XVIII World Water Congress
International Water Resources Association(IWRA)
Beijing, China | September 11-15, 2023

Digital twin River & Smart water
-
Changjiang practices

Yan Huang | 12 Sept, 2023

Changjiang Water Resources Commission

Special Session
Development & Application of
Digital Twin River Technology

Digital twin technology provide opportunity to better management

- A **Digital Twin** is a computer model that virtually **reflects and simulates** a real object, its environment and interaction, providing a picture as **accurate** as possible of how that object **behaves** in real time.

- **Digital Twin River:** A highly accurate digital model of the river basin to **monitor** and **predict** the interaction between natural phenomena and human activities.

River is heavily interfered by human activities

River

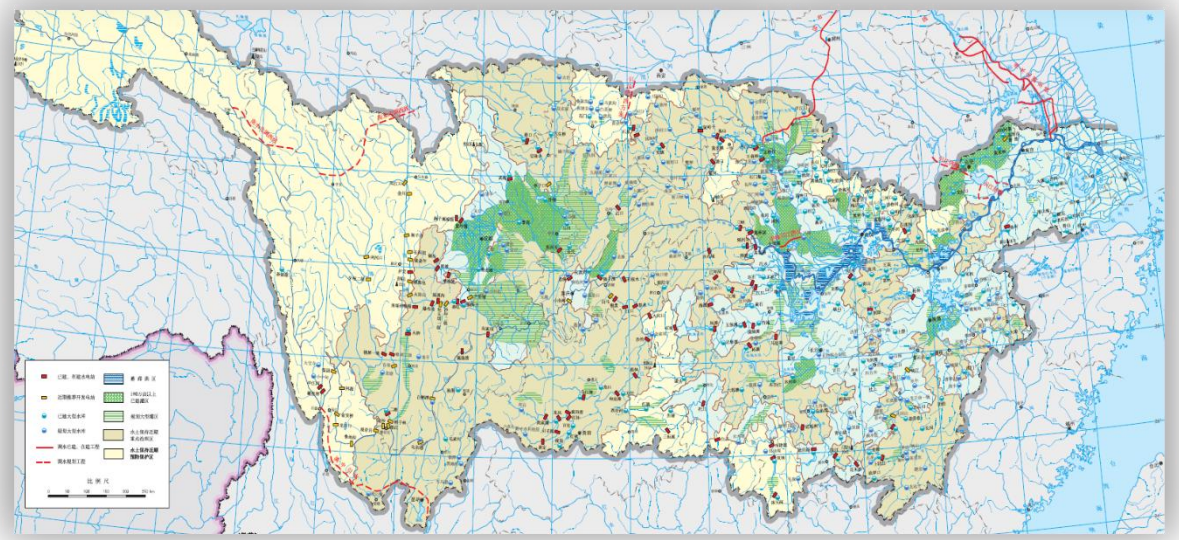
Nature river
→
Water projects dominated

Water projects

Designed individually
→
Jointly regulated

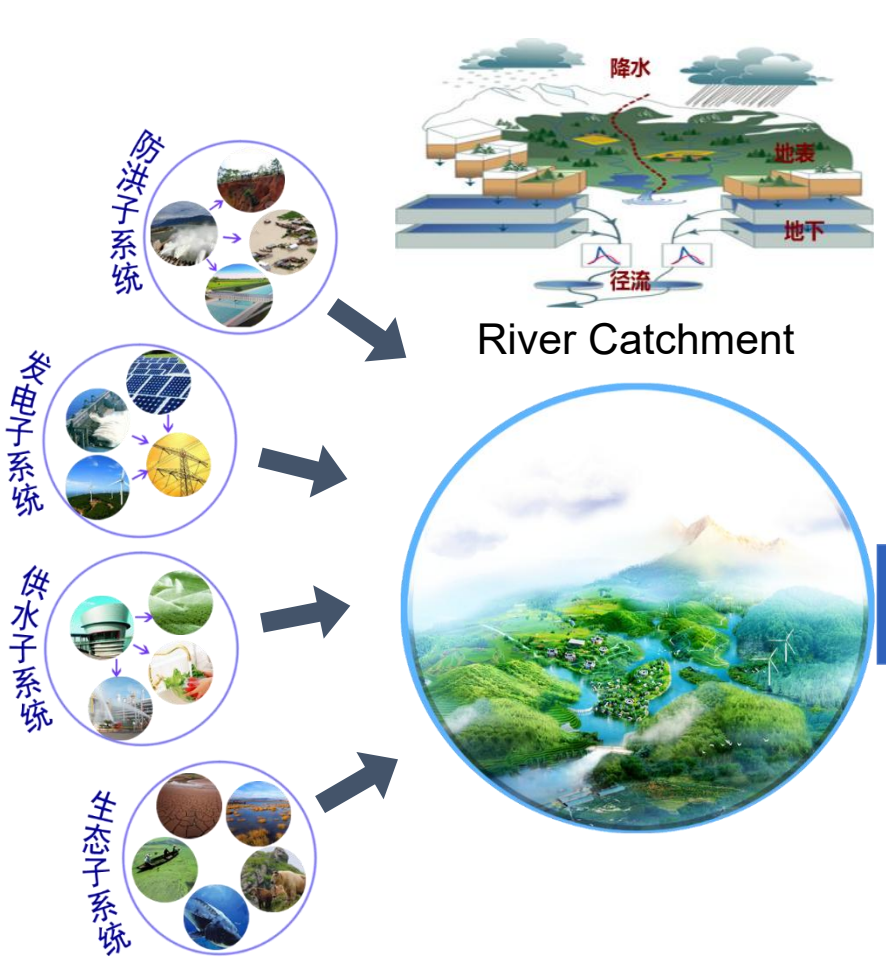
Regulation scheme

Single objectives
→
multi-objectives



- Reservoirs: **98,002**, Total volume > **932.3** billion m^3
- Gates/Sluices: >1m^3/s **268,476**
- Rubber dam **2685**
- Length of Dikes: **413,679** km
- Pumping stations: **424,451**
- Others: retention basins etc……

Decision making requires multi-objective consideration



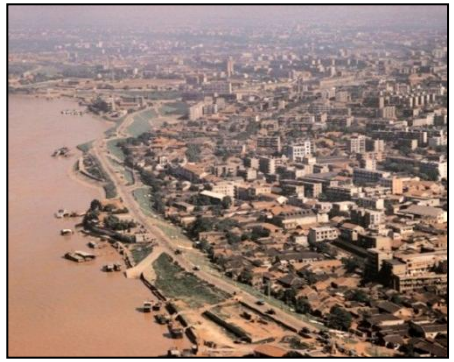
Multiple objectives

- Flood management
- Water supply
- Hydropower
- Shipping
- Ecosystem restoration
- Environmental protection

