Featured Articles

Information and Control Systems to Support Planning, Operation, and Maintenance Activities for Sustainability of Water Supply and Sewage Facilities

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OVERVIEW: Water supply and sewage are the parts of the social infrastructure that deal with the water that is essential to life. In addition to providing safe, secure, and trouble-free access to water, these systems are part of the water cycle and need to take account of water's role in the environment, including biodiversity. To satisfy these diverse needs, Hitachi has a track record of supplying systems and solutions for water supply and sewage that are based on information and control technology. In addition to the monitoring and control functions associated with routine equipment operation, Hitachi is also utilizing operational data accumulated by the systems and pursuing the ongoing development of technologies that contribute to water supply and sewage infrastructure throughout its life cycle, including equipment planning and maintenance.

INTRODUCTION

WATER supply and sewage systems are essential parts of the infrastructure for maintaining life and social activity, as well as for protecting water ecosystems. In Japan, meanwhile, where a large amount of infrastructure installed during the country's period of rapid growth is coming due for replacement, there is a need for planned upgrades to keep water supply and sewage services operating. Also, more effort is needed to ensure the actual and perceived safety of water in the environment, with recent threats to the environment including the Great East Japan Earthquake of 2011 and the detection of formaldehyde in the Tone River system in 2012, which led to water supplies being shut down. On the other hand, water supply and sewage services need to proceed with a variety of initiatives in the face of a difficult business environment, with pressure on finances arising from the prospect of a falling population and the diminishing availability of experienced staff.

With reference to these circumstances, the Ministry of Health, Labour and Welfare published its "New Water Supply Vision" in March 2013, summarizing the directions to be followed by the water supply industry in the future in terms of safety, resilience, and sustainability[(1)]. The Ministry of Land, Infrastructure, Transport and Tourism meanwhile published a document on sewage, entitled "New Sewerage Vision," in the summer of 2014.

Hitachi has been supplying systems that utilize control and information technologies, and the fusion of the two, to meet these evolving requirements[(2),(3),(4)].

This article describes the component technologies for information and control and the latest activities relating to system technologies that improve the efficiency of water supply and sewage services through each phase of their life cycle, from planning to operation and maintenance, and that maintain the health of water ecosystems.

In component technologies, this includes a review of the technologies used in Hitachi's information and control systems, particularly those for extending services over wider areas. For the operational phase, the article describes a water supply operation system, water distribution control system, and a nitrification control system for sewage treatment. These system technologies are implemented on an information and control system platform and provide control techniques to satisfy requirements for saving energy, cutting peak power demand, and reducing the environmental load. For the maintenance phase, the article describes an asset management system and the pipe network management system. These provide techniques for utilizing information collected during maintenance in the planning phase (see Fig. 1).

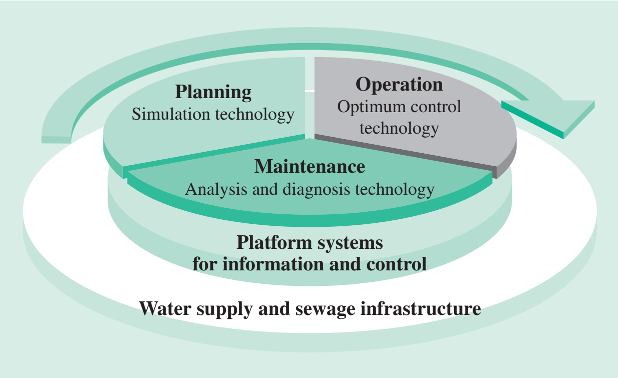

Fig. 1—Information and Control Systems to Support Planning, Operation, and Maintenance.
Hitachi deploys a wide variety of system technologies for use in planning, operation, and maintenance based around component technologies for information and control.

PLATFORM SYSTEMS FOR INFORMATION AND CONTROL WITH WIDE-AREA COVERAGE

Based on the underlying concepts of scalable architecture, seamless operation, and human-machine interfaces (HMI) that support operations, Hitachi has made ongoing functional enhancements to its information and control systems. The following sections describe two of these technologies that help extend services over wider areas. The first of these is the use of the domains concept by platform systems, the second is platform system for web services, which uses digital devices to provide ways of sharing information.

