# Dams in Japan
# Overview 2018

JCOLD

JAPAN COMMISSION ON LARGE DAMS

# CONTENTS

# Japan Commission on Large Dams

## History

In 1931, three years after the International Commission on Large Dams (ICOLD) was established, Japan joined ICOLD as the Japan National Committee on Large Dams. In 1944, Japan withdrew from ICOLD during the World War II, then rejoined in March 1953. On September 13, 1962, the Japan Commission on Large Dams (JCOLD) was established, and in January 2012, it became a General Incorporated Association.

## Operation

JCOLD is involved in operations such as surveys, research, international technology exchanges, etc. concerning large dams and related facilities (below, "large dams"), in order to improve the design, construction, maintenance, and operation of large dams and to contribute to the development of the Japanese economy. Responsibilities include:

(1) Collection of information, surveying, and research concerning large dams

(2) Exchange of technology and guidance concerning large dams

(3) Participation in ICOLD, assistance to its activities, and international exchange of technology concerning large dams

(4) Dissemination of and spreading awareness of the achievements of surveys and research concerning large dams

(5) Other activities necessary to achieve the goals of JCOLD

In recent years, JCOLD has actively conducted a program of surveys and research on methods of harmonizing dam development with the environment and on ways to mitigate their environmental impacts to achieve the sustainable development of dams.

## Organization

Under the leadership of the Chairman, there is a Planning Committee, Technical Committee, and Administrative Office. These committees undertake work in their respective areas.

## Membership

The members of JCOLD are incorporated bodies involved in dam construction. They include government bodies concerned with dam construction, electric power companies, survey and research bodies, academic associations, industrial associations, construction consultants, construction companies, and manufacturers (78 members as of January 2018).

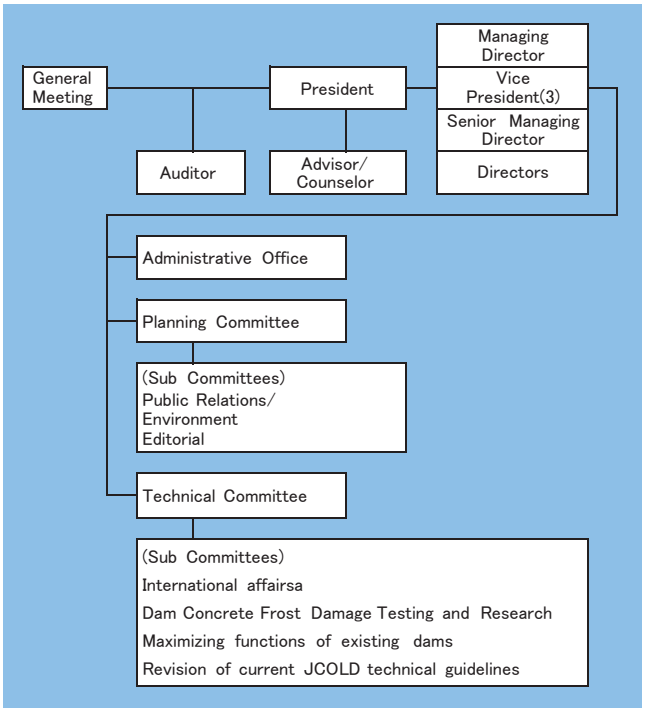



**Figure-1 Organization Chart of JCOLD**

## Publication

JCOLD publishes its Journal, “Large Dams”, four times a year (January, April, July, October), which is distributed to members and subscribers. At ICOLD Congresses held once every three years, JCOLD publishes Current Activities on Dams in Japan in English, which introduces the state of dams and dam technologies in Japan, and distributes it to Congress participants (1997, 2000, 2003, 2006, 2009, 2012 and 2015).

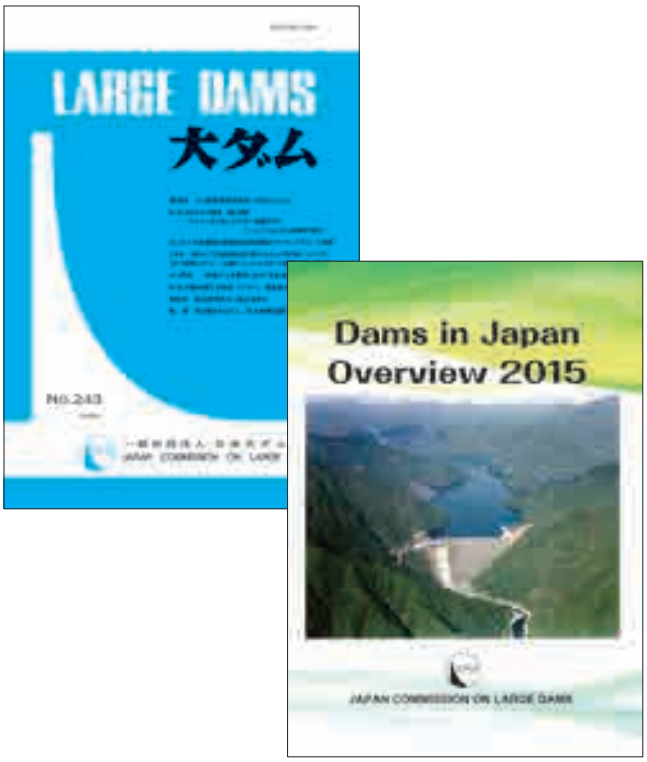



**Figure-2 Publicaitons of JCOLD**

## Annual lecture meeting

**Dam Technology Lectures and Discussion Meetings**

(Held jointly with the Japan Association of Dam & Weir Equipment Engineering)

At the meeting, the results of surveys and research by the various JCOLD technical sub committees, papers presented to the ICOLD Congress, and results of activities by the Japan Association of Dam & Weir Equipment Engineering are reported widely to people concerned with dams. In addition, the lecturers and participants in the Technology Lecture and Discussion Meeting discuss the reports in order to improve the technologies, maintenance, and operation of dams.

**Figure-3 Dam Technology Lecture and Discussion Meeting**

**Study Tour**

To increase mutual awareness among engineers, including JCOLD members and others concerned with dams, on improving dam and hydroelectric power plant technologies and the construction of dams, JCOLD holds tours of dams and hydroelectric power plants still under construction with the cooperation of various organizations.

**Figure-4 Tour of the site of the Hirase Dam (2017)**

## Contribution to ICOLD

JCOLD submitted 357 ICOLD Congress papers until now. In addition, Many Japanese engineers participate in ICOLD Annual Meeting and Congress.

JCOLD participates in 24 technical committees at Annual Meeting and exchanges technical information.

JCOLD held Annual Meeting in 1960(Tokyo) and 1984(Tokyo), and Congress in 2012(Kyoto).

Susumu NAGATA(1957-1960), Masayoshi NOSE (1966-1969), Shigeru ICHIURA (1982-1985), Kyohei BABA (2001-2004), Norihisa MATSUMOTO(2007-2010) and Tadahiko SAKAMOTO(2011-2014) served as a vice president of ICOLD.

**Table-1 Number of participants from Japan**

| Year | Host country (Host city) | Number of participants from Japan |
|---|---|---|
| 1998 | India (New Delhi) | 43 |
| 1999 | Turkey (Antalya) | 56 |
| 2000 | China (Beijing) | 87 |
| 2001 | Germany (Dresden) | 60 |
| 2002 | Brazil (Iguazu) | 47 |
| 2003 | Canada (Montreal) | 49 |
| 2004 | South Korea (Seoul) | 143 |
| 2005 | Iran (Tehran) | 77 |
| 2006 | Spain (Barcelona) | 107 |
| 2007 | Russia (St. Petersburg) | 79 |
| 2008 | Bulgaria (Sofia) | 63 |
| 2009 | Brazil (Brasilia) | 46 |
| 2010 | Vietnam (Hanoi) | 75 |
| 2011 | Switzerland (Lucerne) | 70 |
| 2012 | Japan (Kyoto) | 398 |
| 2013 | USA (Seattle) | 73 |
| 2014 | Indonesia (Bali) | 79 |
| 2015 | Norway (Stavanger) | 80 |
| 2016 | South Africa (Johannesburg) | 58 |
| 2017 | Czech Republic (Prague) | 84 |