Optimi zation

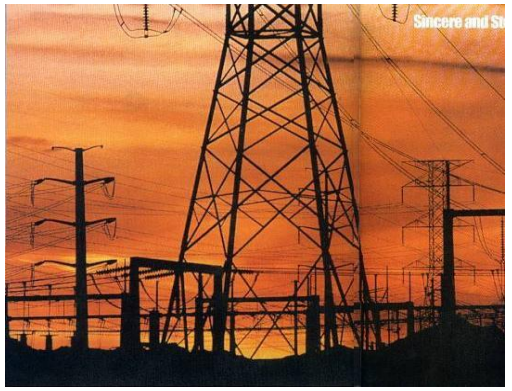
Joint regulation of engineering works

Reservoir become the most valuable engineering measure for IWRM



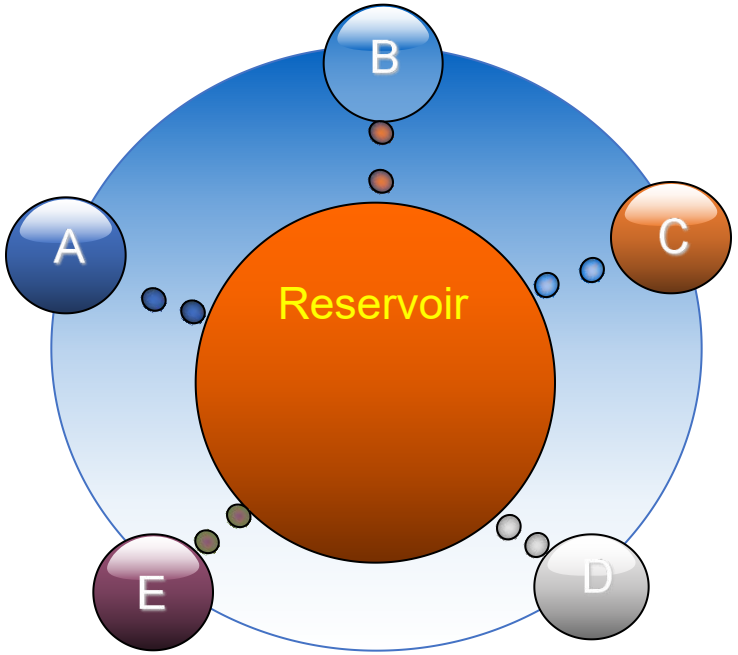
Flood management

Irrigation & water supply



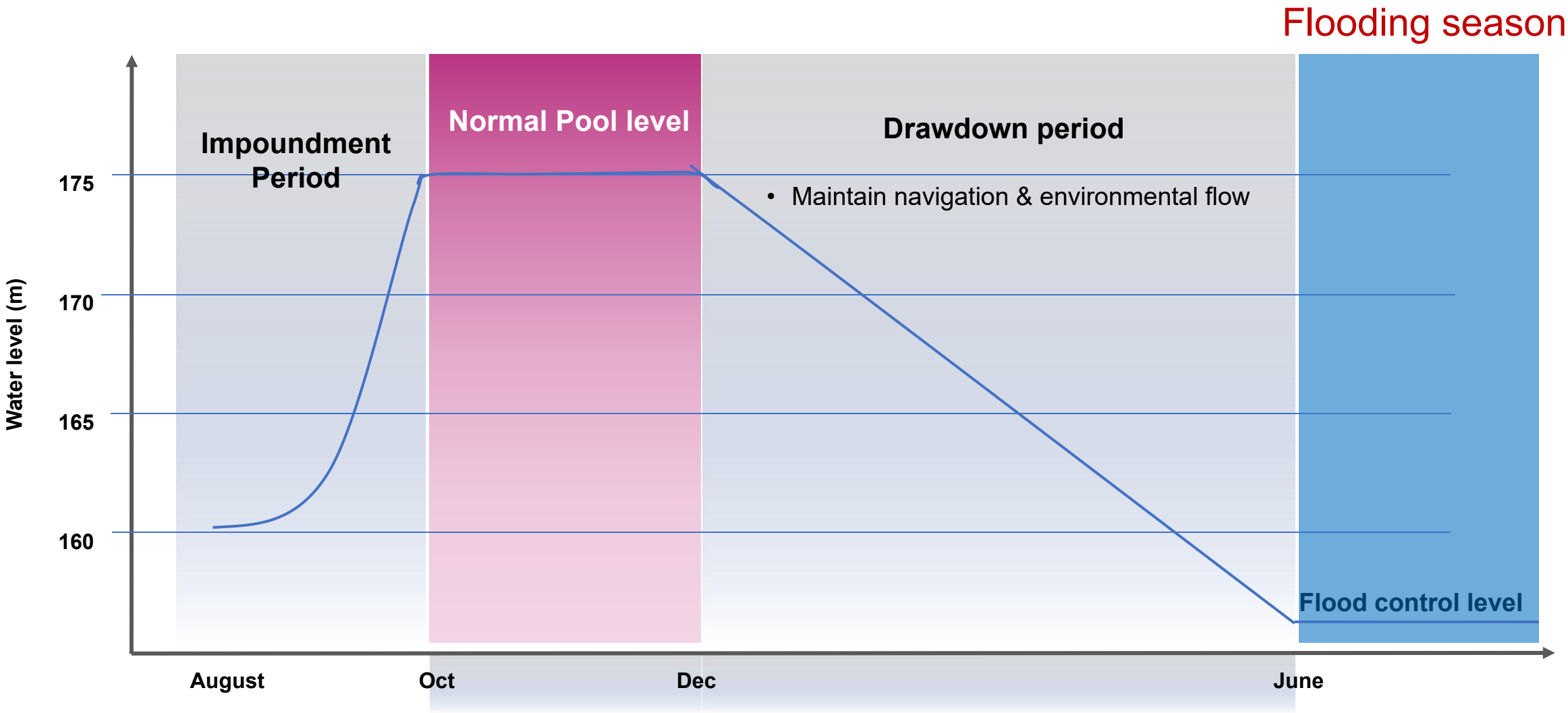
Generate hydropower

Protect ecosystem & environment

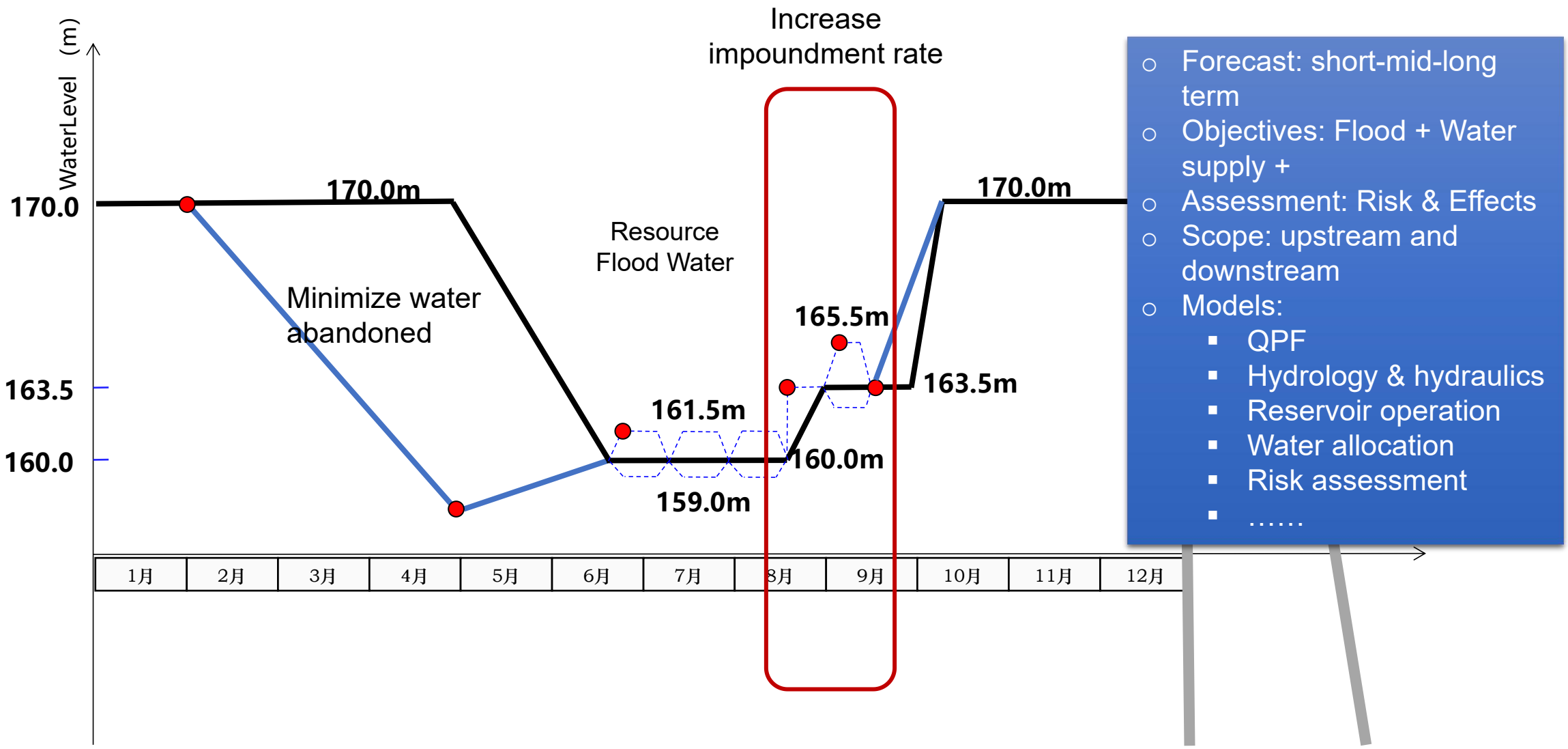


Improve navigation

How to achieve multiple-objectives - Reservoir regulation

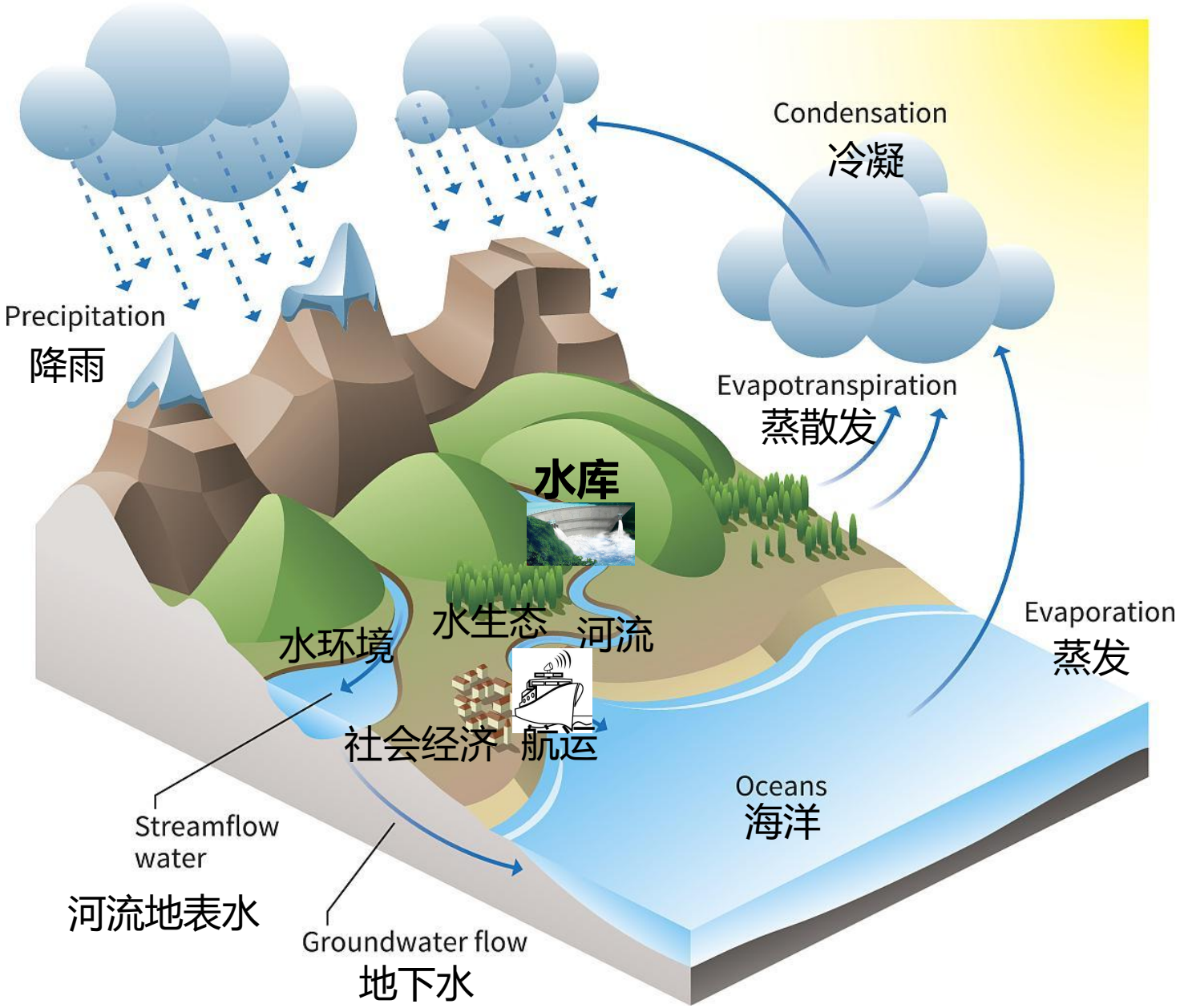


Real time regulation of reservoirs requires complex modelling system



- Forecast: short-mid-long term
- Objectives: Flood + Water supply +
- Assessment: Risk & Effects
- Scope: upstream and downstream
- Models:
  - QPF
  - Hydrology & hydraulics
  - Reservoir operation
  - Water allocation
  - Risk assessment
  - ……

Digital Twin River = Mirroring + Interaction physics & process



❑Basis - data

- ❿ Hydrology, meteorology, environment, ecology, GIS, socio-economy…
- ❿ To build a data-bord

Drive - models

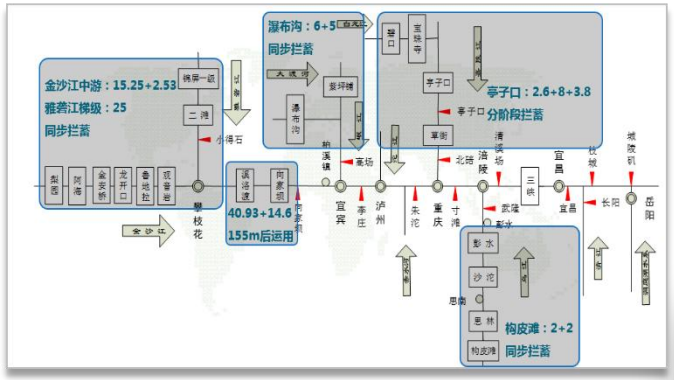
- Physically-based mathematic models (hydrology, hydraulics, water quality, ecology, risk assessment, **engineering regulation** etc.) + Data-driven approaches
- to build interconnection between all elements of nature and management.

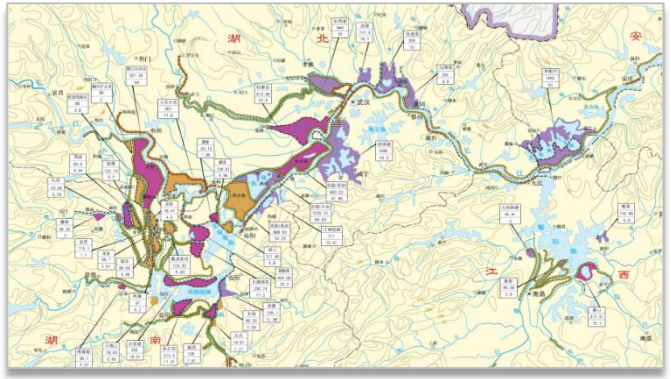
Path – integrated ICT

- Cloud computing, big-data, IOT, AI, internet, BIM, GIS, VR/AR/MR…

DSS needs more “intelligence”

Digital Twin River with joint regulation of water projects is an **inevitable choice** for river basin management.





Demands

Maximize benefits of water projects

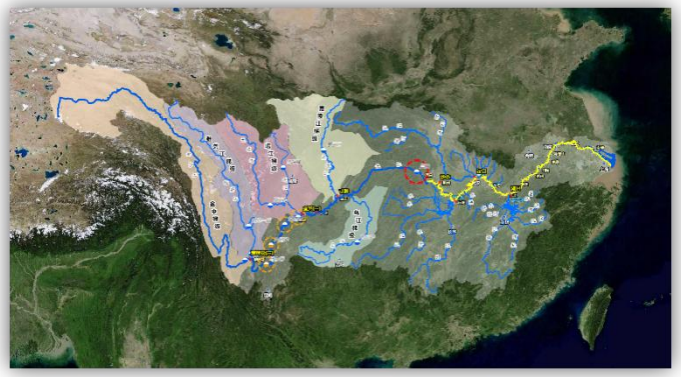
1 Large scale water projects

- Integrate Forecast + Regulate
- Intelligent regulation

2 Efficient response to major floods
Efficient use of water resources
Water ecological restoration and environmental protection

- Dynamic risk assessment
- Visualization of multi-scenario analysis

Needs to improve management capacity through joint operation of water infrastructures



❑ Large river, many engineering works

- **L = 6300** km， A = **180** million km²(**18.8 %**China)
- **300+** large reservoir, **46** retention basins, **45.3** billion m³ water diversion

Flood management

❑ To improve flood forecasting **accuracy** and regulation **intelligence**

Water utilization and saving

❑ Water saving and water use efficiency

❑ **Regulation** management ability needs to be improved

Environmental - ecology

❑ How to **protection** or prevent pollution

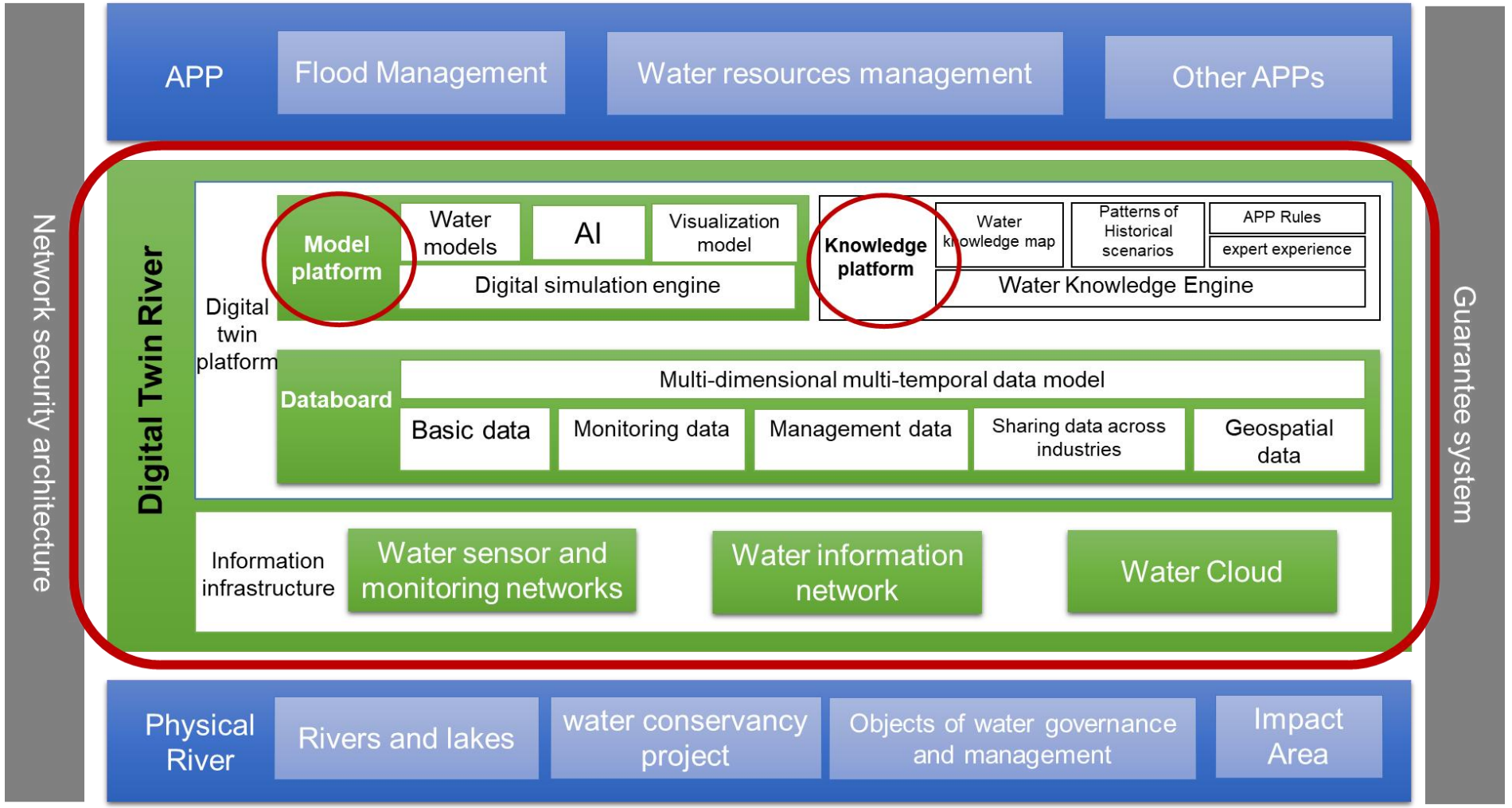
❑ Ecology decline needs to be prevented

Management capacity

❑ Flood management is relatively advanced

❑ Others are not so good

Digital Twin river is the core of Smart River / water



Digital Twin River

- ❑ Infrastructure
- ❑ Data-board
- ❑ Model platform
- ❑ Knowledge platform
- ❑ Interface + Engine

Smart River = Digit River + APPs

General requirements for development of DTR

Data

- Sufficient coverage:
  scope + elements +
  process + technology
  High accuracy
  High frequency
  Data has **value**