Making effective use of information spread over a wide area is essential for the application of system technologies to the operation, maintenance, and planning phases. This is a challenge that information and control systems needed to overcome.

Use of the Domains Concept for Monitoring and Control over Wide Areas

Along with being implemented in stages across a number of fiscal years, monitoring control systems for water supply and sewage require centralized management through the integration of these systems for a variety of different equipment in order to achieve wide-area coverage. In many cases, however, this has proceeded no further than connecting monitoring control systems together via a network and passing process input and output signals between systems, with the sharing of information from monitoring control system databases (message history and trend

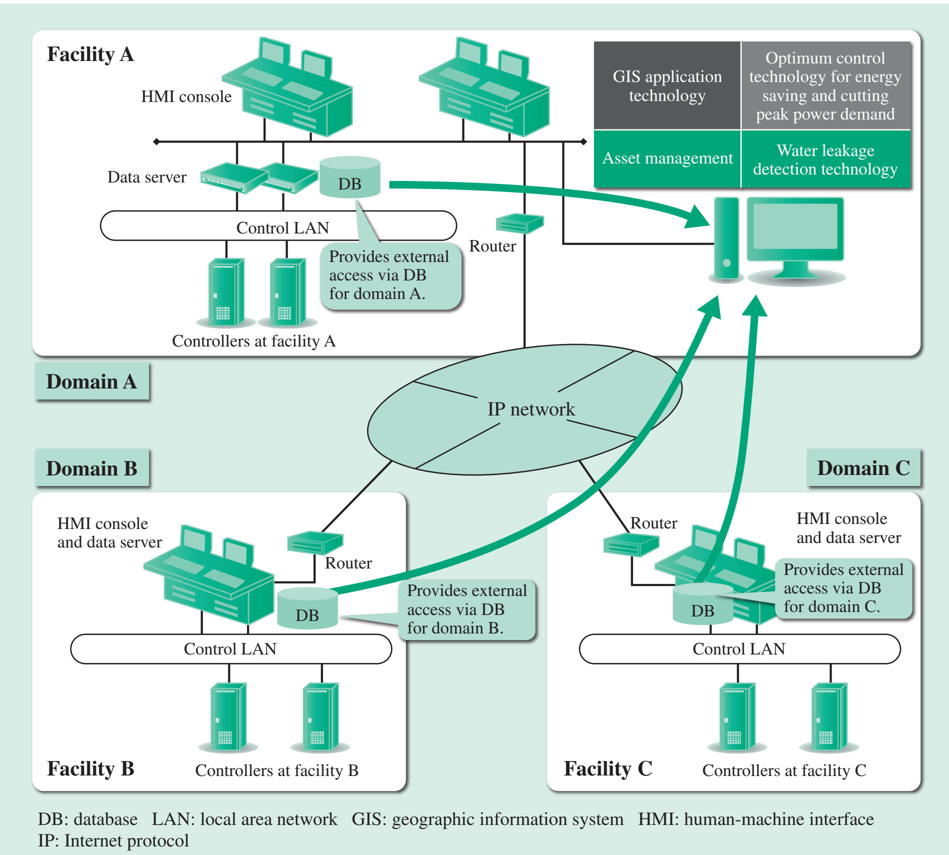

Fig. 2—Use of Domains for Wide-area Monitoring and Control.
Dividing the network into domains makes it possible for systems to access each other's databases. It also provides information systems with efficient access to databases spread over a wide area.

database) having proved difficult. Accordingly, utilizing operation, fault, trend, and other information held by the monitoring control systems for each item of equipment in an integrated system results in inefficient system maintenance because it requires the configuration of separate databases of the same type based on process input and output signals collected via a communications system, and duplication of software administration.

To overcome this problem, Hitachi's platform systems for information and control have adopted the concept of domains in their middleware layers. Here, a domain means a section of the network that is managed as a single entity. By assigning a domain identification number to the monitoring control system for each item of equipment, the equipment monitoring control systems are able to access each other's databases (message history and trend database), including process input and output signals (see Fig. 2).

Use of Digital Devices for Information Sharing

The platform system for web services can distribute operational and management information to a wide variety of devices, including widely used consumer products ranging from desktop personal computers to smart devices such as smartphones and tablets.