**Table-2 Number of submitted Congress papers**

| Year | No. | Host country (Host city) | Number of submitted papers |
|---|---|---|---|
| 1933 | 1 | Sweden (Stockholm) | 3 |
| 1936 | 2 | United States (Washington) | 5 |
| 1955 | 5 | France (Paris) | 4 |
| 1958 | 6 | United States (New York) | 13 |
| 1961 | 7 | Italy (Rome) | 8 |
| 1964 | 8 | United Kingdom (Edinburg) | 13 |
| 1967 | 9 | Turkey (Istanbul) | 11 |
| 1970 | 10 | Canada (Montreal) | 8 |
| 1973 | 11 | Spain (Madrid) | 12 |
| 1976 | 12 | Mexico (Mexico) | 9 |
| 1979 | 13 | India (New Delhi) | 11 |
| 1982 | 14 | Brazil (Rio de Janeiro) | 12 |
| 1985 | 15 | Switzerland (Lausanne) | 17 |
| 1988 | 16 | United States (San Francisco) | 22 |
| 1991 | 17 | Austria (Vienna) | 29 |
| 1994 | 18 | South Africa (Durban) | 25 |
| 1997 | 19 | Italy (Florence) | 28 |
| 2000 | 20 | China (Beijing) | 16 |
| 2003 | 21 | Canada (Montreal) | 20 |
| 2006 | 22 | Spain (Barcelona) | 23 |
| 2009 | 23 | Brazil (Brasilia) | 15 |
| 2012 | 24 | Japan (Kyoto) | 37 |
| 2015 | 25 | Norway (Stavanger) | 16 |

# Dams in Japan

## Development of dams

In Japan, the major purpose of dams was irrigation from ancient times to the end of the feudal period in the mid nineteenth century. The Sayama-ike irrigation pond (Osaka Prefecture), which is considered to be Japan's oldest dam, was completed in 616, and is recorded in the official historic documents.

As Japan was modernized and urbanized after the Meiji Revolution (1867), Japan started to build dams with modern technology, to meet the increased demand for water and electric power. In 1900, the Nunobikigohonmatsu Dam (Hyogo Prefecture) was completed as water supply dam. As for hydropower, the Chitose No.1 Dam (Hokkaido) was first completed in 1910. Later, multi-purpose dams with flood control capacity were constructed, with the first, the Kodo Dam (Yamaguchi Prefecture), completed in 1940.

To make more efficient use of water resources and control of flood, comprehensive projects are promoted under the concept of integrated development of river systems. Also, in recent years, redevelopment projects, such as raising the height of dams, excavating reservoirs, and upgrading discharge facilities, are being carried out more and more.

**Figure-5 Nunobikigohonmatsu Dam**

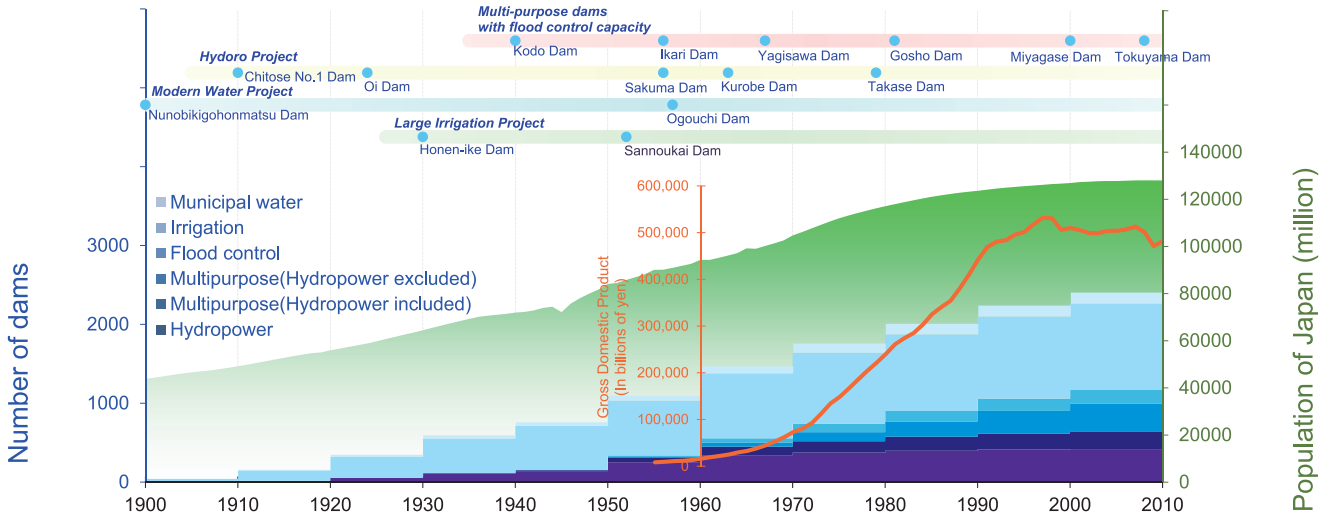



**Figure-6 Development of Dams, Economy of Japan and Population**

## Major dams in Japan

There are many dams over 100 meters high in Japan, though, their reservoir capacities are smaller than those of other dams around the world, reflecting the geographical features of Japan (narrow islands and steep terrain).

**Table-3 Ranking of dams by height in Japan**

| | Dam name | Type | Height (m) |
|---|---|---|---|
| 1 | Kurobe Dam | Arch | 186 |
| 2 | Takase Dam | Rockfill | 176 |
| 3 | Tokuyama Dam | Rockfill | 161 |
| 4 | Naramata Dam | Rockfill | 158 |
| 5 | Okutadami Dam | Gravity | 157 |
| 6 | Miyagase Dam | Gravity | 156 |
| 6 | Urayama Dam | Gravity | 156 |
| 6 | Nukui Dam | Arch | 156 |
| 9 | Sakuma Dam | Gravity | 155.5 |
| 10 | Nagawado Dam | Arch | 155 |

**Table-4 Ranking of dams by reservoir capacity in Japan**

| | Dam name | Reservoir capacity (million $m^3$) |
|---|---|---|
| 1 | Tokuyama Dam | 660 |
| 2 | Okutadami Dam | 601 |
| 3 | Tagokura Dam | 494 |
| 4 | Yubari Shuparo Dam | 427 |
| 5 | Miboro Dam | 370 |
| 6 | Kuzuryu Dam | 353 |
| 7 | Sakuma Dam | 343 |
| 8 | Ikehara Dam | 338 |
| 9 | Sameura Dam | 316 |
| 10 | Hitotsuse Dam | 261 |

**Figure-7 Naramata Dam**

**Figure-8 Miyagase Dam**

## Hydroelectric power plants in Japan

The output of hydroelectric power plants in Japan accounts for about 19% of all electric power sources, and pumped storage hydroelectric power occupies top 10s of the electric power output rankings.

**Table-5 Electric power output ranking of Conventional hydropower plants**

| | Hydroelectric power plant | Electric power output (MW) | Dam name |
|---|---|---|---|
| 1 | Okutadami | 560 | Okutadami Dam |
| 2 | Tagokura | 400 | Tagokura Dam |
| 3 | Sakuma | 350 | Sakuma Dam |
| 4 | Kurobegawa 4 | 335 | Kurobe Dam |
| 5 | Arimine 1 | 265 | Arimine Dam |
| 6 | Tedorigawa 1 | 250 | Tedorigawa Dam |
| 7 | Miboro | 215 | Miboro Dam |
| 8 | Shinojiya | 206 | Miyanaka Dam |
| 9 | Hitotsuse | 180 | Hitotsuse Dam |
| 10 | Shinanogawa | 177 | Nishiotaki Dam |

**Table-6 Electric power output ranking of Pumped Storage hydropower plants**

| | Hydroelectric power plant | Electric power output (MW) | Dam name (upper reservoir / lower reservoir) |
|---|---|---|---|
| 1 | Okutataragi | 1,932 | Kurogawa Dam / Tataragi Dam |
| 2 | Okukiyotsu | 1,600 | Kassa Dam / Futai Dam |
| 3 | Okumino | 1,500 | Kaore Dam / Kamiosu Dam |
| 4 | Shintakasegawa | 1,280 | Takase Dam / Nanakura Dam |
| 4 | Okouchi | 1,280 | Ota Dam / Hase Dam |
| 6 | Okuyoshino | 1,206 | Seto Dam / Asahi Dam |
| 7 | Tambara | 1,200 | Tambara Dam / Fujiwara Dam |
| 7 | Matanogawa | 1,200 | Doyo Dam / Matanogawa Dam |
| 7 | Omarugawa | 1,200 | Ouseuchi Dam / Ishikawauchi Dam |
| 7 | Kazunogawa | 1,200 | Kamihikawa Dam/ Kazunogawa Dam |