Computing Power

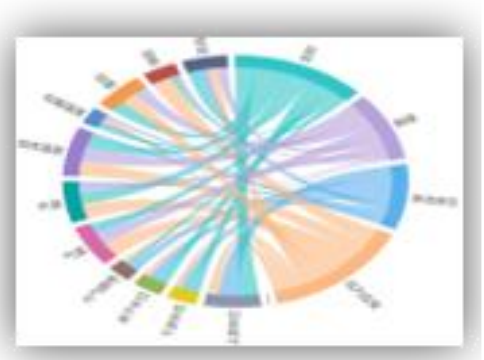
•Fast transmission

•More storage

•

High computing performance

Models



▪Full coverage of field: hydrology, hydraulic, water quality, space, engineering etc.
High accuracy
Strong in intelligence

Applications

- Upgrade flood management
- Enhance capacity for water resources management
- Improve spatial and basin monitoring apps

Digital Twin River → Smart River

Technical specifications and requirements issued by water ministry

水 利 部 文 件

水信息〔2022〕146 号

水利部关于印发数字孪生流域共建共享管理办法(试行)的通知

部机关各司局,部直属各单位,各省、自治区、直辖市水利(水务)厅(局),各计划单列市水利(水务)局,新疆生产建设兵团水利局,中国长江三峡集团有限公司、中国南水北调集团有限公司、有关水利工程管理单位:

《数字孪生流域共建共享管理办法(试行)》已经部务会审议通过,现印发给你们,请结合实际认真贯彻落实。

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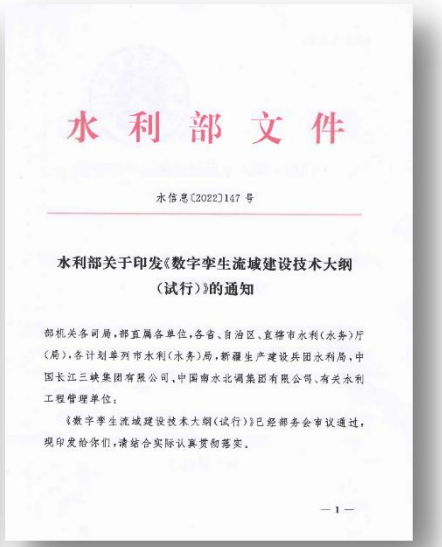

水 利 部 文 件

水信息〔2022〕147 号

水利部关于印发《数字孪生流域建设技术大纲(试行)》的通知

部机关各司局,部直属各单位,各省、自治区、直辖市水利(水务)厅(局),各计划单列市水利(水务)局,新疆生产建设兵团水利局,中国长江三峡集团有限公司、中国南水北调集团有限公司、有关水利工程管理单位:

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水 利 部 文 件

水信息〔2022〕148 号

水利部关于印发《数字孪生水利工程建设技术导则(试行)》的通知

部机关各司局,部直属各单位,各省、自治区、直辖市水利(水务)厅(局),各计划单列市水利(水务)局,新疆生产建设兵团水利局,中国长江三峡集团有限公司、中国南水北调集团有限公司、有关水利工程管理单位:

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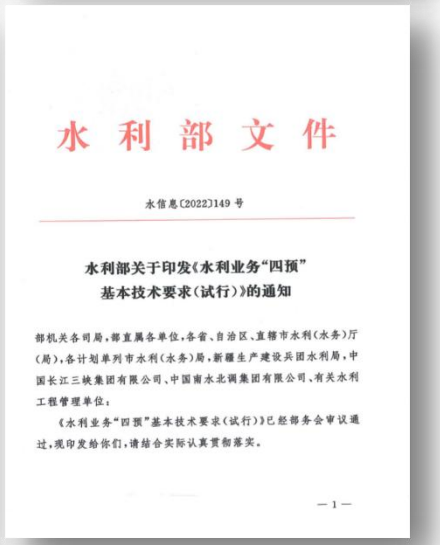

水 利 部 文 件

水信息〔2022〕149 号

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In March 2022, the Ministry of Water Resources issued the technical standards and specifications for the construction of digital twin river and water engineering projects:

- ❑ "Digital Twin **River** Construction Technical Outline (Trial)“
- ❑ "Technical Guidelines for construction of Digital Twin Water Conservancy Engineering Construction (Trial)“
- ❑ Basic Technical Requirements for "Four Advances" of Water Conservancy applications (Trial)“
- ❑ Administrative Measures for the Co-construction and Sharing of Digital Twin River (Trial)"

Key elements of developing Digital Twin River

Drive
Model

Basis
Data

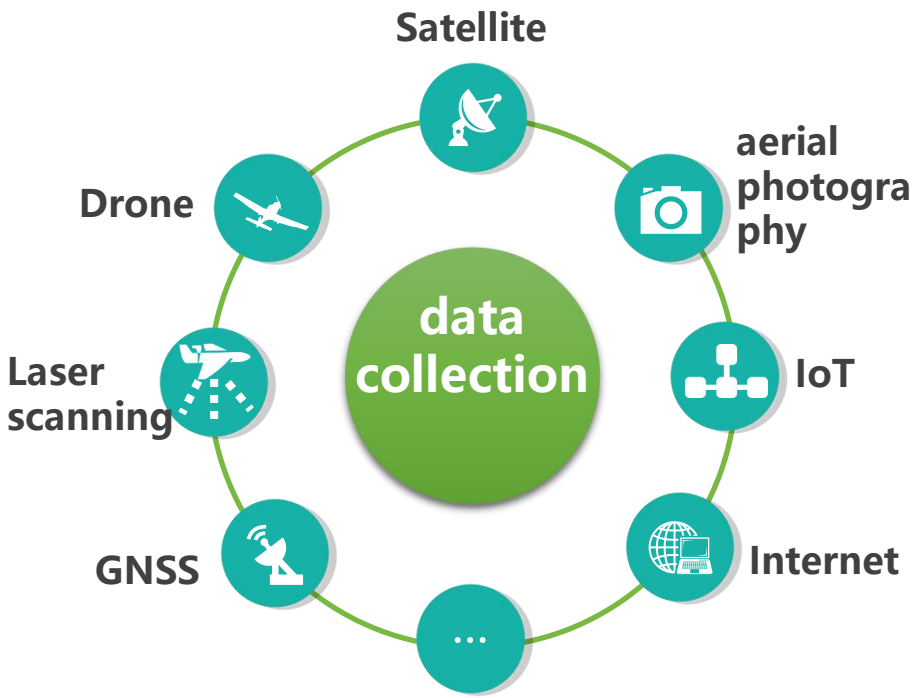
Core
Intelligence

Platform
Service

Data Acquisition

Data collection & acquisition

Full coverage of data measuring



地形地貌、地质、水文、气象、土壤、水土保持、土地覆盖、**人群**……

Integrated information collection processing
→integrated application

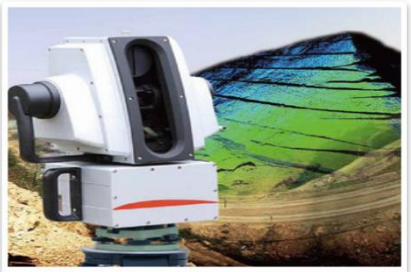
LBS

Water flow, environment, ecology, water disaster sensor

Large aircraft
Air

Fixed Wing / Rotary Wing
UAV
low altitude remote sensing

Airborne/vehicle laser scanning



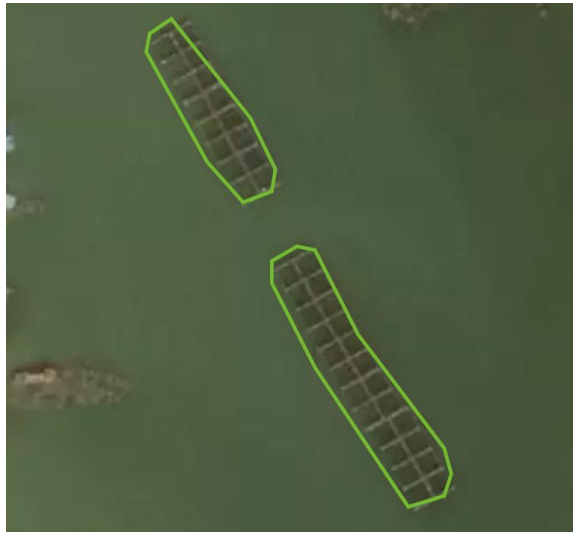
Measuring robot

Communication
Satellite/Monitoring
Satellite
Satellite

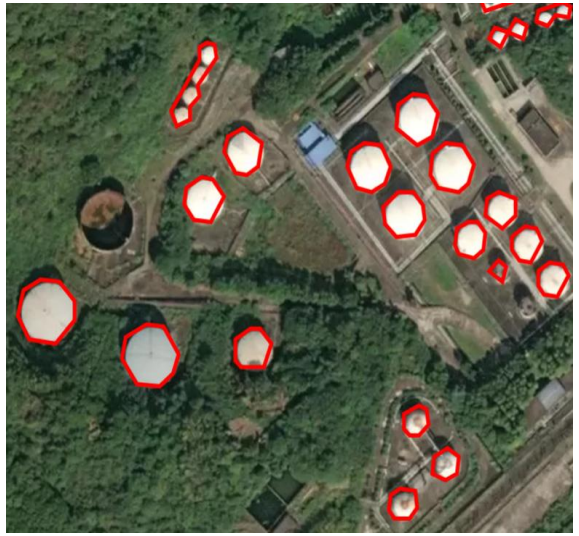
Improve interpretation ability of remote sensing data

- To protect river bank and river course identification of prohibited ground constructions or object is needed.
- Using remote sensing data, **intelligent identification models** for **6 major categories of river-related construction projects**, such as docks, dams, net farming, water bodies, storage tanks (chemical plants), buildings, etc., has been developed using about 25,000 samples. The accuracy is >85%.
- More models are needed with better accuracy.

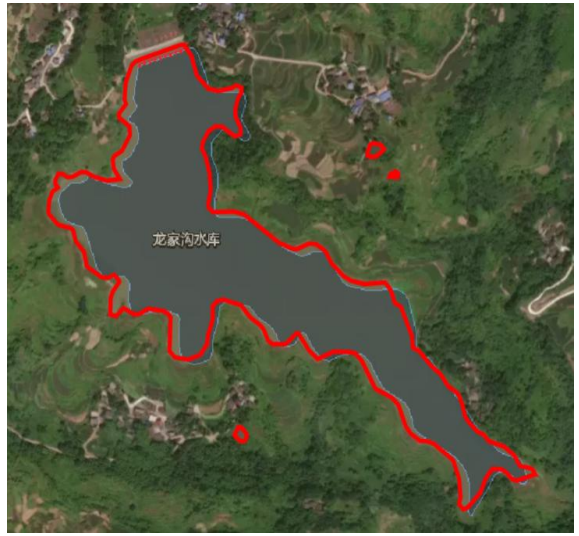
Identification of wharf



Identification of cage culture



Storage tank



Water body

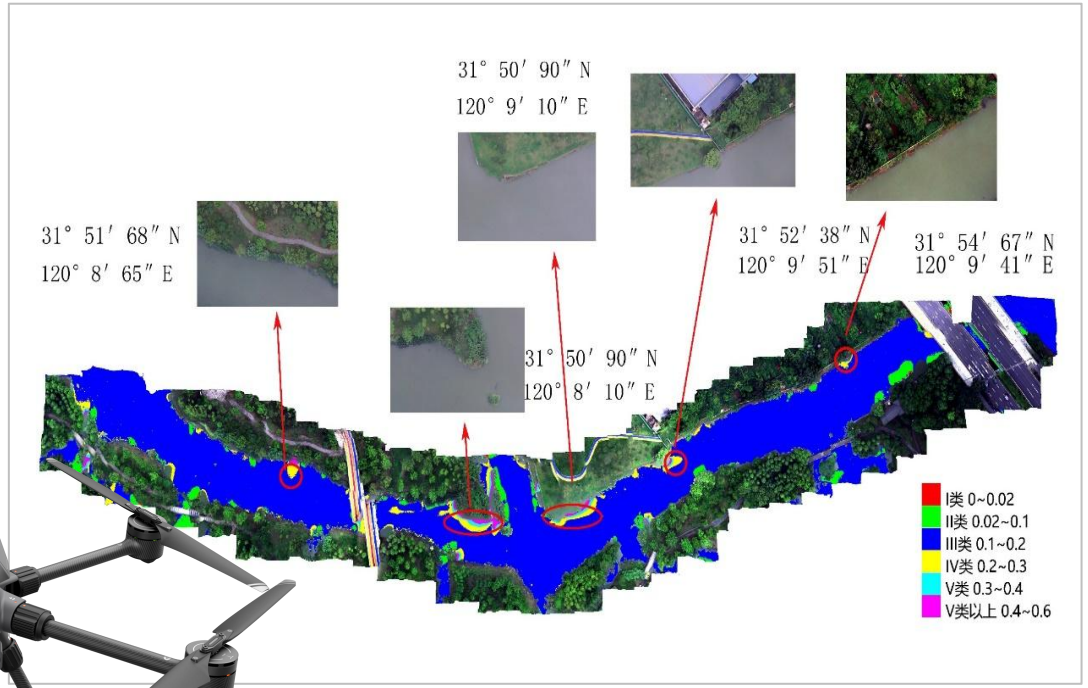
Application of new technology - Infrared Monitoring Technology

Infrared Thermal Imaging Shooting

- Distinguish thermal infrared image features of sewage
- Thermal imaging at night is still sensitive and effective