When operation and management cover a wide area, geographically dispersed facilities need to be managed efficiently by a limited workforce. Smart devices can be useful monitoring tools for staff who visit sites around the area being managed. Since they include a function for sending e-mail notifications of faults in important equipment, they are also useful in times of emergency when speed is critical. Another feature is their ability to connect to the Internet, which means their use is not restricted just to the intranet of the water supply or sewage service operator. This opens up the potential for a number of operators managing wide-area services to exchange information (see Fig. 3).

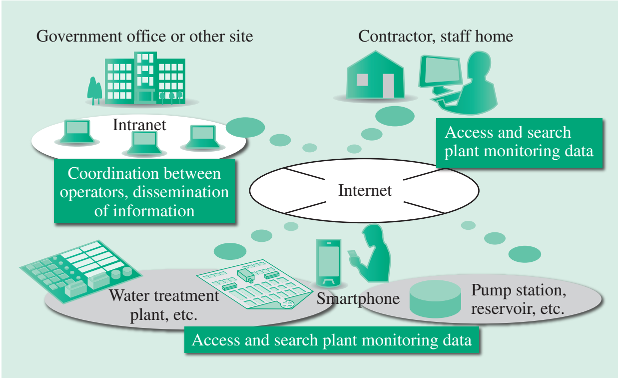

Fig. 3—Use of Smart Devices and the Internet.
This contributes to rapid decision-making by sharing information from monitoring control systems. Mobility is also improved through the use of smart devices.

OPERATIONAL TECHNOLOGIES THAT TAKE ACCOUNT OF ENERGY AND WATER ENVIRONMENT

Water Operating Plan and Water Distribution Control System

Water supply operation systems and water distribution control systems are two solutions that help save energy and ensure reliable water supplies (see Fig. 4).

Water supply operation systems are used by water distribution networks made up of a number of water treatment plants and reservoirs. They produce a daily plan for the water treatment, intake, and distribution volumes needed to satisfy that is forcasted based on information such as weather conditions, the turbidity of incoming water, and equipment condition. They can use multi-objective optimization techniques to generate plans that balance trade-offs such as between ensuring reliable operation and reducing environmental load(5).

Because they can generate operating plans that smooth pump operation by taking advantage of the buffering capabilities of reservoirs while ensuring that they stay within their upper and lower limits, these systems can also help shift or cut peak demand for electric power by water services, which are major consumers of electricity.

Water distribution control systems ensure that the treated water stored in reservoirs is delivered to users efficiently. Water pressure needs to be managed appropriately. If the pressure is too high, it wastes energy and increases leaks, and if the pressure is too low, it reduces the flow rate at the point of delivery. The system uses an online pipe network simulation for the dynamic detection of locations where the pressure is low, and then responds by adjusting valves or pump discharge pressures to restore the required pressure. This keeps water distribution pressures at appropriate levels despite changing demand.

These systems have been installed in waterworks utilities in Japan and are helping ensure reliable supply and energy savings. Functions are also under development for maintaining appropriate operation across the entire process, from water intake to delivery,

