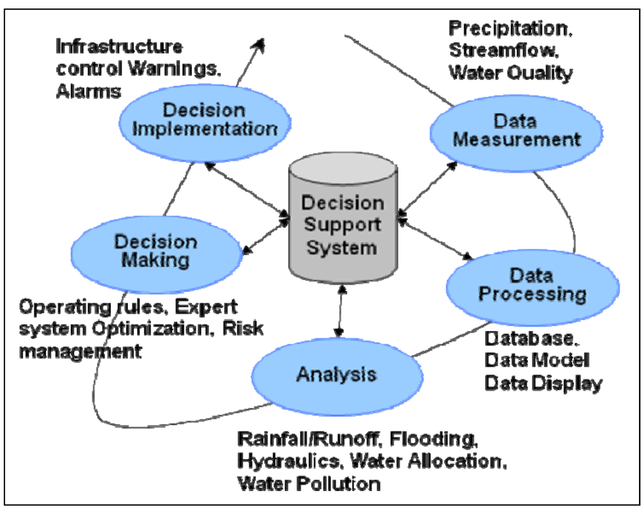


Figure 4. Overview of Decision Support System

Main function of the DSS are :

a. Planning and evaluation
   Monitoring, planning, and evaluation for integrated water resources management in citarum river basin to support the basin managers.
b. Operation
   Water resources management :
   - Establish short-term water supply plan
   - Balance seasonal water demands between users through reservoir and stream flow management
   - Integrated river-reservoirs system operational planning
c. Management
   - Hydrological and GIS Data Management (Data collection, archiving, management and validation, data sharing and dissemination among agencies and stakeholders)
   - Water Resources Management (Quantity spatial and temporal runoff amounts, improve the efficiency of basin reservoir system management, drought contingency planning and water right analysis)
   - Water quality management (simulation of steady state water quality in stream, reservoir water quality management, propose water quality improvement alternatives

2. DSS Structure

Several factors have been considered in order to develop a functional, effective and optimally flexible DSS structure without compromising on usability. A comprehensive situation and data analysis was required before DSS structure component should be agreed upon. The situation analysis activities will include meeting, consultation, data collection, surveys and data analysis. The GIS hydrological map for the CRB is available as a model in sufficient detail and resolution and can easily be exported to other formats and software.

2.1 Key DSS and Database Design Parameters

One of the most important objectives of DSS development is to ensure the delivery of a sustainable system including human resources. This would require striking the perfect balance between ease of use and range of functionally. The DSS will be developed as a flexible system capable of incorporating advanced modules with ease and little expert input, while at the same time providing an easy to navigate interface for the daily users who may not be an expert. This may require building modules within the DSS that will incorporate current spreadsheet and/or GIS based programs such as GR4J and H2U which are already in use. The user would be moved to advanced models such as RIBASIM. HYMOS implementation of geo-spatial mapping would be replaced by a GIS database that presents an easier to use interface.

One of the key elements to consider in the initial design and development phase of DSS is the trade-off between data transformation and capacity building. For the selection of model for the forecasting module in DSS, the following factors are needed to be considered : (1) training users and validated input data for a model, (2) Practical implementation with the local human resource and expertise environment.

Despite the above reasons, the models currently in use may not be the most appropriate models for future expansion of DSS with the finer resolution and robust forecasting. An optimum balance has to be struck between the need to find the optimum models for robust forecasting in a wide range of scenarios versus the requirements of porting and transforming data and capacity building on newer models. The final selections of model will reflect the careful consideration of both sides of the argument.

2.2 DSS Components

The DSS will consist of module for water allocation, water quality, and rainfall-runoff modeling besides the GIS database. The potential software options to be utilized for modeling were identified on the basis of situation analysis in Indonesia. Final selection for the key DSS components based on a quantitative analysis of the available options on the criteria of design parameters.