Hyperspectral remote sensing

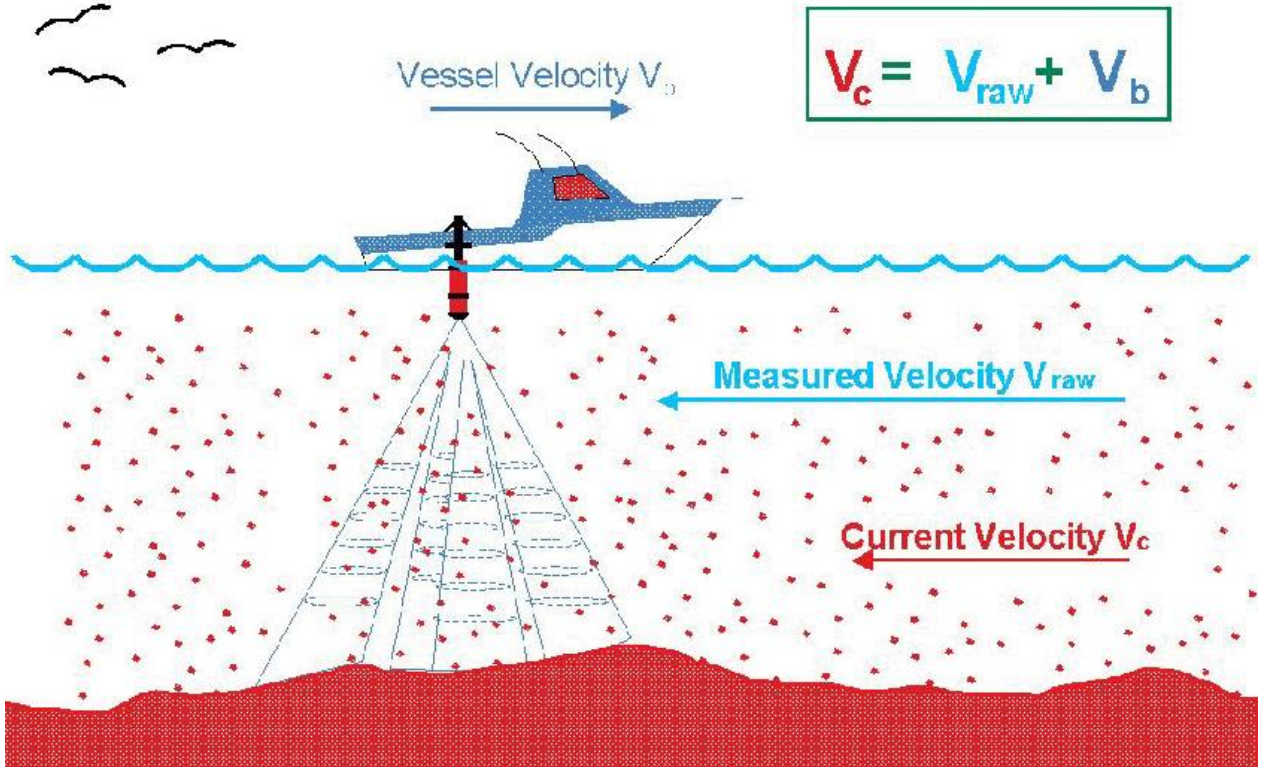
- Analysis and inversion of various water quality parameters of surface water in a large area **to find out suspected water pollution points**.
- After the polluted area is locked, the refined investigation of the sewage outlet can be carried out by using the human-computer interaction method.
- **Need more AI to identity pollution sources.**



New tools - unmanned boat

Mainly used as a **carrier** to carry monitoring equipment

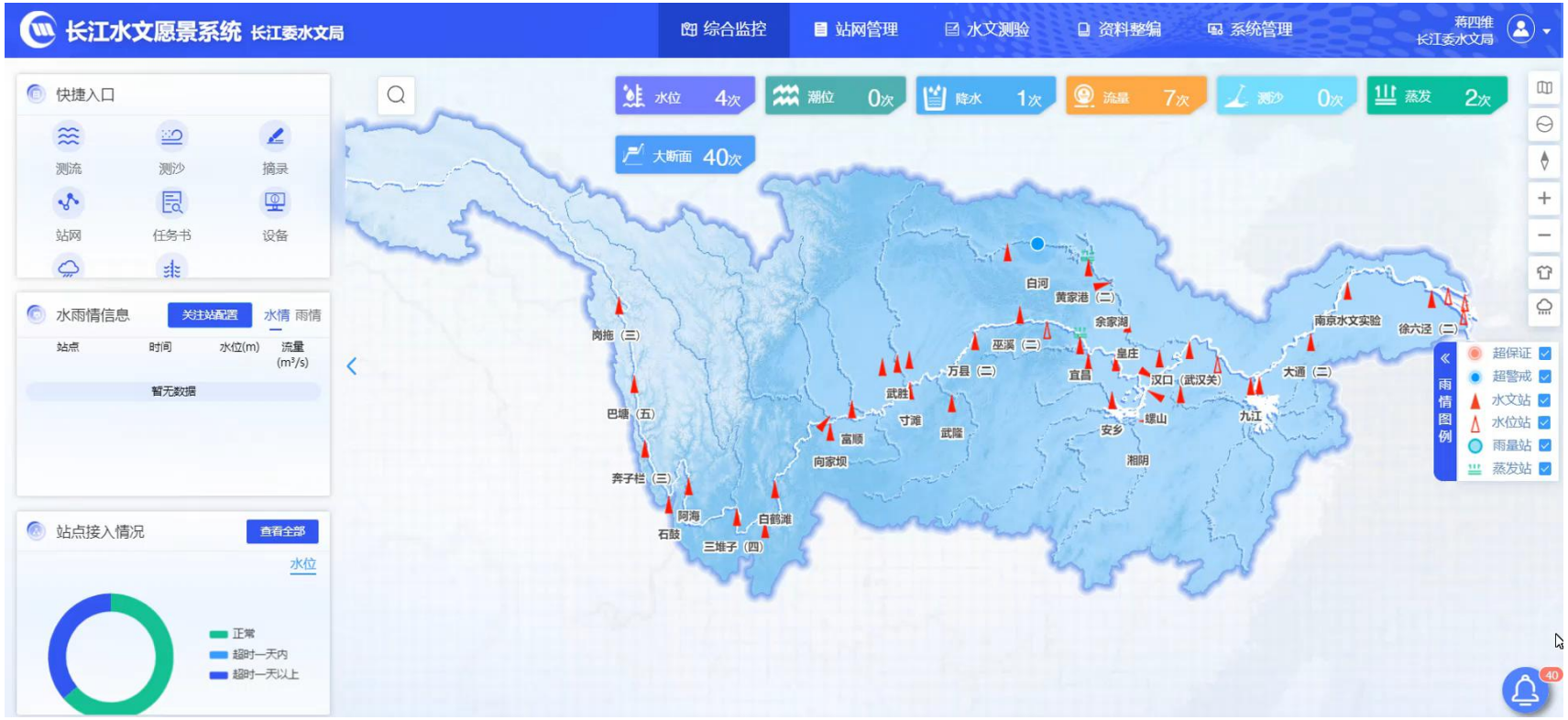
- ❑ Equipped with GNSS, depth sounder, etc. for underwater terrain monitoring
- ❑ Device equipped with ADCP for flow test
- ❑ Equipped with **sampling** equipment for water sample collection
- ❑ Equipped with a **sand meter** for sediment testing
- ❑ Carry out patrol management and related event detection



Data fusion

- **Multi-source fusion data base. T**hrough intelligent data collection and **aggregation** technology, realize full-element, full-scale, fully automatic monitoring and perception**.**

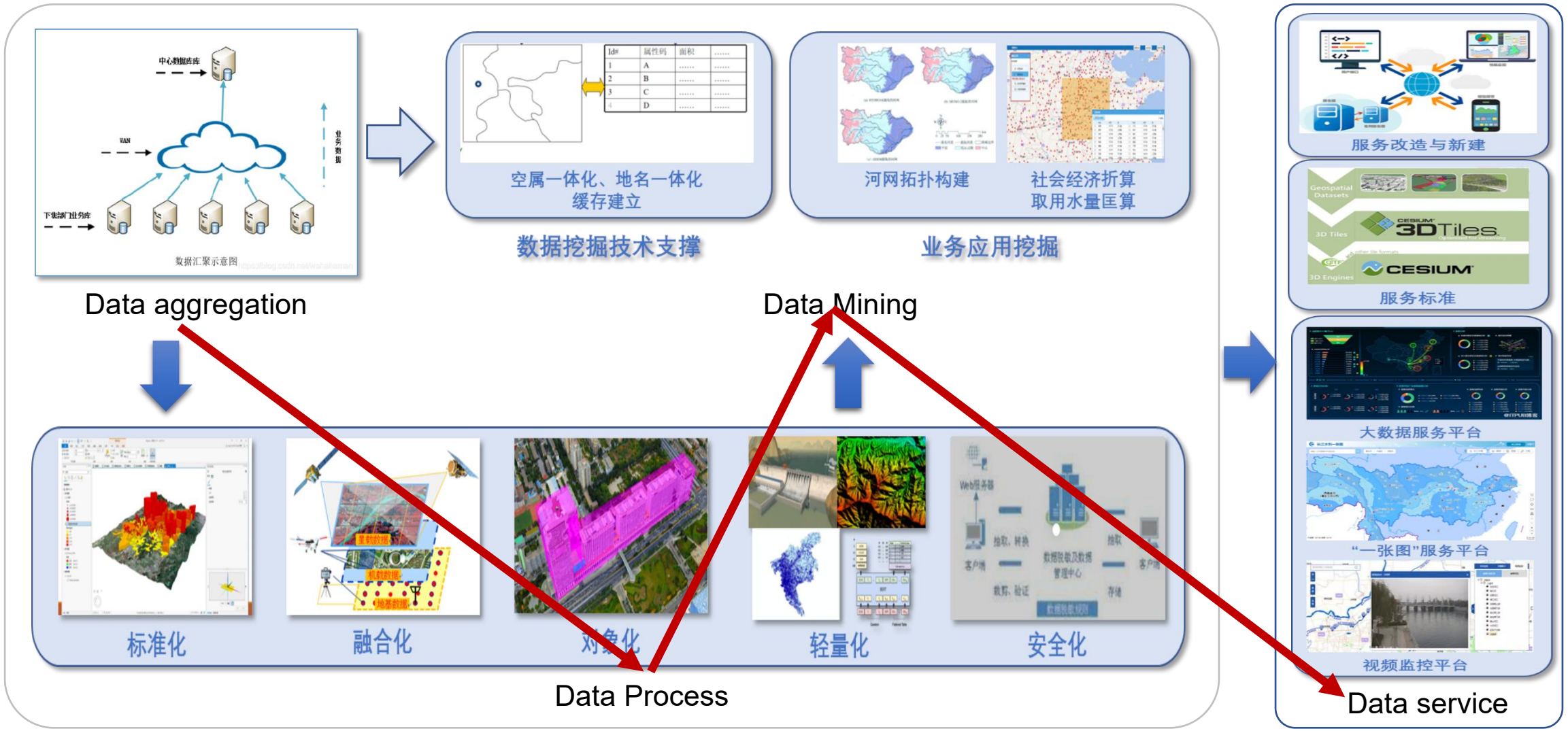
- **Vision**: fully empower the high-quality development of hydrology and water conservancy and the construction of digital twin rivers.



Data board

Data board

- Through the data engine to aggregate→process → mining to realize data value and provide data services.



Ways to build data for digital twin rivers

Info Categories	Data Elements	Research is needed	Expected results
Flow related	Rainfall, evaporation, water level, flow, sediment, project scheduling, water temperature, etc.	Mining historical information through **machine learning** to find patterns and **create data**	A useful supplement
Basin related	The scope, area and form of encroachment on the shoreline, damming, filling the reservoir to create land, soil erosion, etc.	Summarizing patterns and **mining data** values through the interpretation of remote sensing information	Automatic data acquisition
Work-related	Seepage flow, seepage pressure, displacement, openness, infiltration line variation, etc.	Identify the characteristics of objects, **collect data** through the application of **IoT technology**	Full process data monitoring
Management-related	Justification, licensing, planning, progress, supervision, enforcement, daily office, etc.	**Collect data** through full process inspection of management activities	Full process data collection
Cross-industry related	Meteorology, transportation, social economy, natural resources, ecological protection, etc.	**Share data** by building a cross-industry data sharing mechanism	Realize data sharing

Data board - Changjiang River Data Center

Water-related business data

- Flood
- Drought
- Water Safety
- water conservancy project
- water resources development
- urban and rural water supply
- water-saving
- ……

Basin and provincial data

- River basin authorities
- provincial institution

Sharing data across industries

- ministry of natural resources
- ministry of emergency management
- ministry of ecology and environment
- state statistical bureau
- China meteorological bureau
- ……

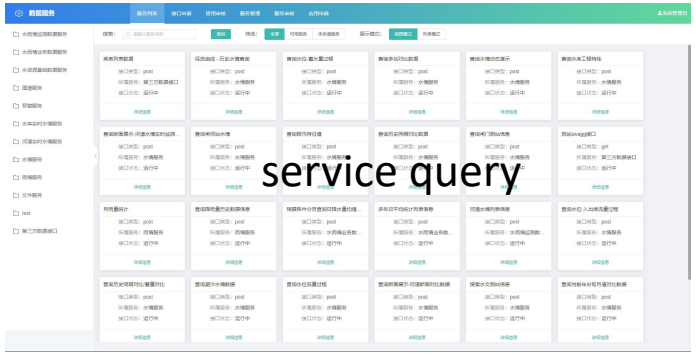
Business acquisition data

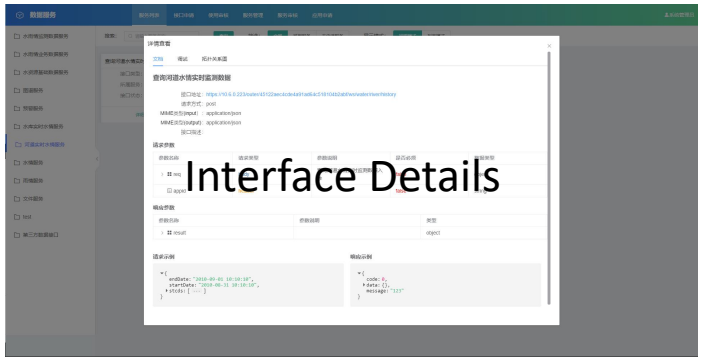
- State Grid Corporation of China
- CMCC
- Big Data Companies
- ……

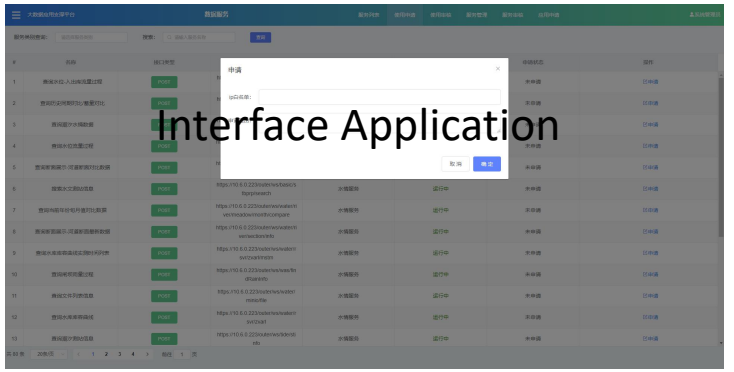
Internet public opinion data

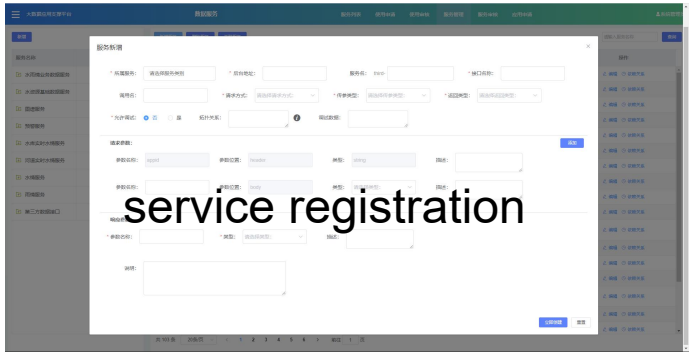
- Bidding website
- Search Site
- social network site
- ……