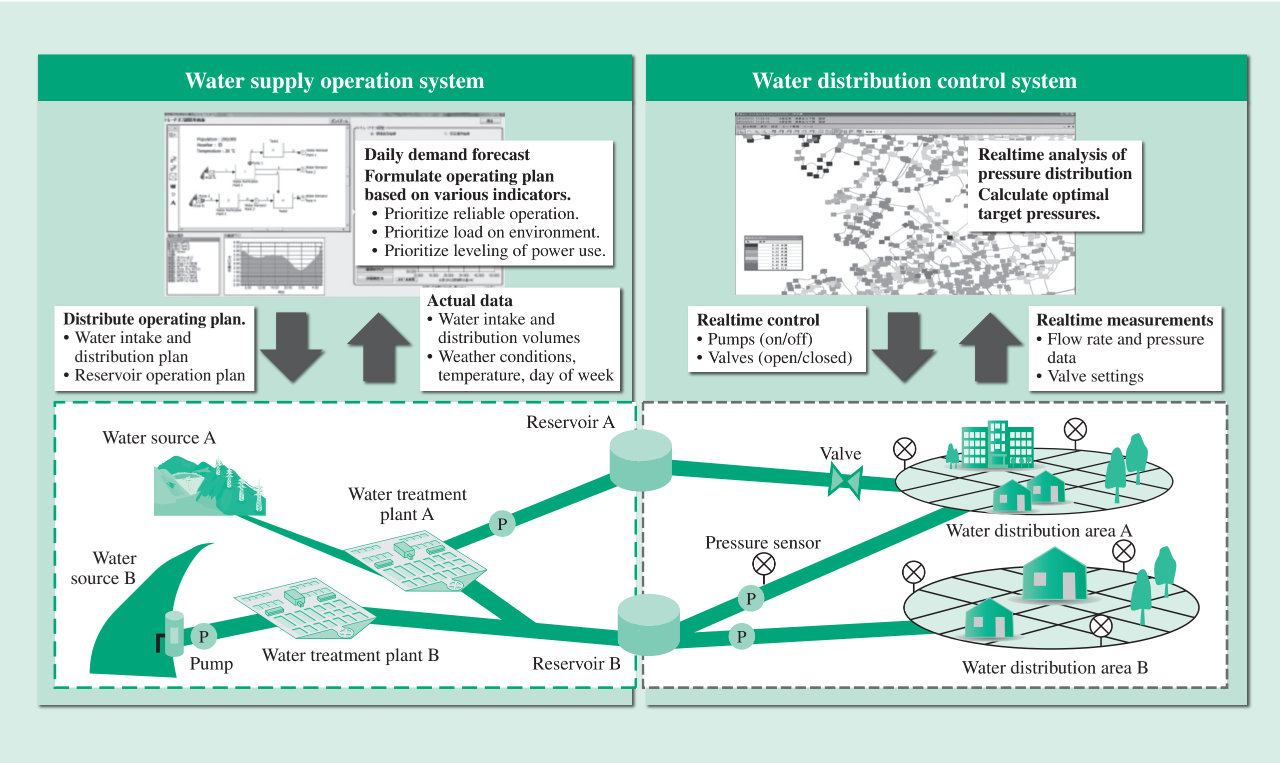

Fig. 4—Water Supply Operation System and Water Distribution Control System.
These systems provide solutions for water distribution networks that contribute to saving energy and to the intake, distribution, and reliable delivery of water.

through the interoperation between the water supply operation and water distribution control systems. These should achieve even higher levels of reliability and energy savings.

Sewage Nitrification Control System for Reducing Environmental Load

"New Sewerage Vision" includes references to both reducing the load on the environment by cutting carbon emissions and the need to protect the water environment(6). This means that there is a need for sewage treatment process technologies that can save energy and cut carbon emissions while also improving water quality.

Nitrogen removal, one of the issues associated with protecting the water environment, consists of nitrification and denitrification. The nitrification process involves oxidizing ammonia nitrogen to nitrate nitrogen in the incoming wastewater. This consumes electric power because it uses blowers for aeration to provide the required oxygen. Accordingly, optimizing nitrification through precise control of the blowers is one way to save energy and improve water quality.

Hitachi has developed a system for determining the appropriate air flow rates. The system calculates separate target air flow rates for the upstream and downstream sides using not only a standard dissolved oxygen (DO) sensor at the end of the aerobic tank, but also two ammonia sensors located respectively at the mid-point of the aerobic tank, and at a further upstream side of the aerobic tank. This system performs nitrification control in a way that considers not only the target for ammonia concentration in the treated water, but also a target for the mid-point of the process. This stabilizes the process and minimizes over- or under-aeration, reducing blower power consumption while also maintaining water quality. The upstream air flow rate is calculated based on the measured upstream ammonia concentration and the target mid-point concentration. The downstream air flow rate is calculated based on the measured mid-point ammonia concentration, flow rate, and DO measurement.

Commissioning time can be shortened by using a sewage water quality simulator to set the initial control parameters for the calculation. Maintainability can also be improved by adding a function for automatically updating the control parameters based on actual measurements, which eliminates the need to tune the parameters again over time (see Fig. 5).

