IHI Project:

Title Resilient water management modeling against global warming and for sustainable food supply

Industrial Partner IHI Corporation (https://www.ihi.co.jp/en/)

IHI Corporation (formerly Ishikawajima Harima Heavy Industries Corporation) is a comprehensive heavy-industry manufacturer, with a history extending back to the establishment of Ishikawajima Shipyard, Japan's first modern shipbuilding facility, in 1853. The technology which began with shipbuilding has been passed on to develop and improve social infrastructure and industrial machinery, with expansion of the IHI Corporation business domain from sea to land and space. We will continue to respond flexibly to social changes and to aim for sustainable development.

Industrial Mentors
Shohei Koga*[1],
Fumio Hasegawa*[1],
Masao Ono*[2],
Kimiaki Yoshida, Ph.D.*[2]
*[1] Social Infrastructure Business Area, IHI Corp., Japan
*[2] Technology & Intelligence Integration, IHI Corp., Japan

Background

Global warming creates many severe and diverse problems worldwide. Climate change is progressing rapidly, causing frequent floods and droughts in many regions. Present and future changes of precipitation (Fig. 1) are expected to cause additional and increasingly intense floods and droughts. Floods are caused by abnormally high rainfall. Rising temperatures caused by global warming increase the moisture content of the atmosphere, which exacerbates torrential downpours. Droughts, by contrast, are caused by increased evaporation attributable to long-term decreased precipitation and increased temperatures. Water shortages are becoming increasingly severe.

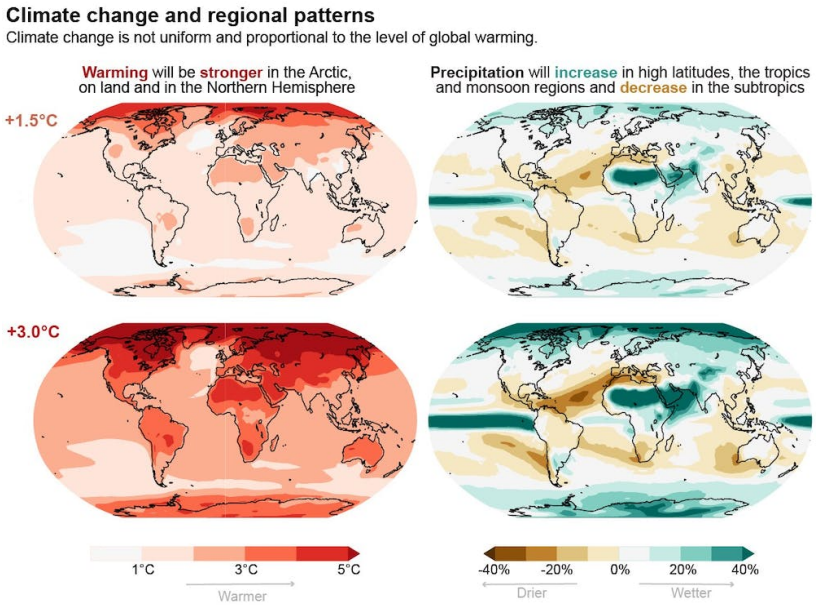

Figure 1. Projected annual average precipitation.

(Source: IPCC Sixth Assessment Report)

For adaptation to this precipitation change, water management becomes crucially important. Specifically addressing water junctions, water circulates mainly in river basins as surface water and groundwater through the process of evaporation, descent, flow or infiltration to the sea area (Fig. 2).