**Figure-9 Okutadami Dam**

**Figure-10 Kurobe Dam**

## Dams completed in 2014 - 2016 in Japan

Dams completed in 2014-2016 in Japan are counted in 15 dams. The features are summarized below. Several dams are illustrated in the following pages.

| | Dam name | Location | Dam | | | | | Owner | Completed |
|---|---|---|---|---|---|---|---|---|---|
| | | | Purpose(s) | Type | Height (m) | Length of Crest (m) | Reservoir capacity (million m³) | | |
| 1 | Toppu | Hokkaido | CSI | PG | 78.4 | 309 | 36 | Hokkaido Pref. | 2014 |
| 2 | Yofudo | Hyogo | CS | PG | 54.4 | 145 | 1.1 | Hyogo Pref. | 2014 |
| 3 | Rogi | Kumamoto | CS | PG | 53 | 169 | 2.3 | Kumamoto Pref. | 2014 |
| 4 | Isawa | Iwate | CSIH | ER | 127 | 723 | 143 | The Tohoku Regional Development Bureau, MLIT*1 | 2014 |
| 5 | Naganuma | Miyagi | CS | TE | 15.3 | 1050 | 31.8 | Miyagi Pref. | 2014 |
| 6 | Kyogoku | Hokkaido | H | ER | 54 | 332.5 | 5.5 | Hokkaido Electric Power Co.,Inc. | 2014 |
| 7 | Kin | Okinawa | CSI | CSG | 39 | 461.5 | 8.6 | Okinawa General Bureau | 2014 |
| 8 | Yubari Shuparo | Hokkaido | CSIH | PG | 110.6 | 390 | 427 | Hokkaido Development Bureau, MLIT*1 | 2015 |
| 9 | Kirimegawa | Wakayama | CS | PG | 44.5 | 127 | 4 | Wakayama Pref. | 2015 |
| 10 | Kurikara | Hyogo | CS | PG | 26.7 | 172 | 0.4 | Hyogo Pref. | 2015 |
| 11 | Tokunoshima | Kagoshima | I | ER | 56.3 | 266.9 | 8.1 | Kyushu Regional Agricultural Administration Office, MAFF*2 | 2015 |
| 12 | Hamada 2 | Shimane | CS | PG | 97.8 | 218 | 15.5 | Shimane Pref. | 2016 |
| 13 | Shobara | Hiroshima | CS | PG | 42 | 118.5 | 0.7 | Hiroshima Pref. | 2016 |
| 14 | Tsugaru | Aomori | CSIH | PG | 97.2 | 342 | 140.9 | The Tohoku Regional Development Bureau, MLIT*1 | 2016 |
| 15 | Gima | Okinawa | CS | TE | 24.5 | 539 | 0.6 | Okinawa Pref. | 2016 |

Purpose: C - flood control, S - water supply, I - Irrigation, H - hydroelectricity