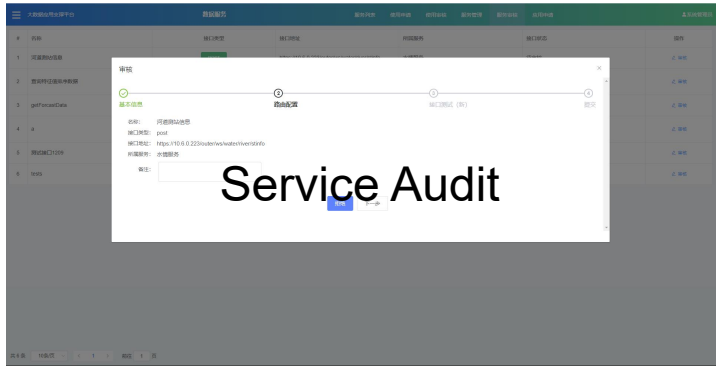
Changjiang River Data Center provides data service

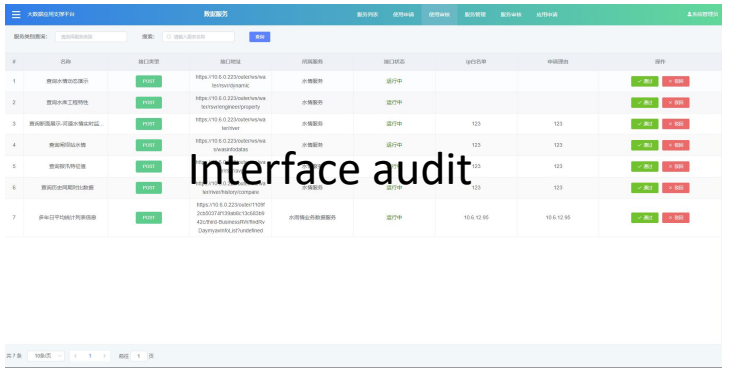


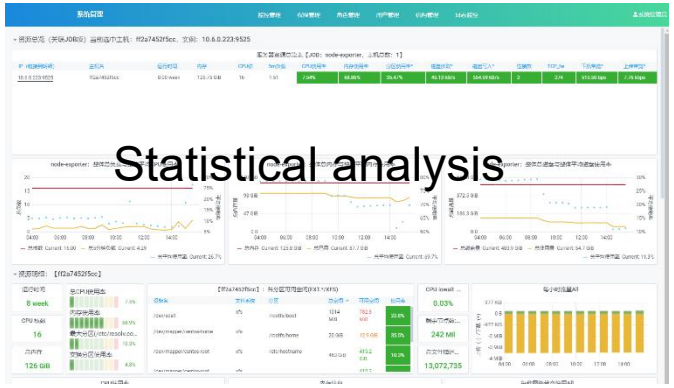


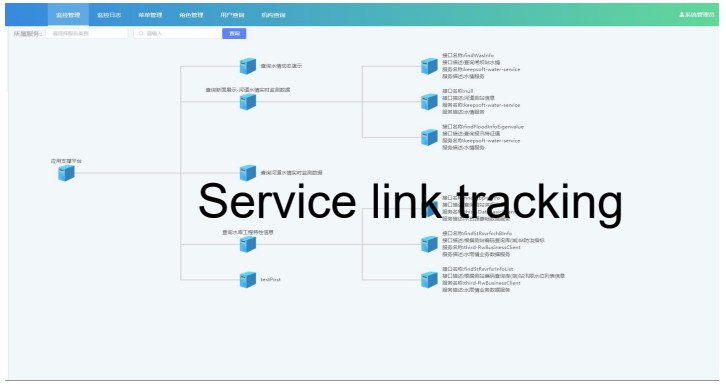












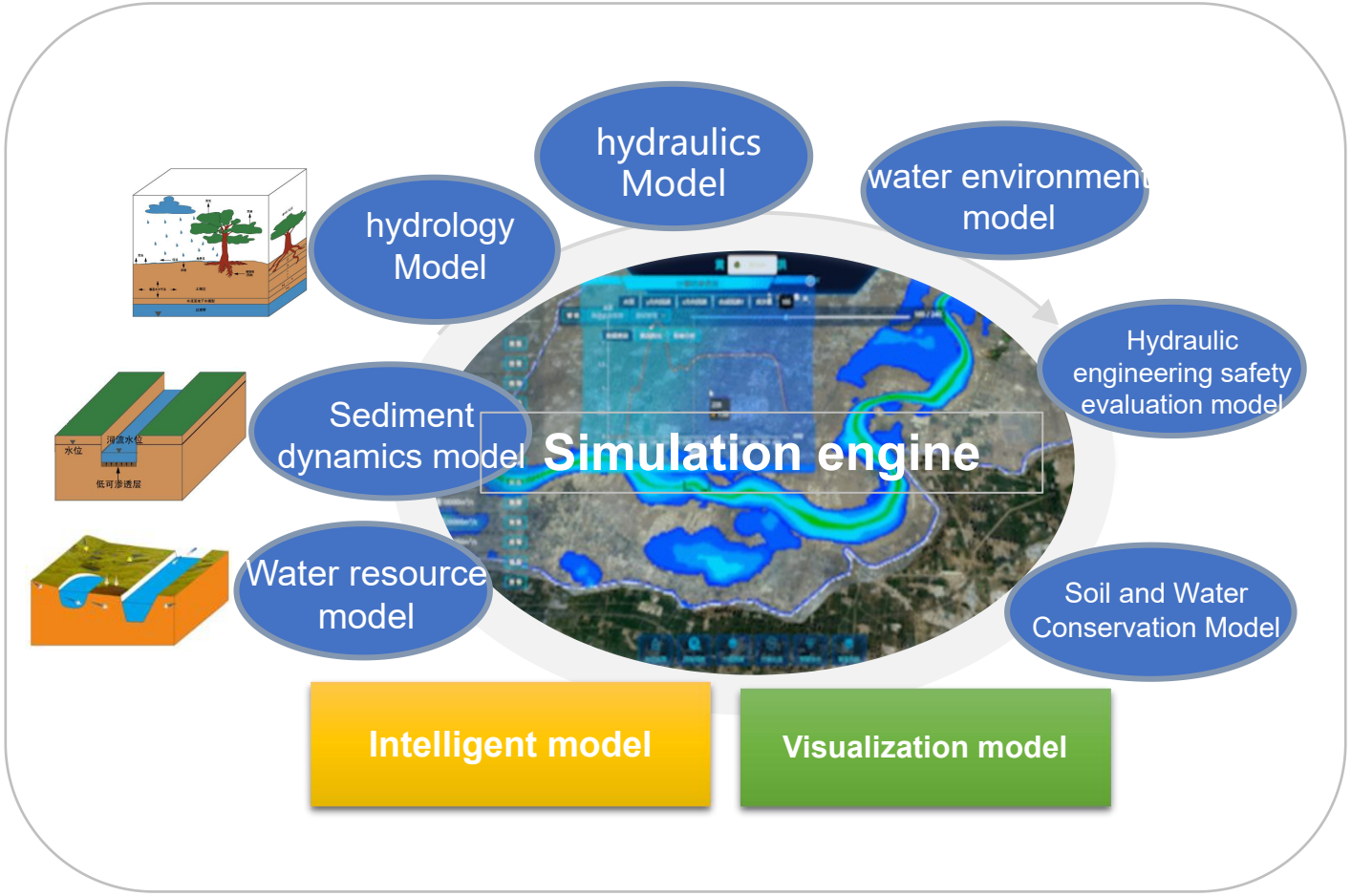
- ❑ Provide and manage data services
- ❑ Registration and application management of models

Model & Model Platform

Model is the driven force for digital twin river

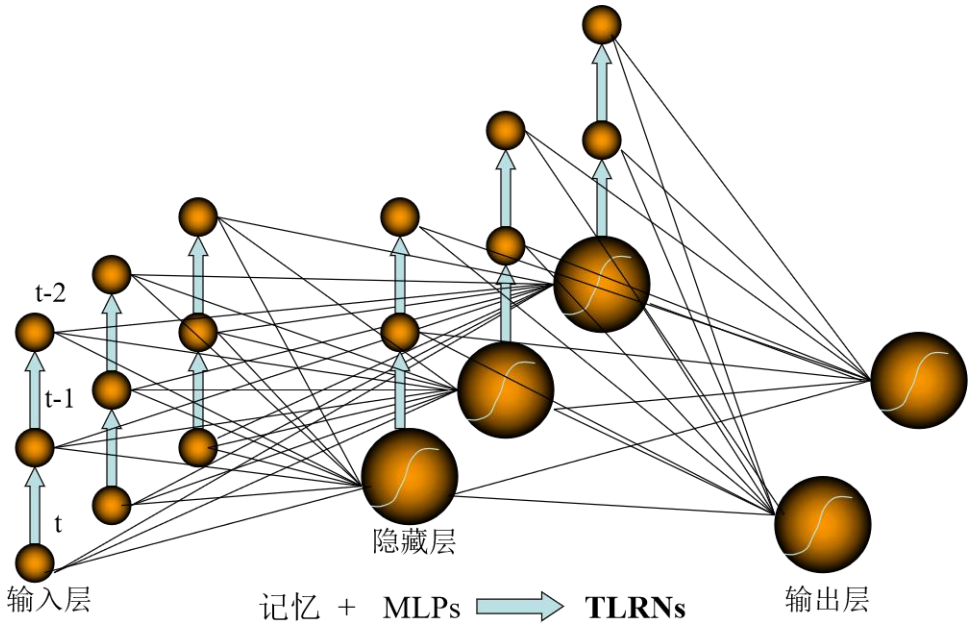
Functionality

- **Provides "algorithms"** for water simulation and provide model registration, verification, Invocation, display, user evaluation and other functions.
- **Provide simulation engine**: connects the data and service interfaces of various models.

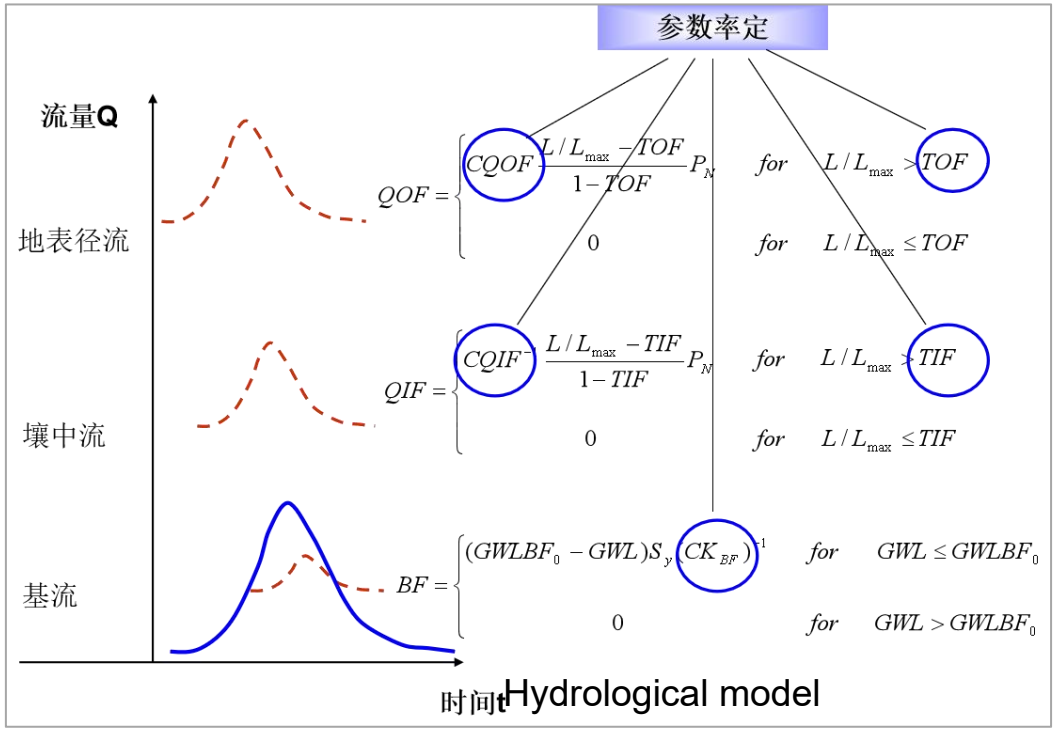


Current Focus: improve model performance

- **Augmented Intelligence**: The complexity of models and their integration can grow with data completeness and maturity, especially when coupling physical-based and data-driven models.
- Data-driven models can be used to assist in optimizing physical model results – updating procedure.