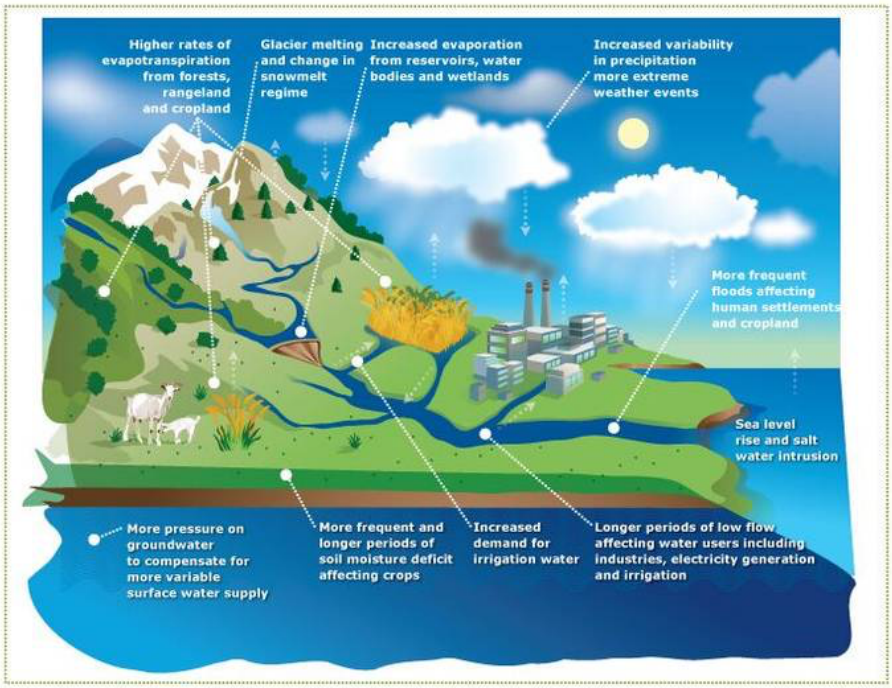

Figure 2. Impact on water supply and demand.

(Source: https://www.fao.org/climate-smart-agriculture-sourcebook/production-resources/module-b6-water/chapter-b6-3/en/)

River basins are dotted with dams, rivers, farmlands, factories and houses, gates for supplying and discharging water to them, pumps, and other installations. Water is used for various purposes. In terms of water use, water is supplied by organizations and individuals who adjust gates to distribute water over large areas from scarce sources. Most of the gates are operated manually, with on-site operations and adjustments made while monitoring water levels downstream. Consequently, most gate operations are based on intuition and experience, with gates operated based on historical methods and data while moving from one gate to another in scattered locations (Fig. 3).

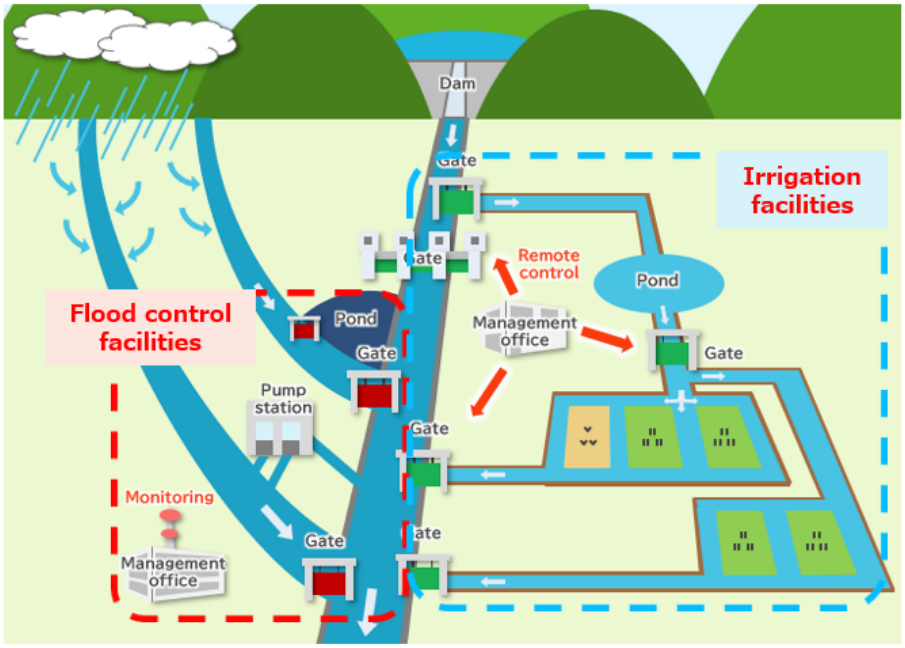

Figure 3. Diagram of water control facilities.

Various issues related to gate and pump operations to prevent flood damage arise during heavy rainfall events. For example, at the confluence of a main river and its tributaries, gates that are normally open are closed when water flows back from the main river, but this operation is conducted while observing the situation on site during heavy rains, which is a dangerous operation.

Nevertheless, the operators of the respective facilities are not unified: they operate according to their own objectives, which results in a lack of overall optimization. In many cases, a surplus of water occurs in one place, but shortages occur in another. Alternatively, water might overflow in one place when it can still be stored in another. Bountiful surpluses and crushing shortages can be expected to occur at different times and places.

Given this background, optimizing gates and pumping facilities in watersheds can be expected to alleviate both flooding and drought difficulties and to contribute to addressing global warming and to ensuring stable food supplies.