Type: PG - gravity in masonry or concrete, ER - rock fill, TE - earth, CSG - CSG

*1 Ministry of Land, Infrastructure, Transport and Tourism

*2 Ministry of Agriculture, Forestry and Fisheries

# Isawa Dam

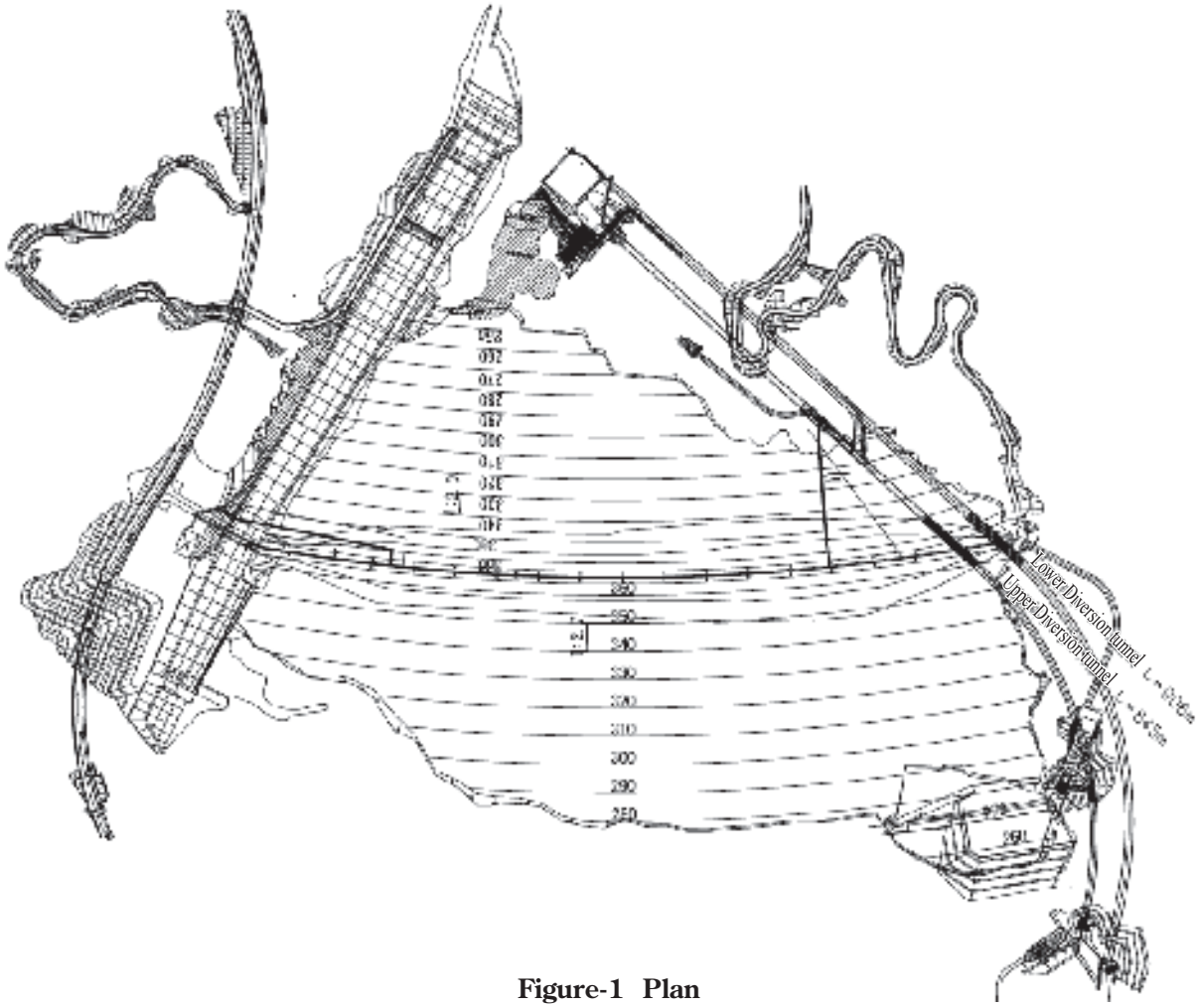




Figure-1 Plan

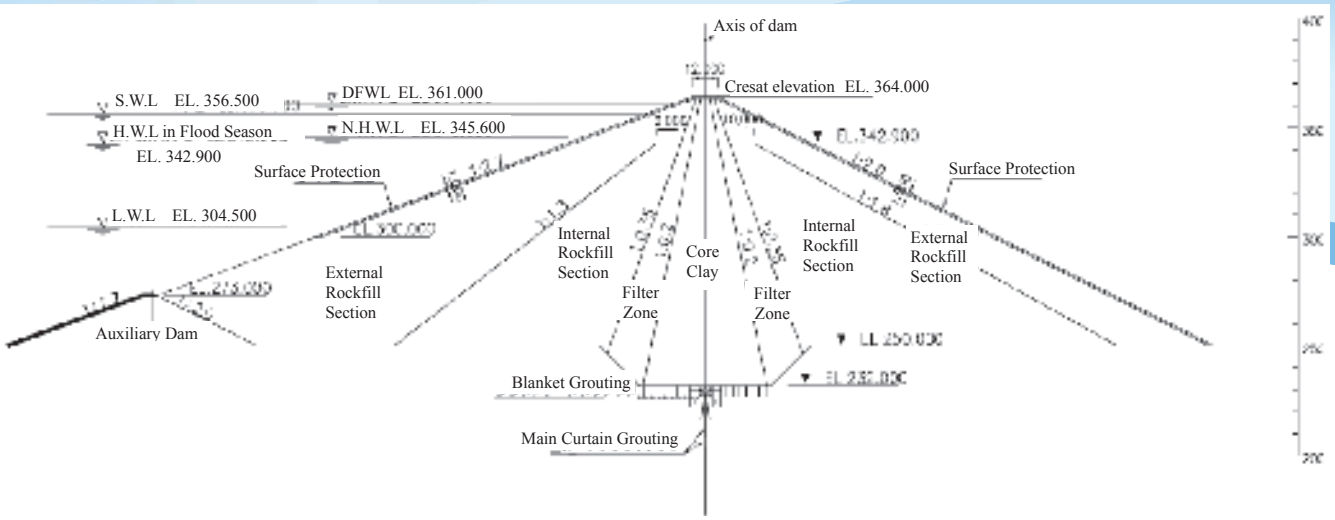