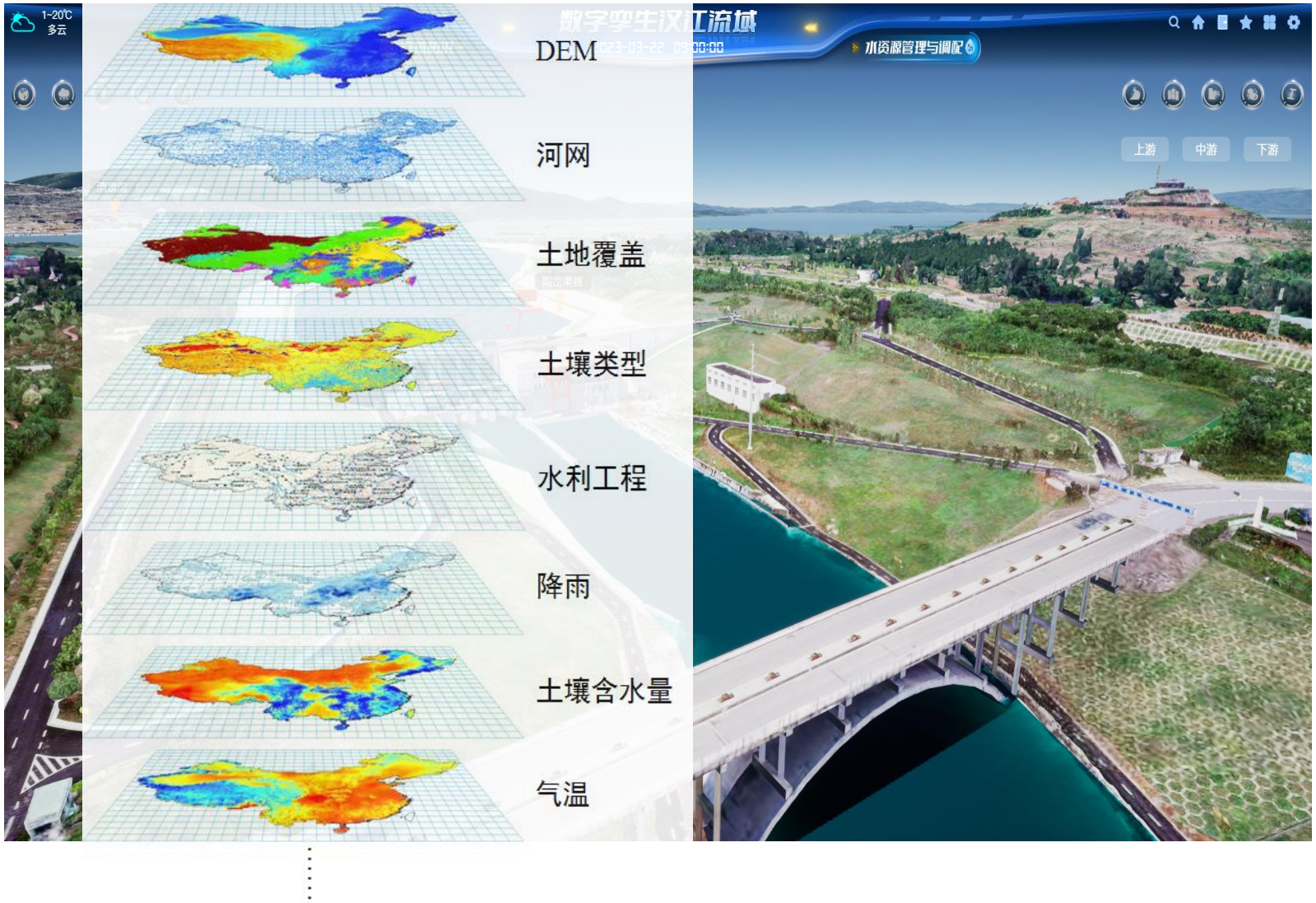


Neural Network



Hydrological model

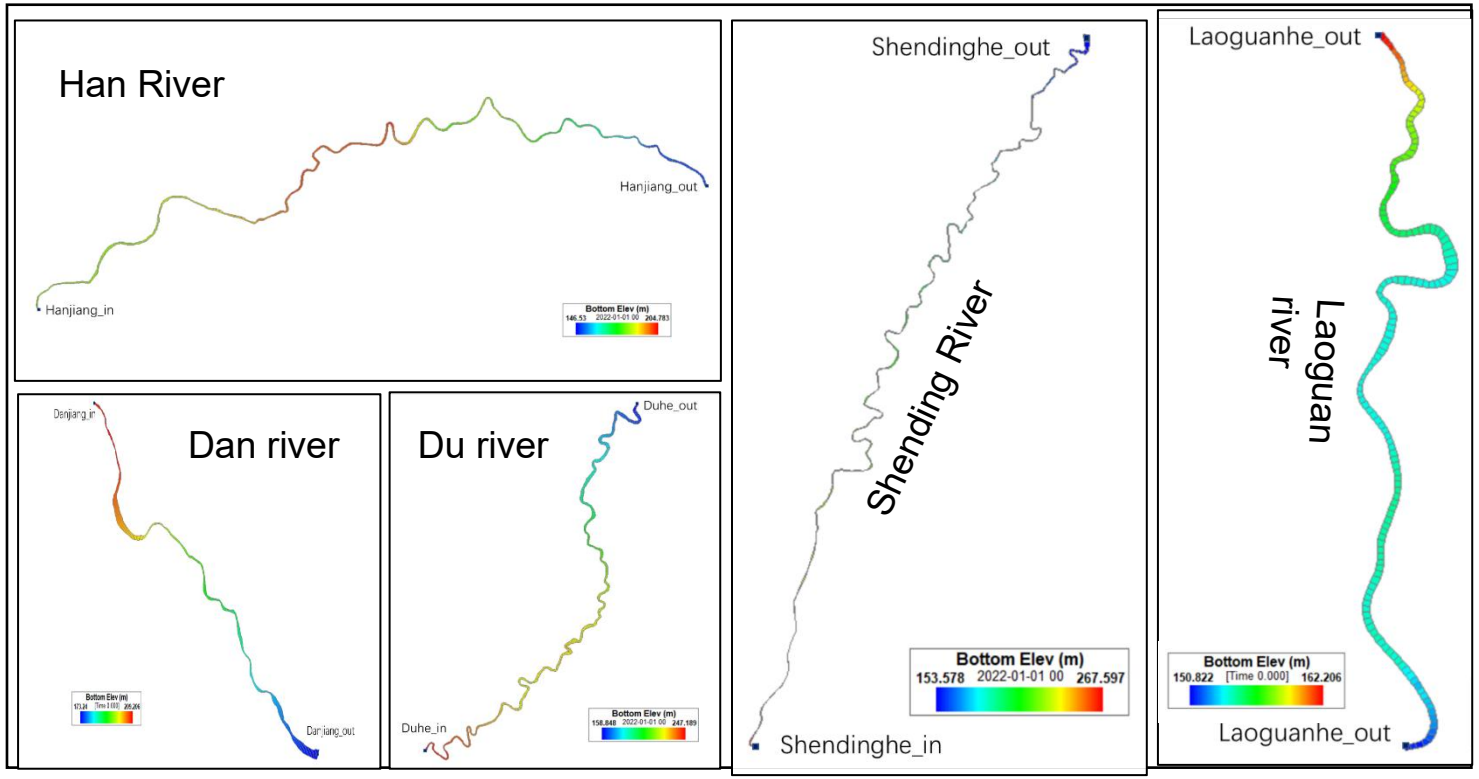
Improve model performance with better data



- Deducing hydrological infiltration related parameters from soil type, or hydrodynamic model roughness on the floodplain
- Determine the filling status of depressions and the runoff threshold from DEM, soil moisture content, etc.

Current focus: improve water quality model performance

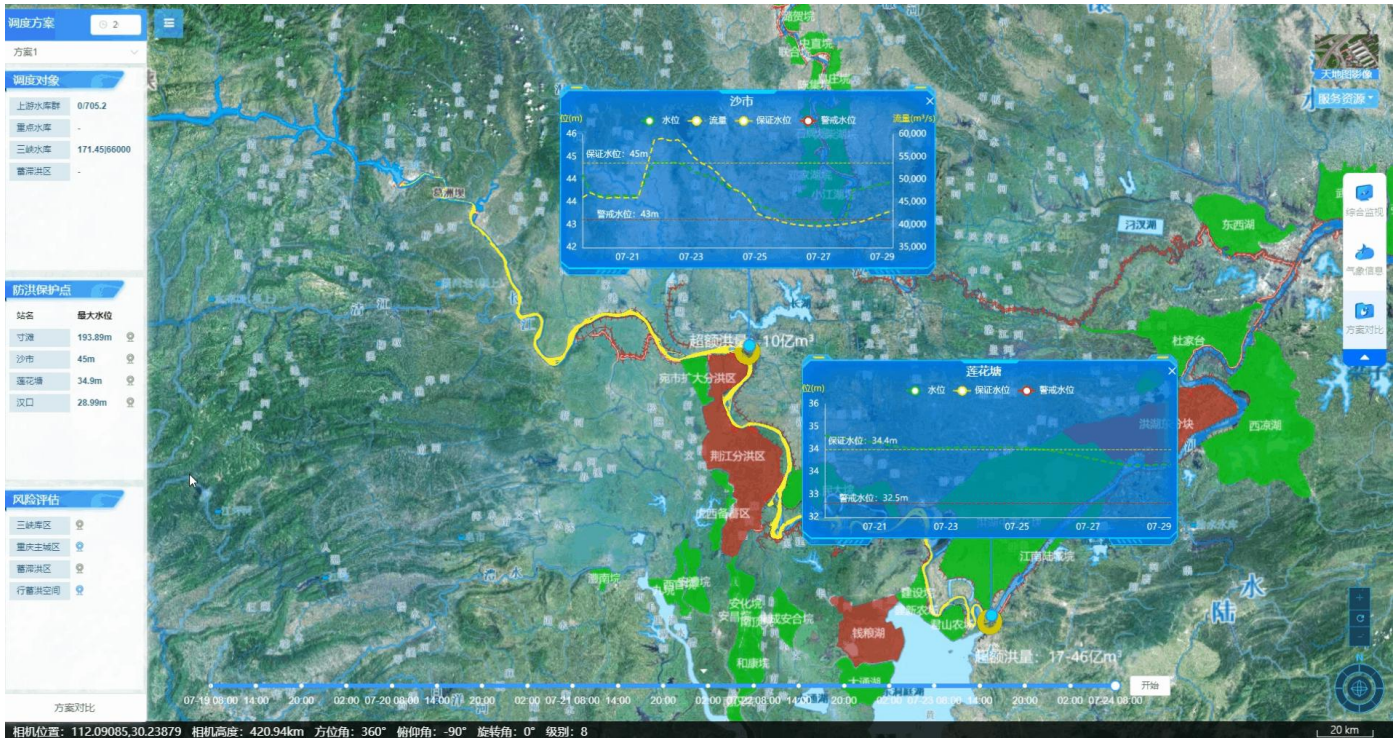
- **Purpose**: to **predict** and **deduce** the spatial and temporal distribution of water quality in rivers for assessment of water quality safety situation and emergency pollution response.
- **Parameter**: total nitrogen, total phosphorus, permanganate index, ammonia nitrogen and antimony etc.

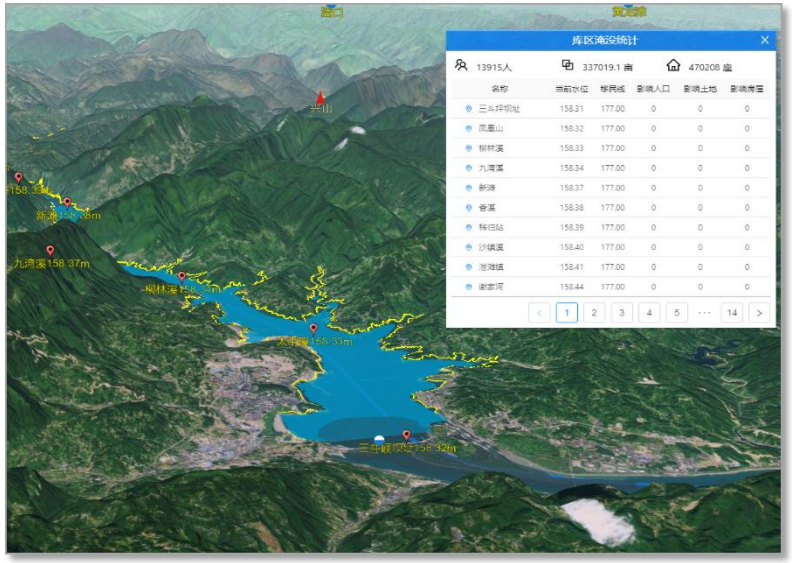


1D WQ model established – calibrated / validated

Dynamic flood risk assessment model

- Based on the results of hydrological prediction and simulation results, dynamically predict the change process of the water profile in the Three Gorges Reservoir area
- Assess the submergence risk of key areas and its impact on society and economy, calculate the benefits of corresponding regulation scheme, and propose real-time regulation suggestions for decision makers.

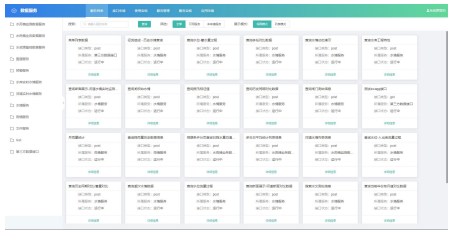




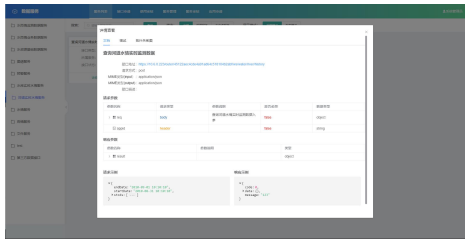
Services provided by the model platform

Model standardization construction:

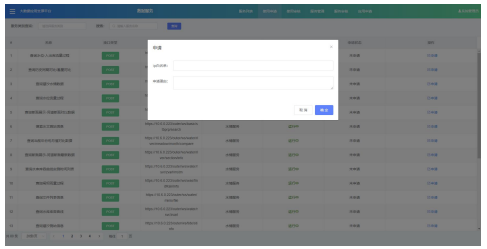
- ❑ Formulate model construction packaging specifications.
- ❑ Unify model call standards.
- ❑ Provide standardized applications for model call calculations.