Technical Background

River basins are dotted with gates and pumping stations. In many locations, a "water management system" is in place to monitor conditions. Some facilities can be operated remotely (Fig. 3). This system collects water level data at various locations and records the opening and closing status of gate facilities. Water level information can be converted to a flow rate where a water level and flow conversion formula is available.

To improve water management efficiency, IHI Corporation has developed a simulation model to recommend which sluice gates should be operated and how they should be operated to distribute water efficiently in a certain area. The model is constructed based on where and what kind of sluice gates are installed. Moreover, the model is optimized to minimize the excess or deficiency of water. As the next step, IHI is striving to expand the simulation model worldwide to reduce water supply stress. Building the simulation model is a time-consuming process. It also makes global expansion difficult. It is important to recommend optimized operations using existing open data and information that are already available for water management systems.

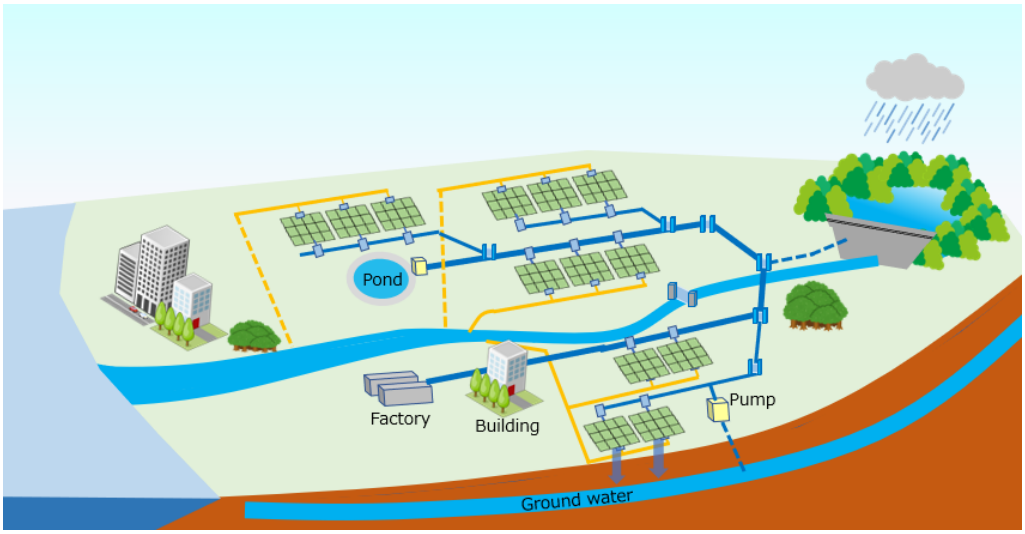

Figure 4. Gate control in a river basin.

Project and Expectations

The project goal is to suggest optimized gate operation to improve water use efficiency using data from the water management system. First, to elucidate the conditions, the relation between the degree of gate opening and the water level and the flow rate is identified using available data in places where no such relation has been reported. In addition to the degree of gate opening, water supply and drainage by pumps and other devices also affect the water flow, so the equation is identified by taking these factors into account as well. For places where no information related to the gate opening degree exists, it is necessary to estimate the degree of gate opening in response to changes in the water level and flow rate. After these operations, the gate operation (opening degree) can be optimized according to each purpose, such as minimizing water use and water shortage to

zero from the viewpoint of water utilization, or minimizing flood damage downstream from the viewpoint of flood control.

The following is a summary of the project.

Input: Water management system data (water level, flow rate (conversion), gate operation data where available). * Some data are unknown.

Output:

(1) Identification of the relation between gate opening degree and water level/flow rate in a wide area, considering factors such as pumps.

(2) Estimation of the degree gate opening corresponding to changes in the water level and flow rate (where no information about the degree of gate opening is available)

(3) Optimization of the degree gate opening according to the purposes of water utilization and flood control

Requirements

- Required Knowledge：

  - Programming skills (Python is preferred).

- Recommended Knowledge：

  - Knowledge of time-delayed control systems

- Preparation：

  Familiarize yourself with the contents of the following websites:

  – Basic knowledge of water flow

  https://phys.libretexts.org/Courses/University_of_California_Davis/UCD%3A_Physics_7B_-_General_Physics/5%3A_Flow_Transport_and_Exponential_-_working_copy/5.03%3A_Fluid_Flow

  - Basic knowledge of water resources

  https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014WR016869