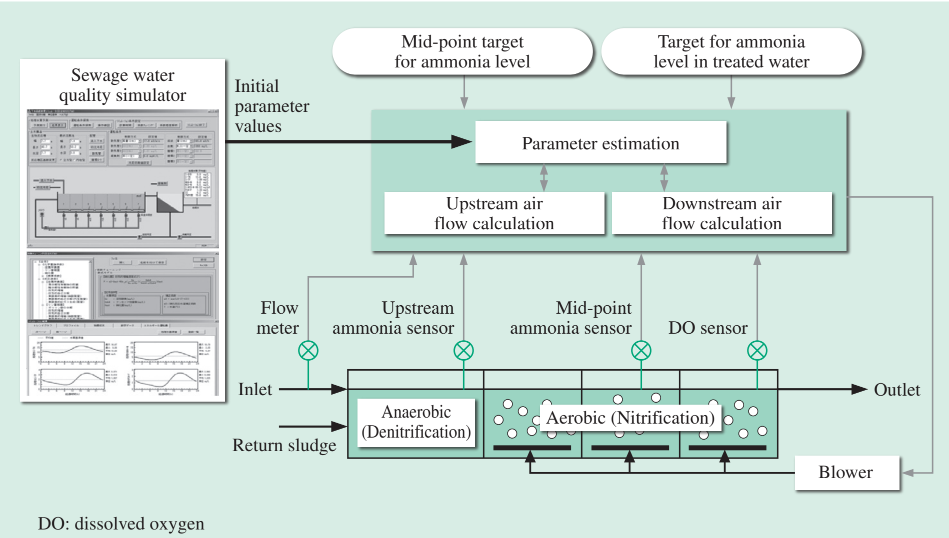

Fig. 5—Sewage Nitrification Control System with Low Environmental Load.
The system controls the air flow to reduce blower energy use. This is done by adding ammonia sensors and calculating the required upstream and downstream air flow rates. Maintainability is also improved by automatically updating parameters based on actual data. To shorten commissioning time, the initial parameter values are obtained using a sewage water quality simulator.

SYSTEM TECHNOLOGIES FOR MAINTENANCE AND REPLACEMENT PLANNING

In Japan, which is entering an infrastructure maintenance phase, replacement planning is also an important part of planning work. This section describes system technologies that make routine maintenance more efficient, and in doing so also make available collected information for use in replacement planning.

Asset Management System

With expenditures on replacements expected to rise as the water supply and sewage infrastructure installed during Japan's era of rapid economic growth approaches the end of its expected service life, its replacement needs to be undertaken in a planned and appropriate manner with limited resources. Accordingly, water supply and sewage service operators need to adopt asset management practices to formulate medium to long-term replacement plans.

Asset management consists of (1) obtaining the necessary information, (2) micromanagement, (3) macromanagement, and (4) utilizing forecasts for replacement demand and financial position.

Micromanagement consists of (1) determining the requirements for existing facilities in terms of factors such as their performance and soundness, (2) inspecting each facility, (3) evaluating the soundness and other facility performance criteria based on the inspection results, (4) predicting future expenditures based on the performance evaluation, and (5) repairing, reinforcing, or replacing equipment and facilities[7]. That is, micromanagement makes it possible to utilize the results of routine maintenance for purposes such as extending facility life or planning replacements. It is recognized as having a key role in working through the plan, do, check, and act (PDCA) cycle for asset management.

In response, Hitachi has developed a system for utilizing equipment management systems, records and other equipment information, operating histories from monitoring control systems, and machinery inspection data for micromanagement (see Fig. 6 and Fig. 7).

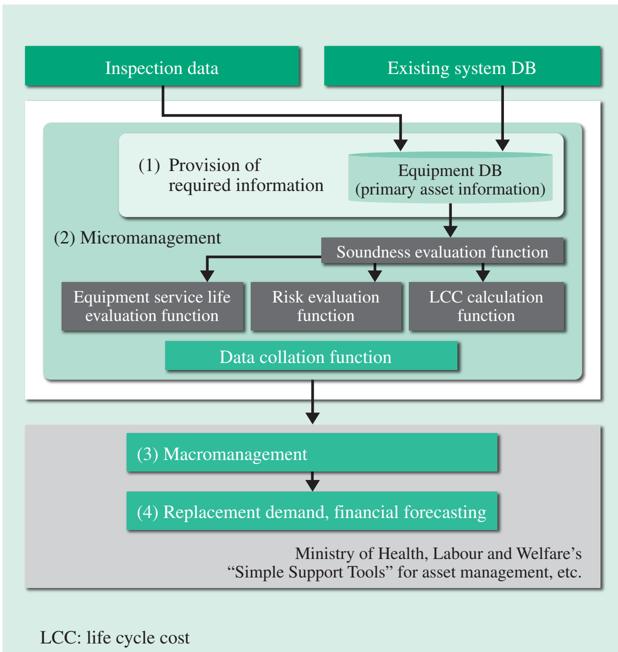

Fig. 6—Overview of Asset Management System.
The system allows micromanagement based on information such as inspection data or operational records from existing equipment.