The DSS will consist of GIS based integrated database interacting with data management system and the users through a convenient Graphic User Interface (GUI). A hydrological and water quality database will be tagged on the spatial database to construct the GIS database. Three core modules, the analysis module, the pre-processing and the post processing module will comprise the data processing engines of the DSS as shown in figure 5.

Figure 5. Components of DSS in the Citarum River Basin

3. Database Structure

The database comparison was also based on the four parameters of functionally, usability, data transformation and capacity building. It is important to note that none of the database options currently in use are either centralized or used globally by all stakeholders. Part of that has to do with the database options not having the functionally required to serve the needs of all the stakeholders, but in other cases, it is because that the database is not being user-friendly enough to be utilized by anyone but highly trained human resources. Typically the GIS database consists of a number of layers. Each layer has three types of components; features class, which can be point, line or polygon features.

a. Database structure for Rainfall-Runoff Modeling

The database structure and data requirement for Rainfall-Runoff modeling is the essential required data are rainfall, temperature, dam release, water demand, and water level (stream flow) data.

b. Database structure for Water Allocation Model

The required database structure and datasets for water allocation model will depend upon the detail of watershed to be managed. At the minimum, control, discharge and flow data for all the reservoirs as well as predicted water demand for agriculture and urban consumption is required.

c. Database structure for Water Quality Modeling

The required database structure and datasets for water quality modeling make the QUAL 2E PLUS model will be used for stream water quality modeling. The model will require flow data as well as field water quality data, withdrawal data, and point and non-point pollutant sources data.

4. Configuration of GIS based system

The database will utilize oracle for database support, ESRI software for geospatial data storage and management and be editable through web browser or Arc Editor depending on user licenses. The database will have two sub-system, one if for planning and management support that will track data on pollution sources and water quality, and linked to the modeling and mapping system. The other sub-system support the regulatory activities of the area, including the discharge licensing system and compliance monitoring system. Ideally, the database would be capable of generating the following report; summary report, key indicator report, report in response to specific request for information and report when a situation is detected by the system as unusual. A such, the database would serve not just as a data processing and storage system, but more importantly as a management and decision-making support. The database system should be designed to facilitate access to socio-economic information via meta-databases. This enables users to track not only the status of water quality, but also the socio-economic condition that act as driving forces or sources of pressure on the environment.

Recommendation - The water resources of the rivers systems in the Citarum River Basin (CRB) are critical to social and economic development of the country. They are essential for urban and industrial development particularly in Jakarta and Bandung areas, the capital city of Indonesia and West Java Province respectively, the cities among highest population density of the country. The system serves water for multiple uses, agricultural production through major irrigation systems, DMI water supplies, hydropower generation, and fisheries. The three reservoirs are all situated on the Citarum River, West java, The Ir. H. Djuanda reservoir is the most downstream one, the next upstream reservoir is Cirata and the Saguling reservoir is the most upstream one. Downstream of Ir. H. Djuanda reservoir two weirs across the Citarum divert water into the three main canal.

Information sharing is a basic principle IWRM planning and data, information, and decision support are key components to the roadmap for IWRM in the Citarum River Basin. This includes collecting, validating, archiving, managing and disseminating relevant data covering surface and groundwater quantity and quality, as well as other natural resource data such as soils, geology, land cover and ecosystems, including such socioeconomic data as population, poverty and land use. This is information can be used to research catchment processes and demography; developing new technologies for water conservation and environmental protection, and developing and implementing decision-support tools. Including geographic information systems, hydrologic and hydraulic models and other analytical tools.

The DSS based on an integrated collection of databases and modeling tools that will provide guidance and suggestions for river basin managers and decision makers concerning planning, design and operations. Presently the DSS will focus on the hydrological and spatial databases, rainfall-runoff models, water allocation models and water quality models. However, within the initial development of the DSS it will be necessary to consider future requests by the river basin managers for additional features, for example water level modeling, flood forecasting and management, and groundwater modeling, and ensure to provide the provision that the future programme for developing the DSS will be included supporting these features.

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