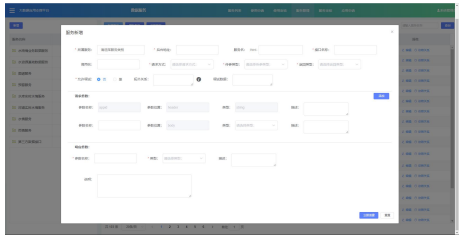
Service inquiry



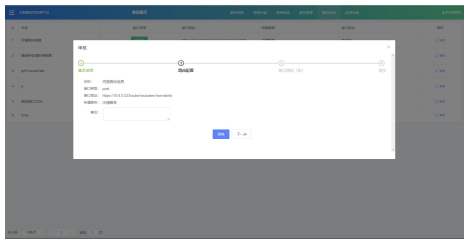
Interface details



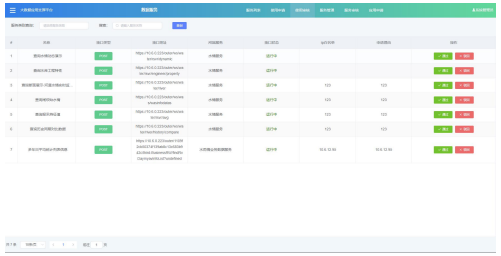
Interface application



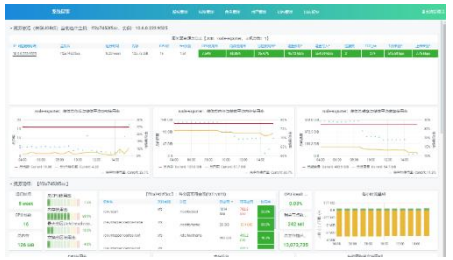
Service registration



Service audit



Interface audit



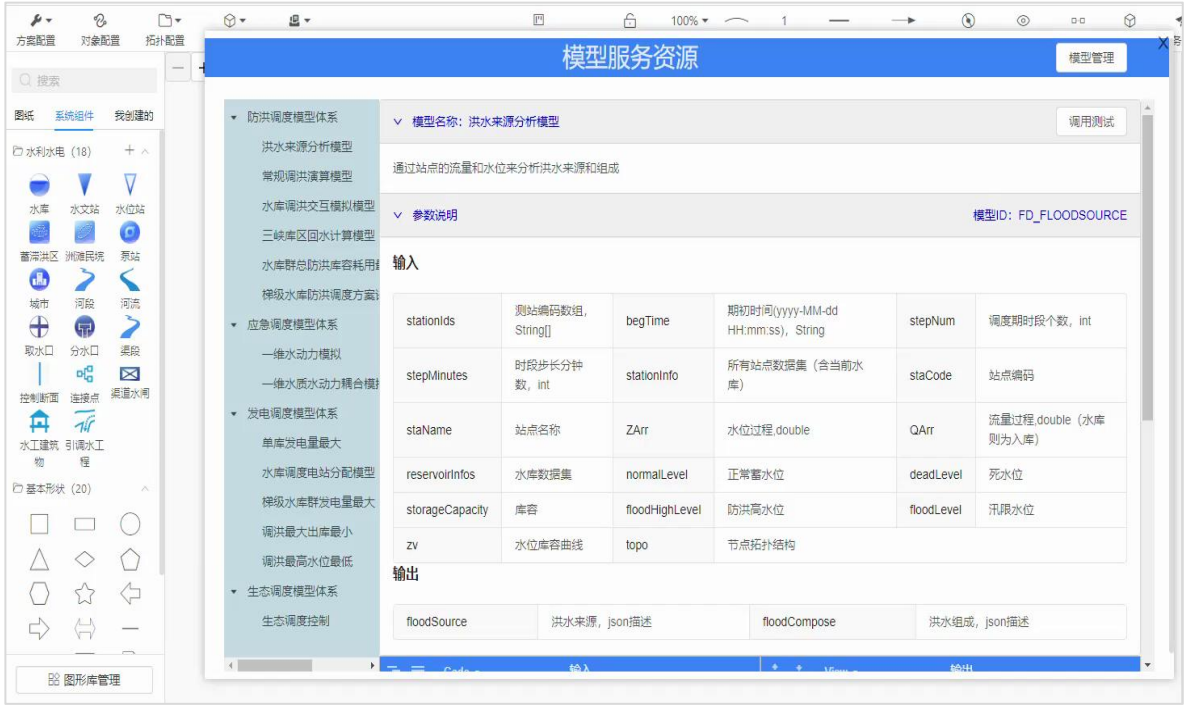
Statistic analysis

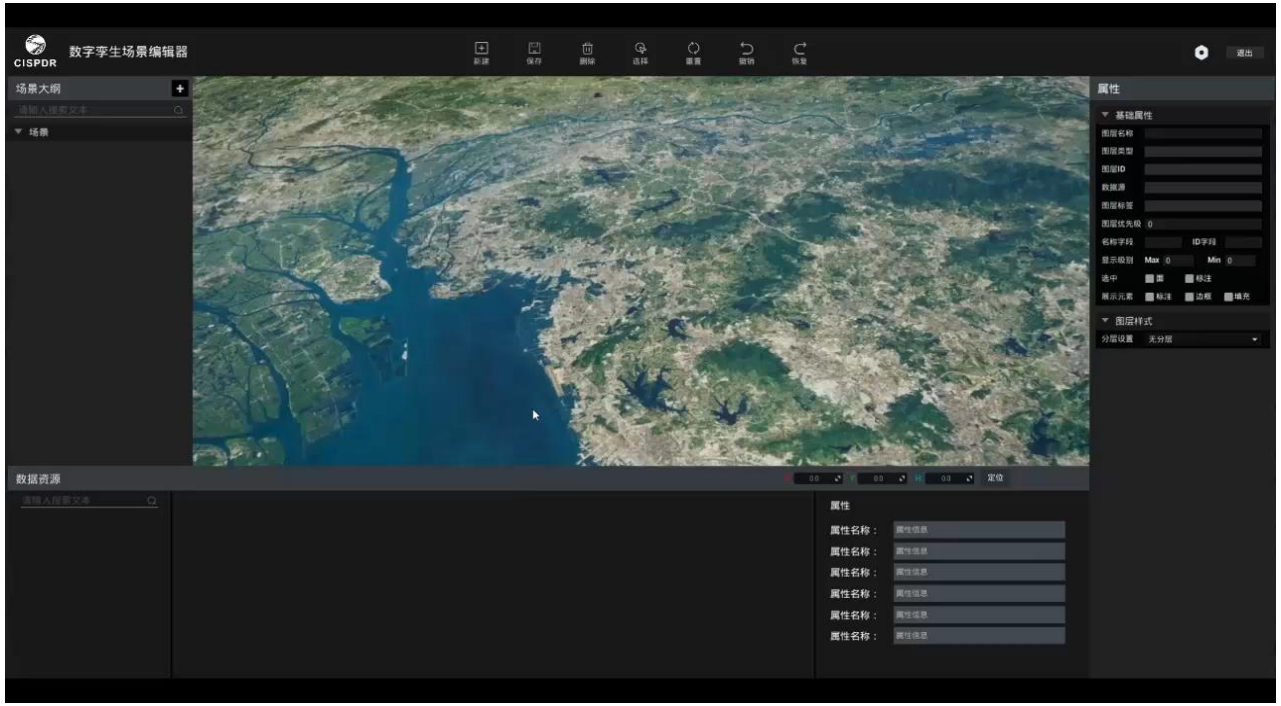
Service Link Tracking

Digital Twin development platform

building blocks

In order to respond to the needs of **fast changing requirements**, a DTR should have efficient and fast building technology to develop systems, applications and scenario, like **building blocks**.