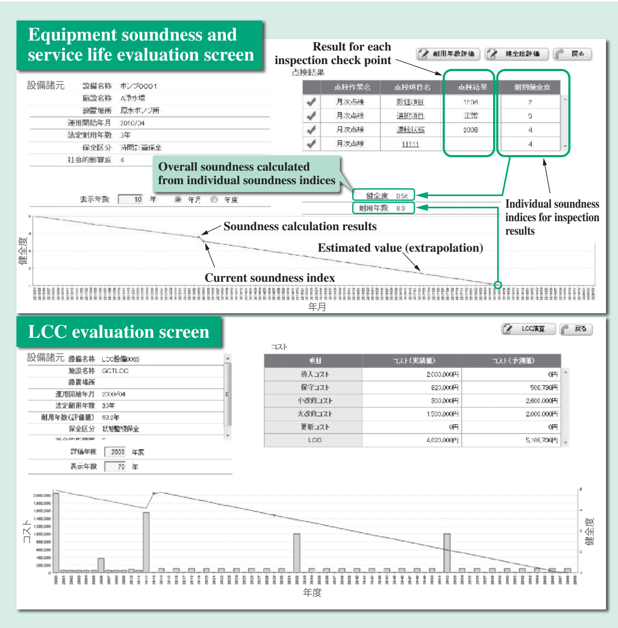

Fig. 7—Asset Management System Screens.
These screens are for equipment soundness and expected service life evaluation, and for LCC evaluation.

(1) Soundness evaluation

This involves calculating equipment soundness based on inspection data, where soundness is an indicator of an item of equipment's current condition. The procedure is to first obtain the individual indices for equipment condition from the results for each inspection check point, and then to use these to calculate an overall soundness index for the machine or item of equipment. The calculation can include not only quantitative inspection data but also qualitative assessments (such as normal/abnormal, or OK/suspect/NG).

The next step is to average the individual soundness indices to obtain the soundness of the entire equipment. The soundness is updated each time an inspection is performed and new data is obtained. Trends in equipment soundness can be assessed by plotting how this information changes over time.

(2) Expected service life evaluation

The expected service life of equipment is obtained by extrapolating how its soundness changes over time to determine when it will reach a level where the equipment needs to be replaced. When repairs are made to improve soundness, the expected life can be updated to take account of the maintenance work by extrapolating from data after the repairs.

(3) Risk evaluation

This evaluates the level of risk associated with an item of equipment by producing a risk matrix of its impact on society versus soundness. The risk level increases when the equipment is degraded due to a decrease in soundness. This risk level is used to prioritize equipment replacements.

(4) Life cycle cost (LCC) evaluation

The LCC is calculated from the sum of actual and predicted costs for installation, maintenance, repair, and replacement.

The system has a function to collate and output collected data. For example, it can produce the input data for the "Simple Support Tools" for asset management[8] published by the Ministry of Health, Labour and Welfare. Evaluations can be performed easily using these tools by inputting the generated information.

Pipe Network Management System

This system uses geographic information system (GIS) technology to manage the locations of the pipe network, water pumping plant, and other equipment spread over a wide area. It also handles attribute information such as dimensions and materials and improves the efficiency of water pipe network equipment management through functions like the examples listed below.

(1) Data statistics function: Uses location data to provide statistics such as supply and demand or incident frequency for different districts.

(2) Supply interruption display function: Uses simulations to determine in advance the effect of water supply interruptions caused by construction work or other incidents.

The functions for evaluating the risks to pipes include displaying the location of water leaks, the frequency of water leaks in each area, which pipes have similar characteristics to a pipe where a leak occurred, and pipes collated according to leak probability estimated from asset data. These functions support pipe replacement plans based on pipe risk.

Also, the various functions provided can utilize unified management of location-linked data such as consumer water use or measurements from monitoring control systems. The water distribution control system described above also utilizes GIS technology for realtime monitoring, with map-based display of analysis results and actual measurements of parameters such as pressures and flow rates.