**Figure-2 Typical section**

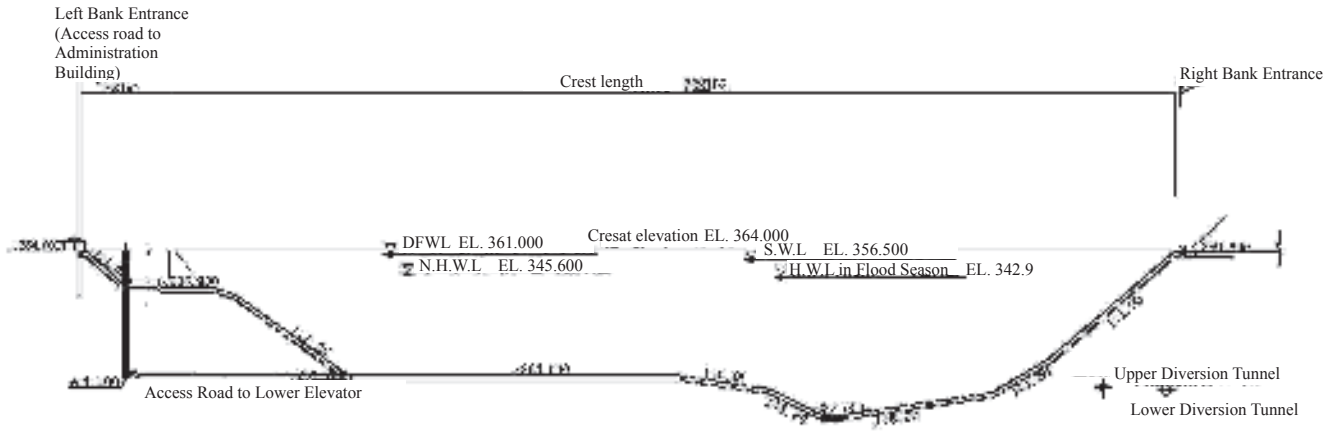



**Figure-3 Longitudinal Cross Section**

# Kyogoku Dam（Pumped-storage Hydroelectric Power Station）

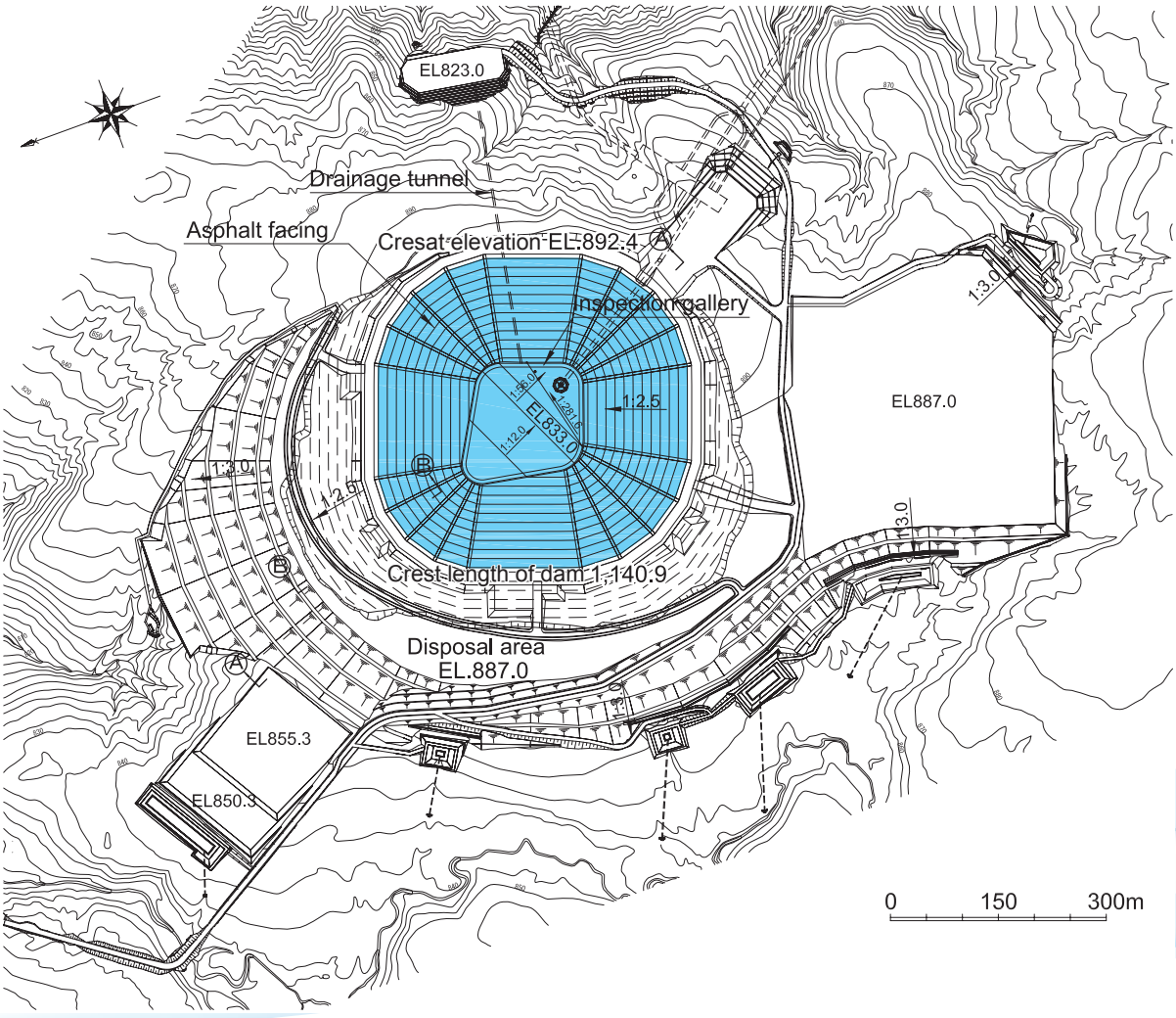




Figure-1 Plan of upper reservoir

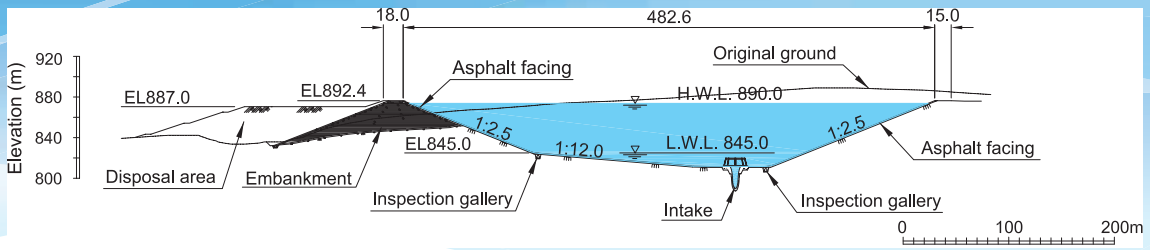



**Figure-2 Section of upper reservoir**

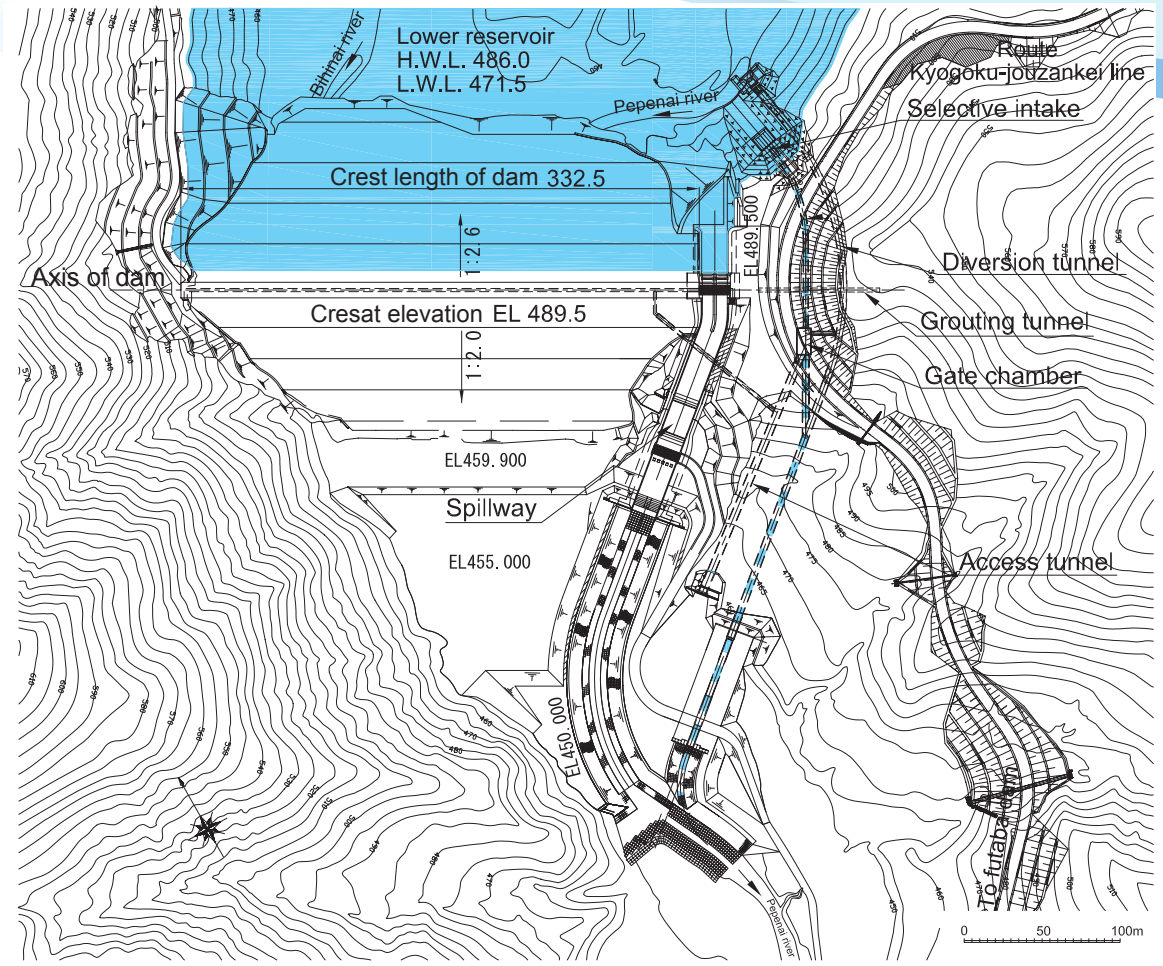