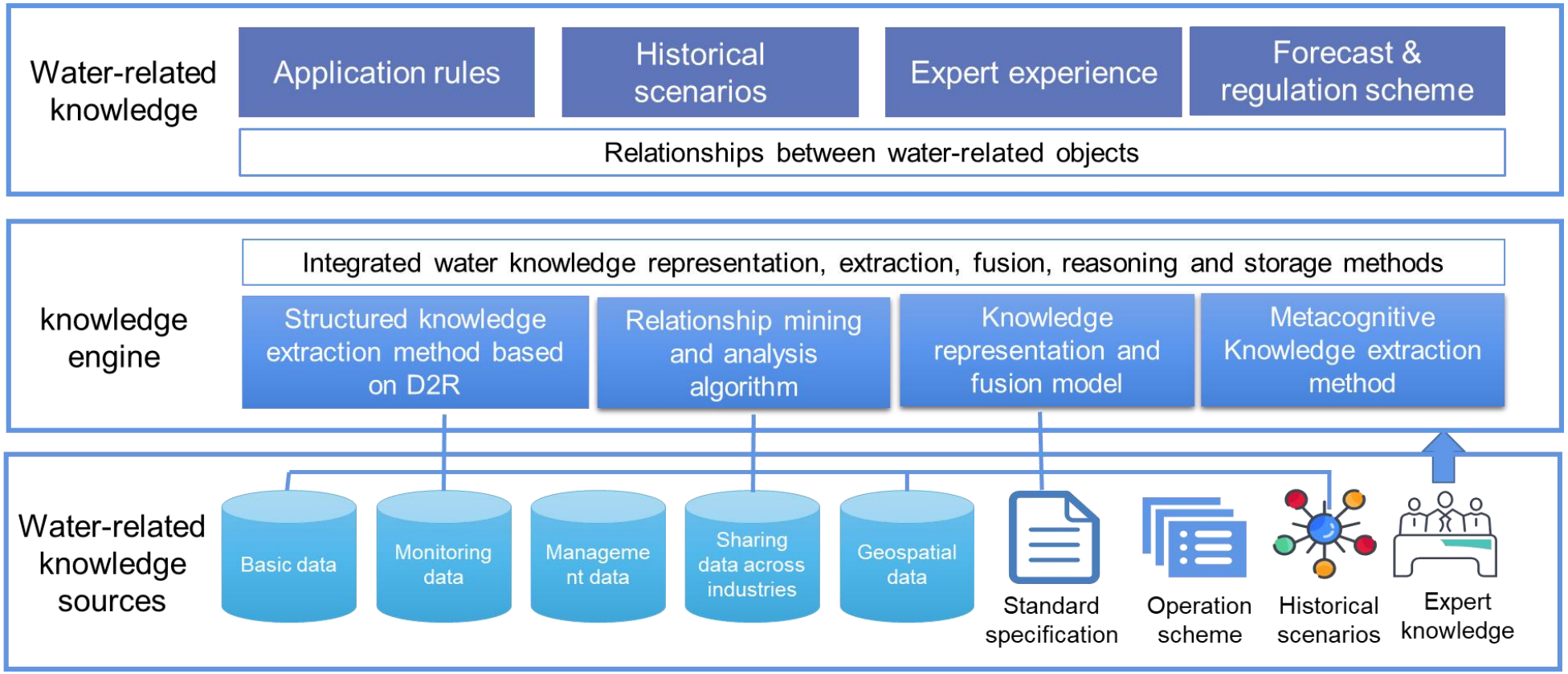




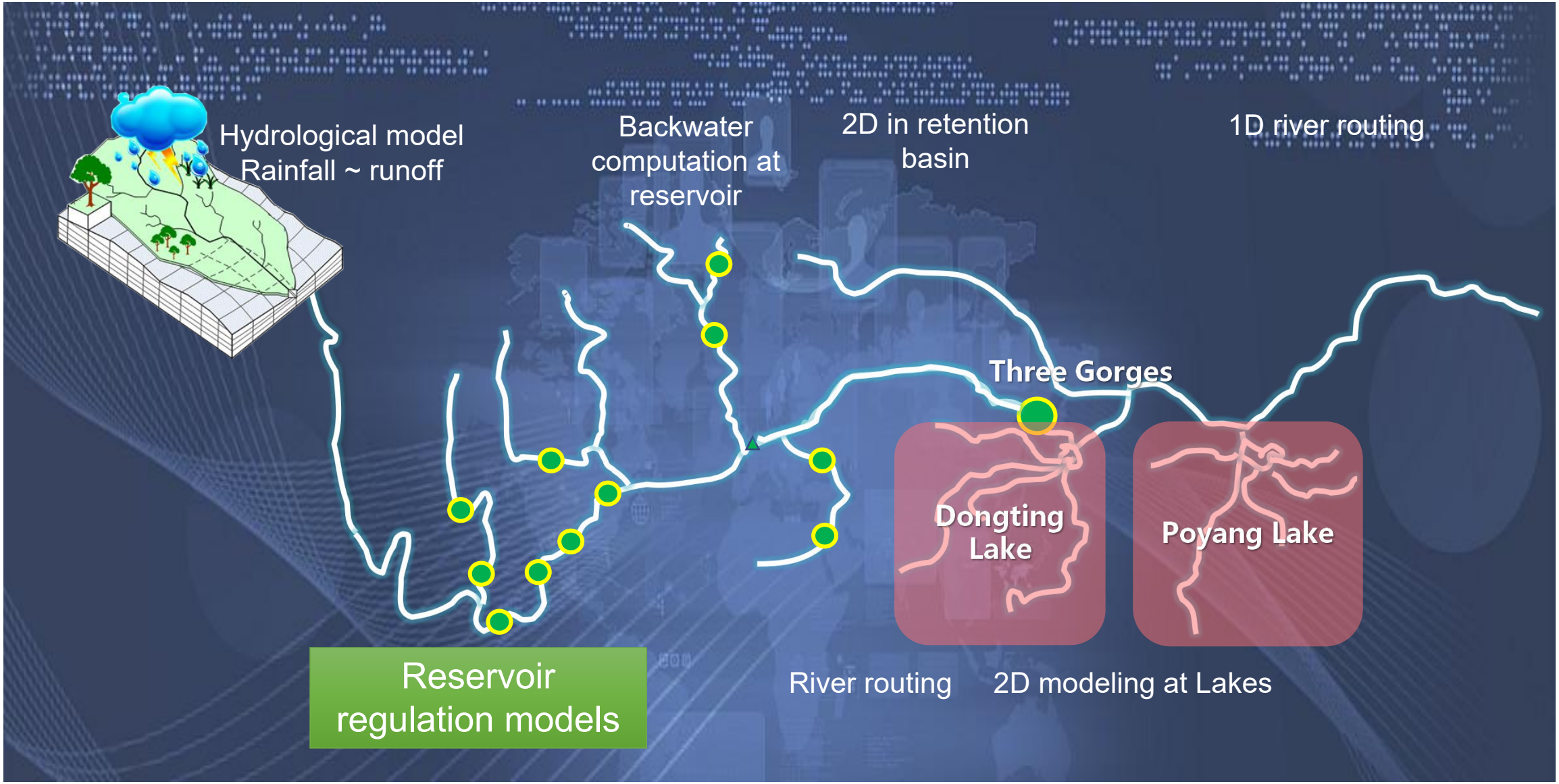
Knowledge & knowledge Platform

Architecture of Knowledge platform – Knowledge + engine

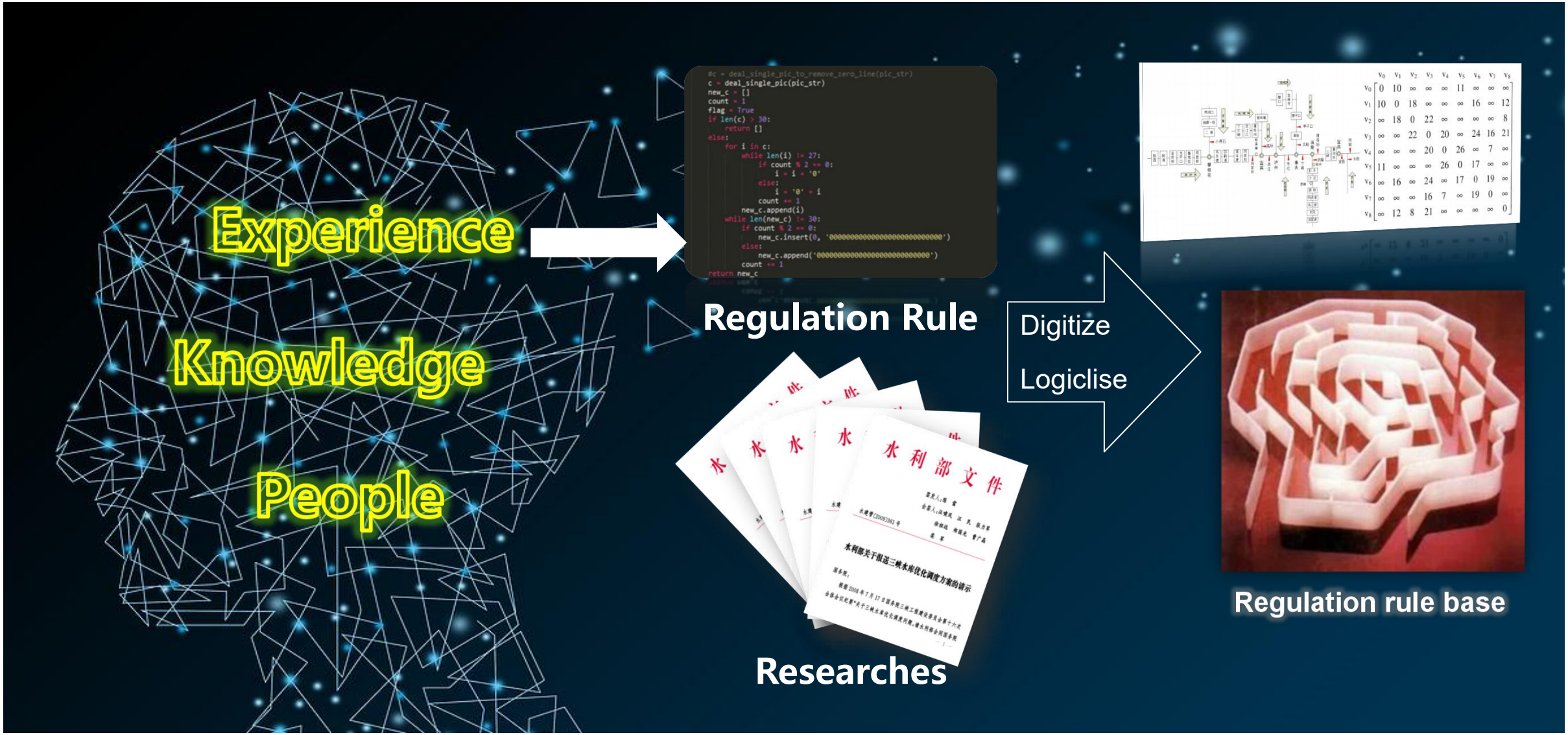
- **Water knowledge:** laws, experiences and rules of water management that are digitized and logicalized using technologies such as **knowledge graphs,** machine learning etc., which allows the system to “think” – like playing rules for ***alpha go***.
- Water knowledge is organized and reasoned by the **knowledge engine** to form information supporting research and decision-making.



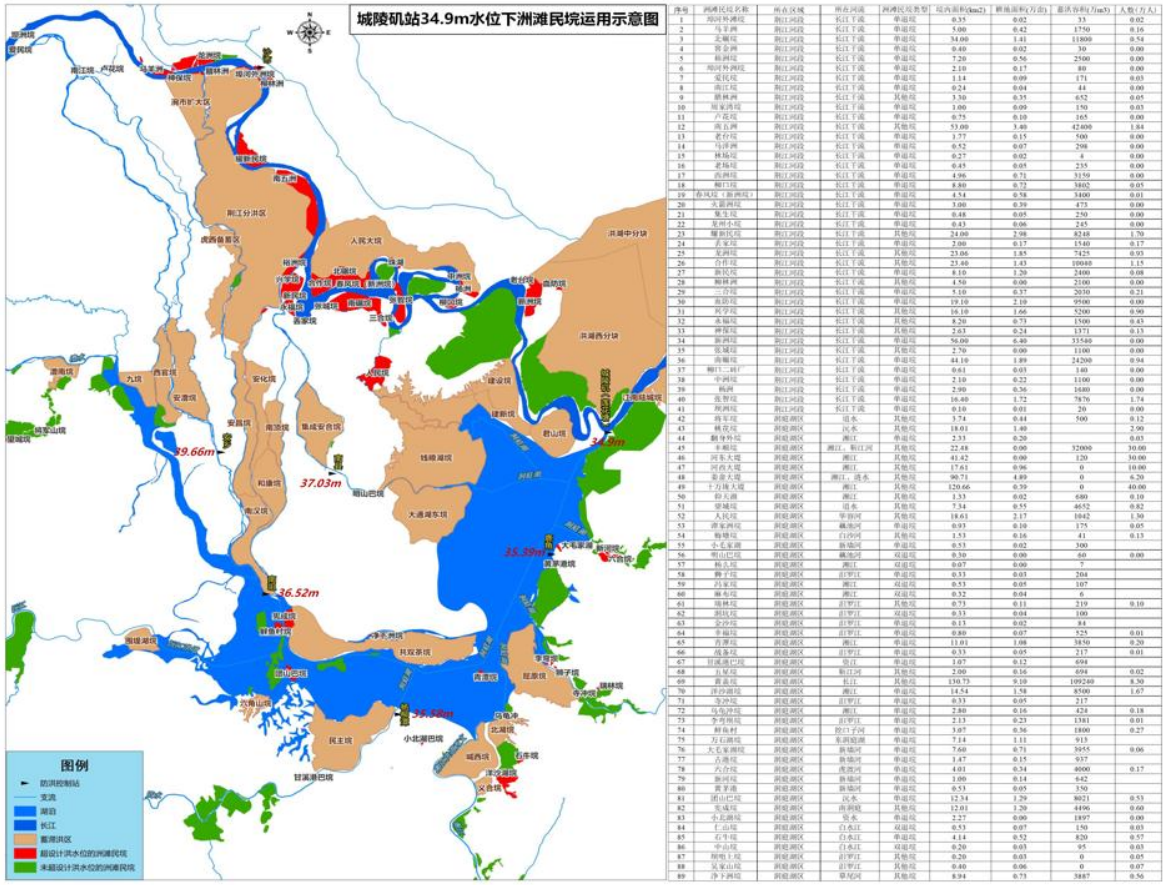
The core of AI is physical rules



Develop reservoir regulation base using knowledge graph - AI

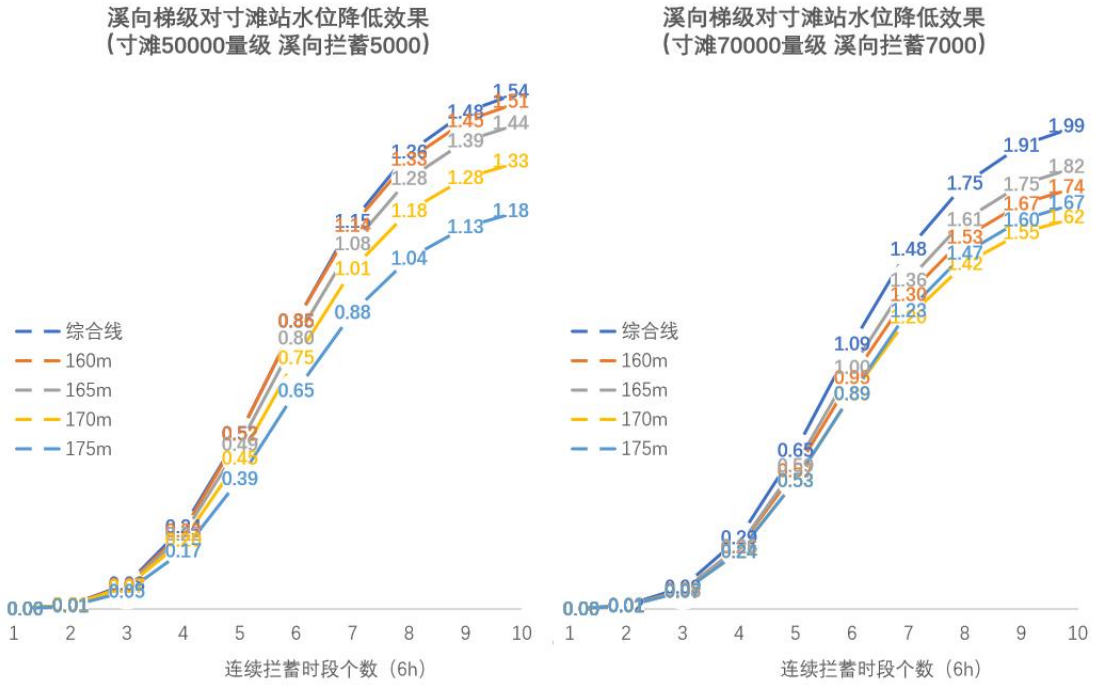


Regulation effects assessment model



Affected areas for water level at Chenglingji station of 34.9m – quick assess to flood risk

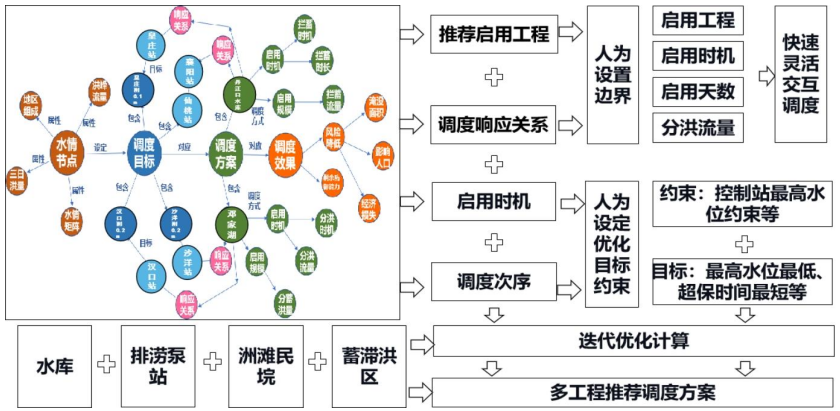
- Objective: Assess effects of regulation of Xiluodu and Xiangjiaba reservoir on Cuntan Station
- Method: run models with historical floods and obtain its effect curve



Regulation ~ Effects curve

Knowledge-base development result – regulation rule-base

- Based on knowledge graph technology, a water engineering regulation rule base with Danjiangkou Reservoir as the core is constructed
- Constructed a regulation impact relationship map for the Danjiangkou Reservoir and flood storage embankment
- Taking into combined consideration of short-term and middle term flood predication, it can support the regulation scheme at short-term (3-5 days) and regulation strategy at longer term (7-10 days)



Develop Smart river with core of DTR/DTP

- Hydro-meteorological forecasting & early warning
- Intelligence - digitized regulation rules
- Real time multi-scenario analysis & dynamic risk assessment

Core – develop water engineering knowledge

Flood management knowledge

- Rule-base using knowledge graph technology, based relationship between retention basins ~ protected areas

- Assess and reallocate risk / flood water based on risk propagation characteristics following the risk-chain and coupling with machine learning technology.

Intelligent regulation

Automatic regulation according to rules

Computer alone

Interactive regulation

Man + computer

Optimization according to goals

Computer receives goals and applies optimization procedure

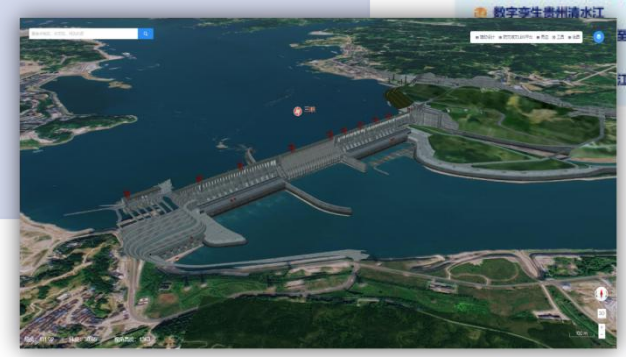
Pilot studies of digital Changjiang River

Digital Twin rivers - 2

- Hanjiang River Basin
- Lishui River Basin

Digital Twin Engineering Projects - 4

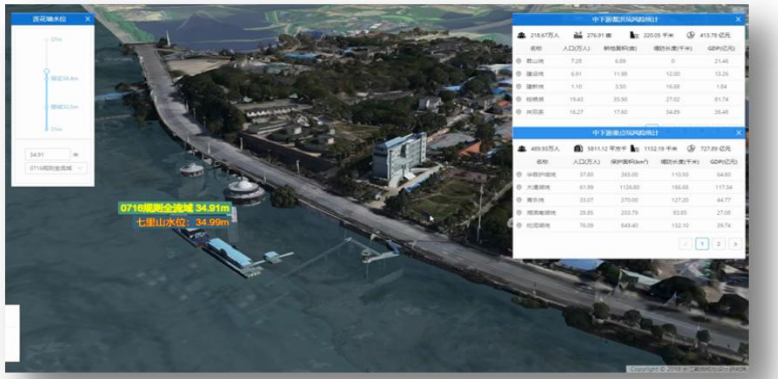
- Danjiangkou reservoir
- Jiangya, Zaoshi reservoir
- Three Gorges Project



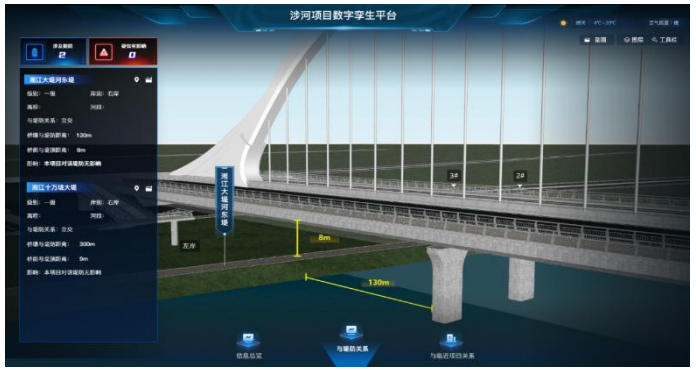
Flood + dam safety + operation + DSS

Three Gorges Project

Flood management



Dam safety



Management of reservoir storage

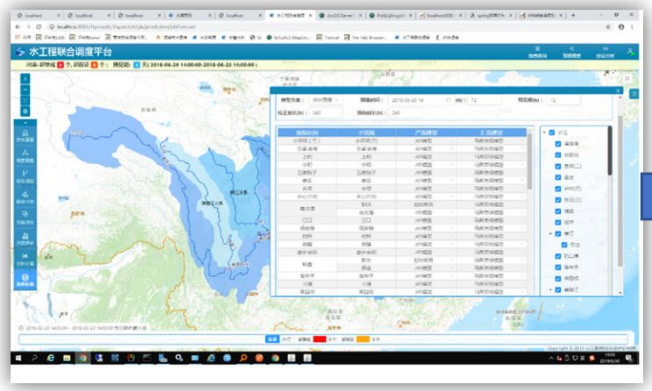
Water quality management

Ecology restoration

Monitoring of construction projects

Link the interfaces between old and new systems

The new system invokes the existing system



The existing system

The new system

Digital Twin Changjiang

Evolution into future system


谢 谢
THANK YOU