There is also a system for estimating the distribution of water leaks that works by dividing the area of interest into virtual areas and using pipe network simulations, water pipe attribute data, equipment data,

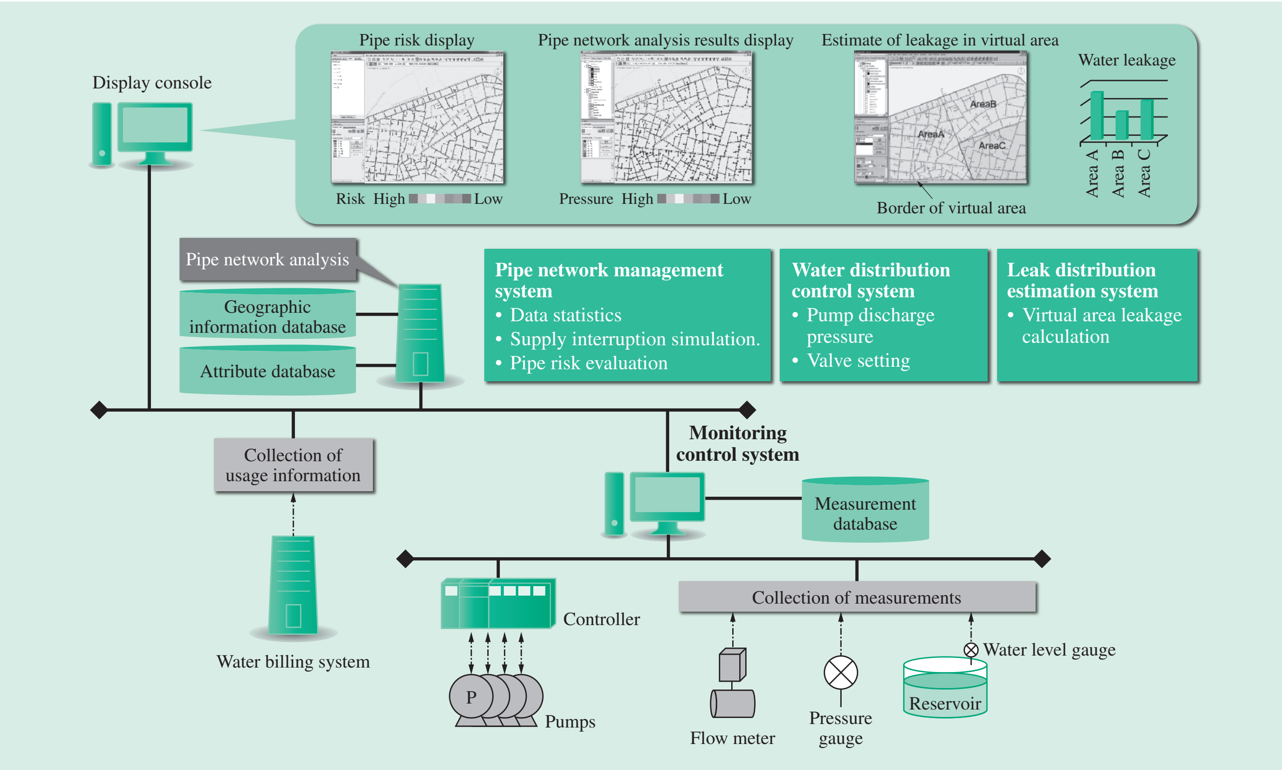

Fig. 8—Example of Integration of Pipe Network Management System with Other Systems.
Energy savings and more efficient maintenance are achieved by analyzing realtime measurements together with pipe network, position, and other data to optimize water distribution and estimate leaks.

and measurements to estimate the volume of water leaks in each of these areas. This can improve the efficiency of water leak investigations by using the amount of leakage in each virtual area to prioritize the order in which they should be investigated (see Fig. 8).

CONCLUSIONS

Hitachi is continuing to work on technical developments that utilize information and control system technologies to overcome the challenges faced by water supply and sewage services. This article has described work on component technologies for extending services over wider areas, and system technologies that include operational technologies for saving energy and reducing the load on the environment, an asset management system that helps smooth capital investment by formulating replacement plans with reference to equipment soundness, and a pipe network management system that provides comprehensive support for maintenance and replacement planning on water distribution networks.

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