**Figure-3 Plan of lower Dam (Kyogoku)**

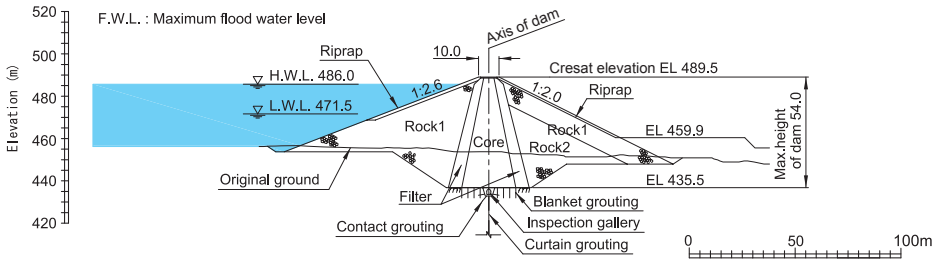



**Figure-4 Typical section of lower reservoir (Kyogoku)**

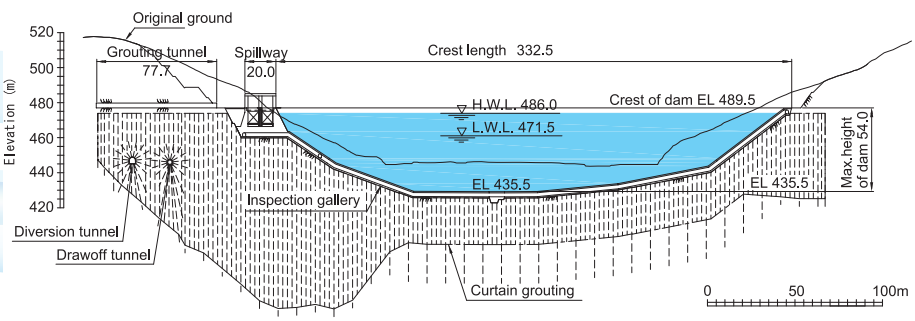



**Figure-5 Longitudinal Cross Section**

# Kin Dam

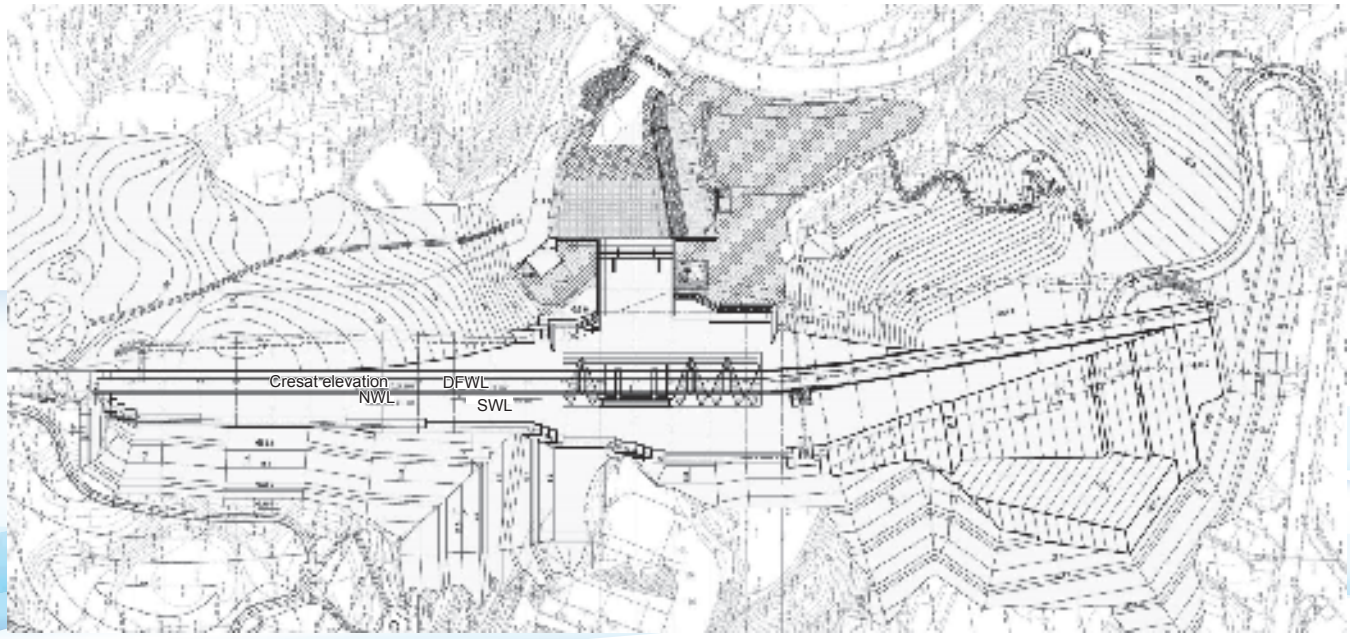




**Figure-1 Plan**

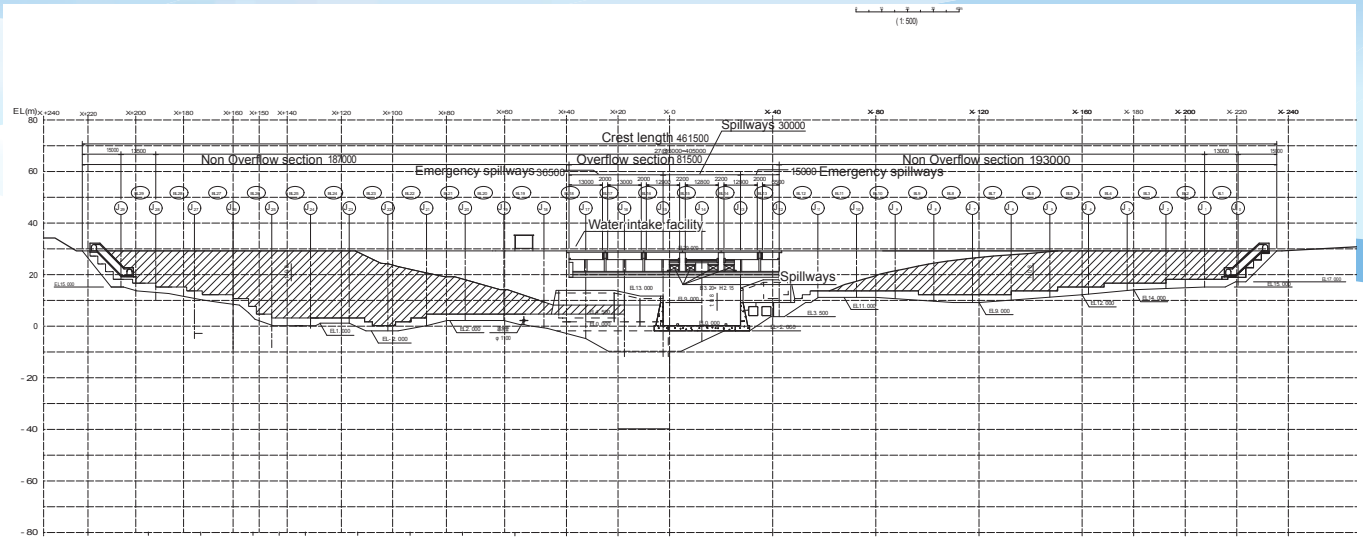



**Figure-2 Upstream elevation**

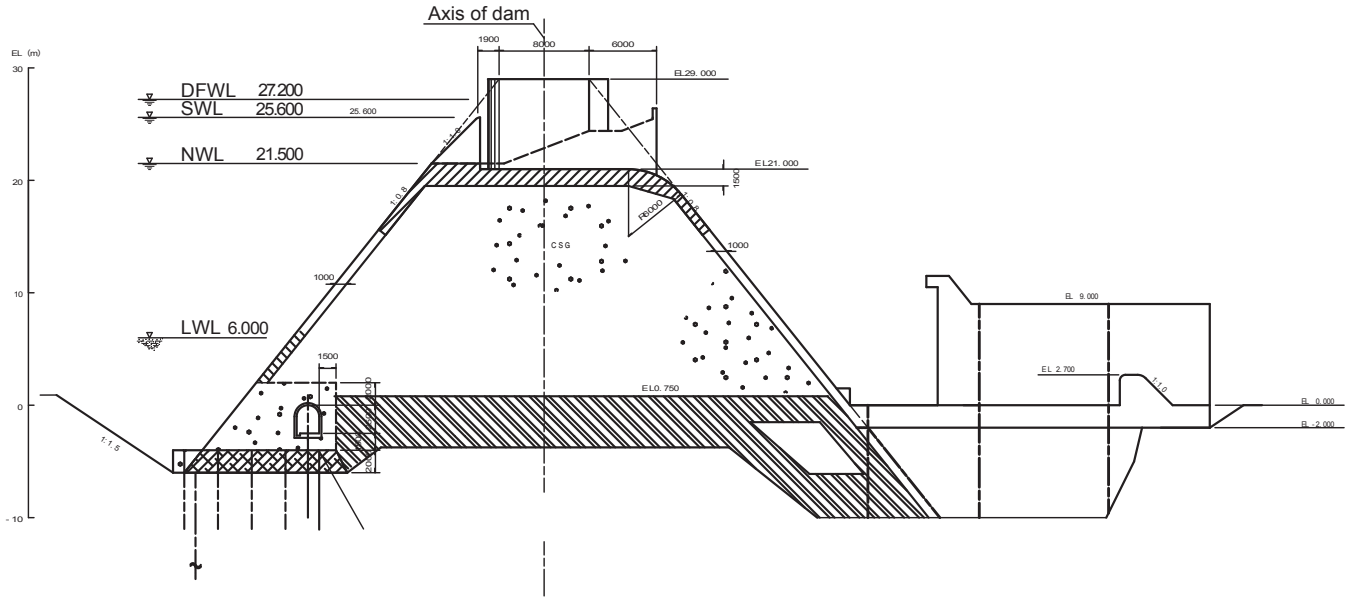



**Figure-3 Typical Section**

# Yubari-Shuparo Dam

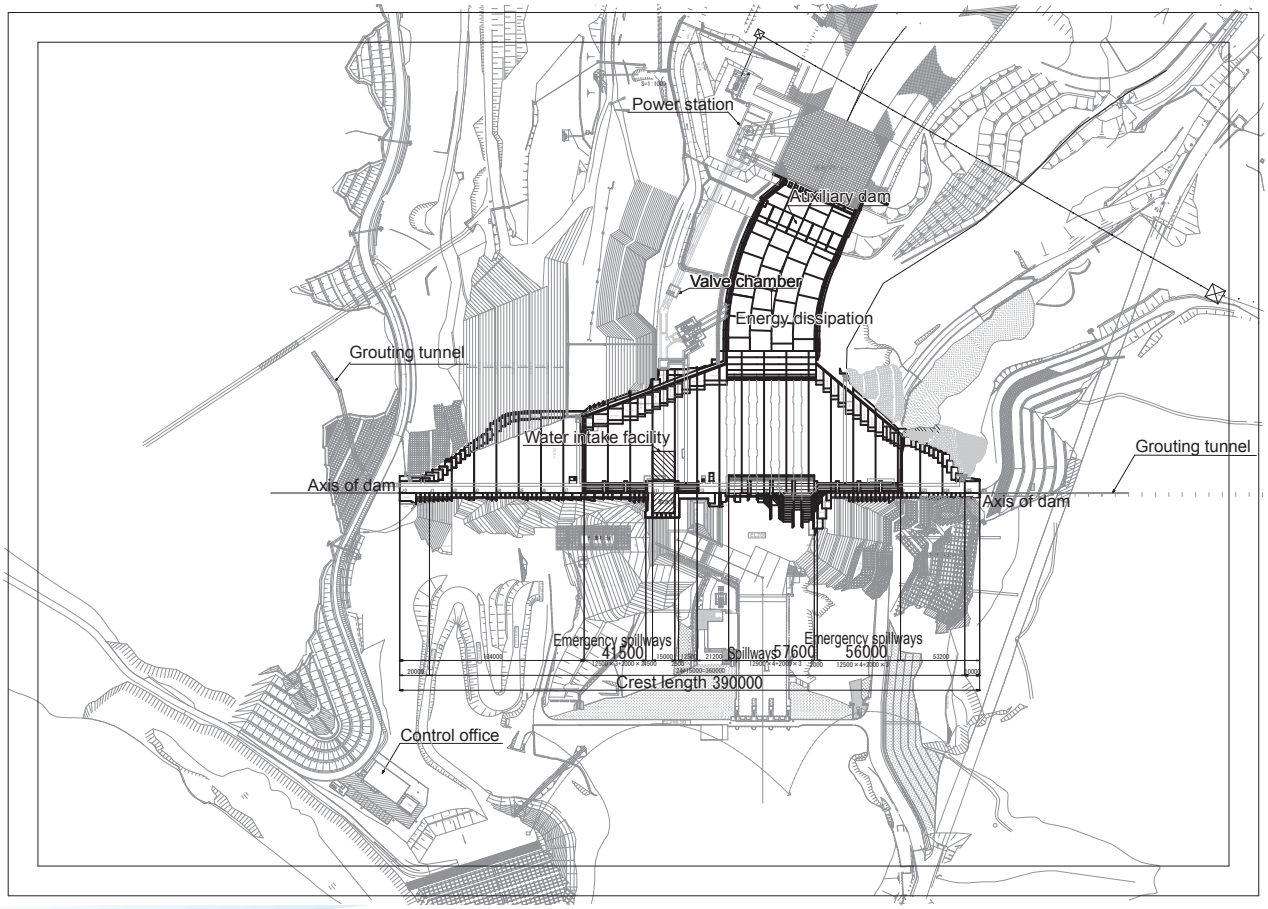




Figure-1 Plan

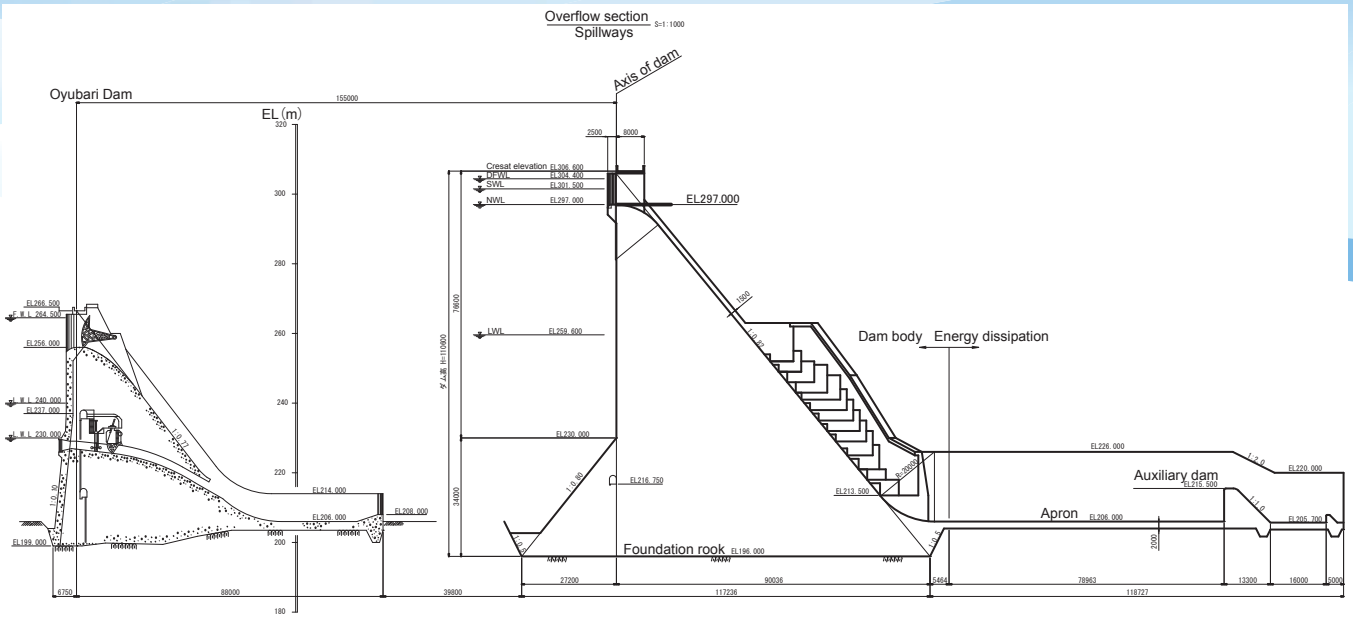



**Figure-2 Typical section**

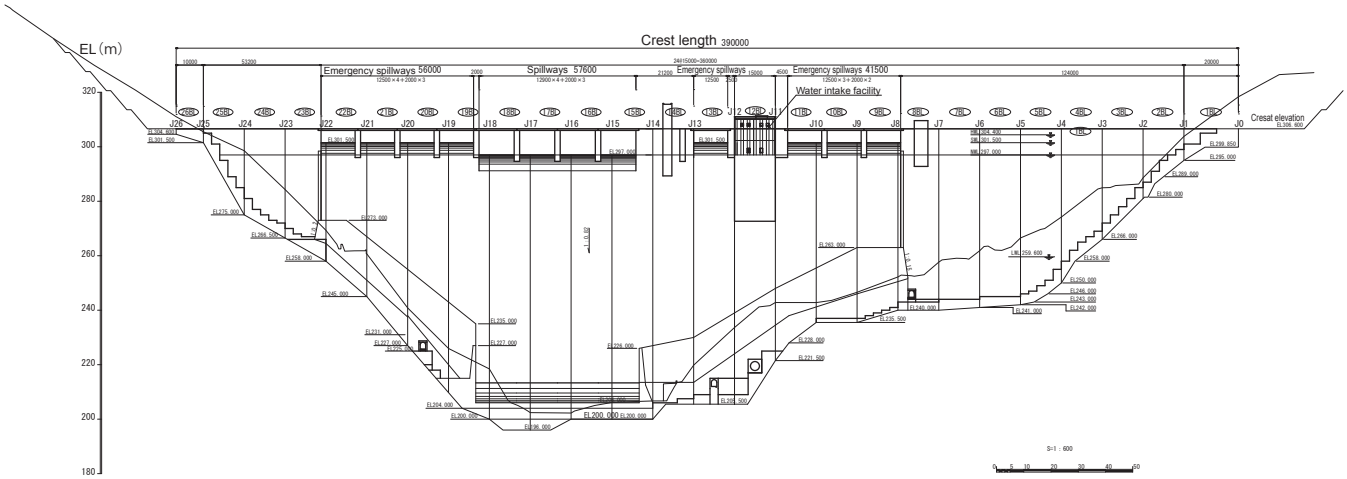



**Figure-3 Downstream elevation**

# Tokunoshima Dam

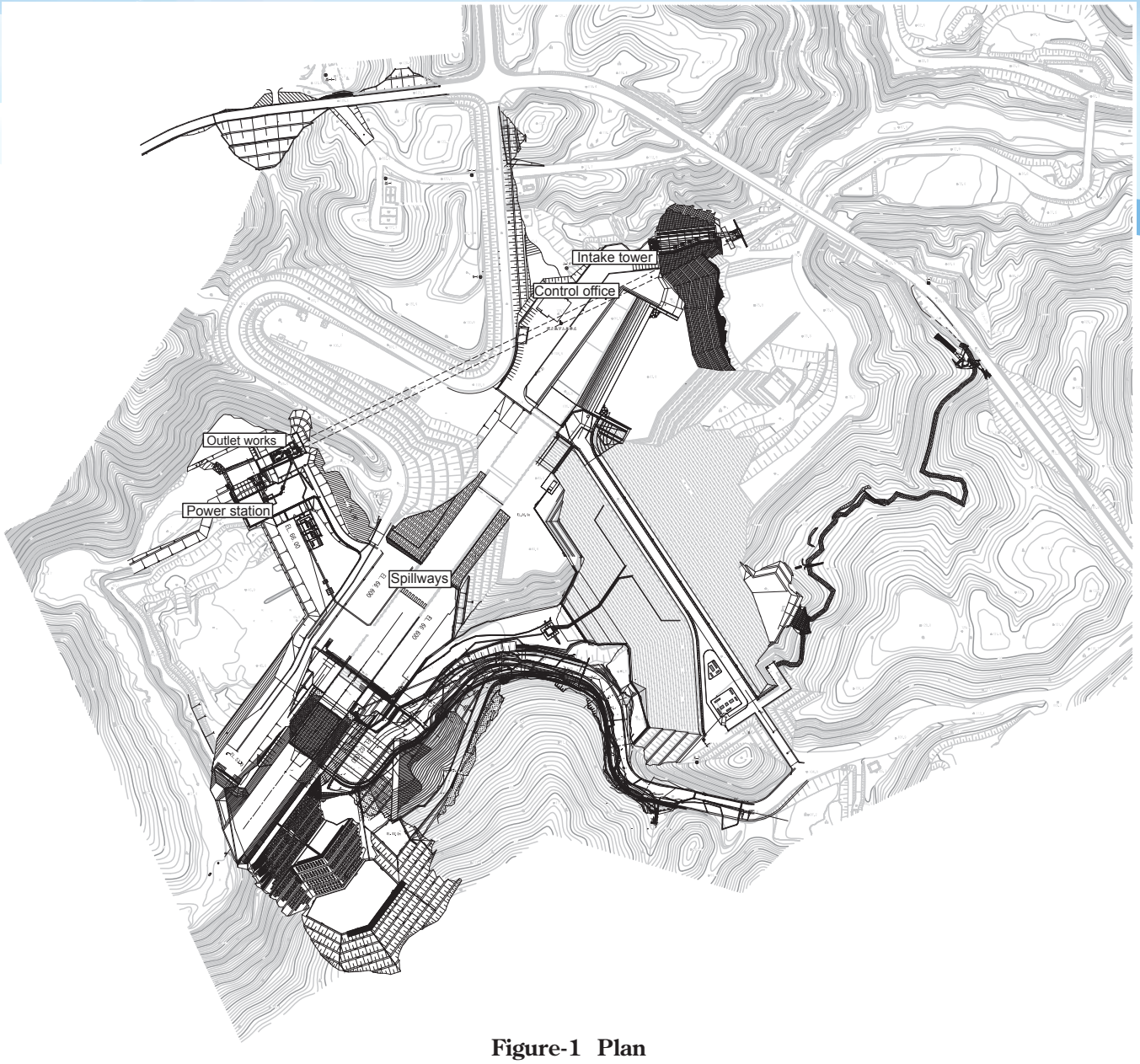




**Figure-1 Plan**

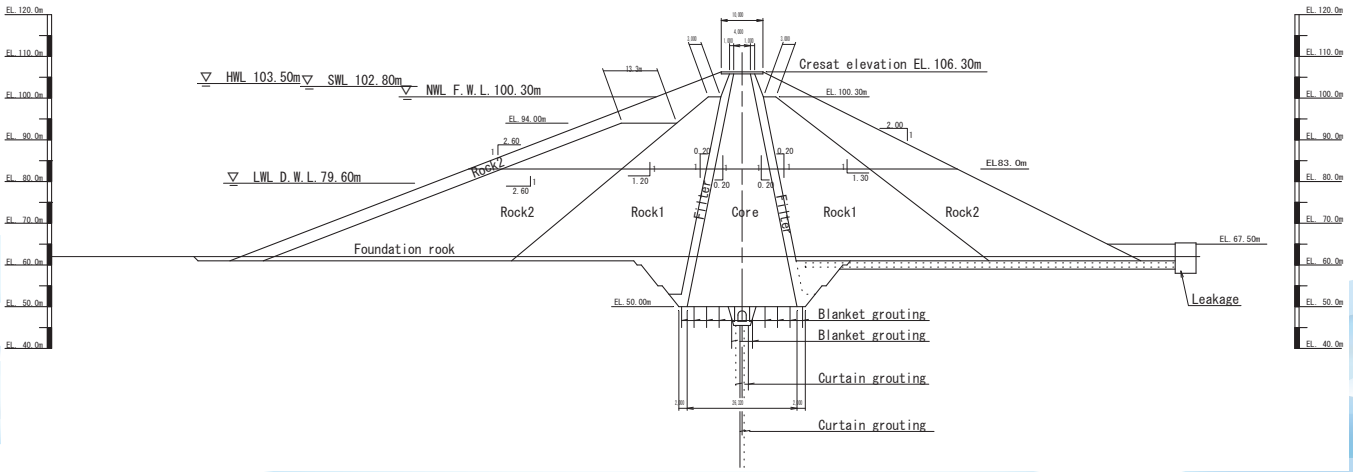



**Figure-2 Typical section**

# Tsugaru Dam

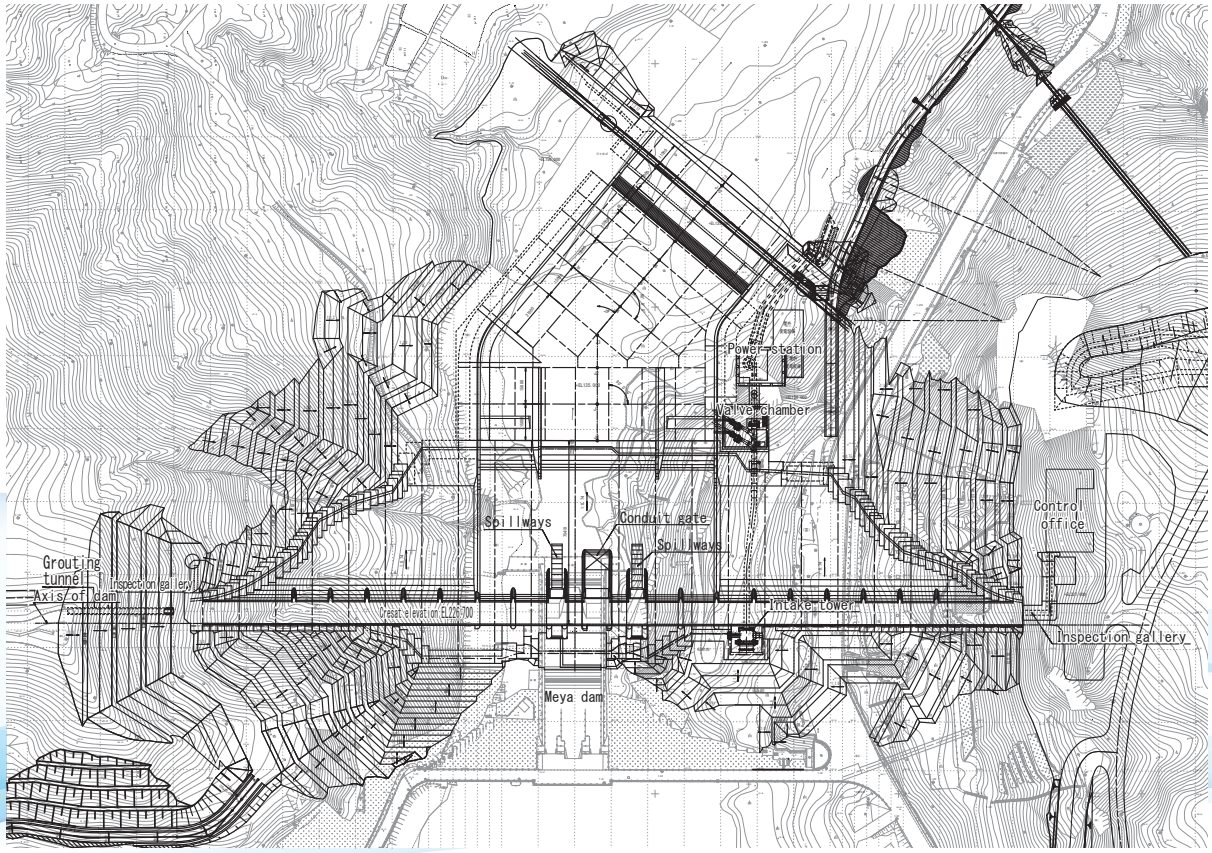




Figure-1 Plan

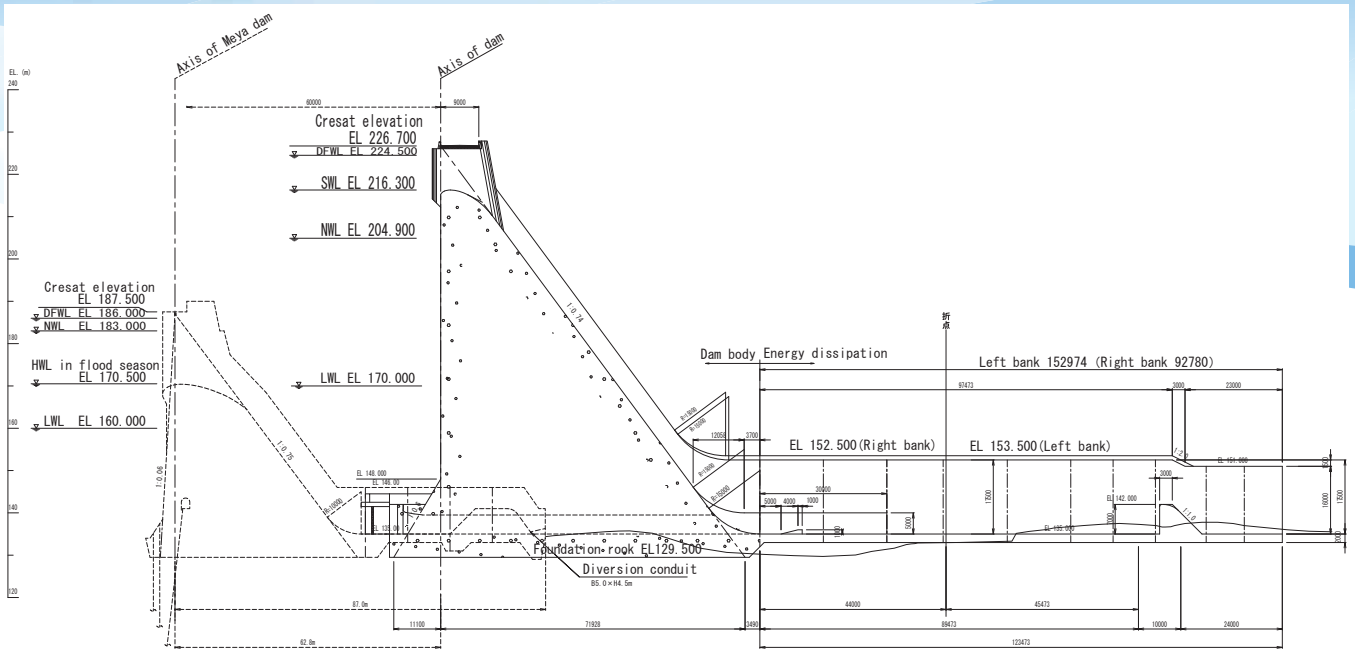



**Figure-2 Typical section**

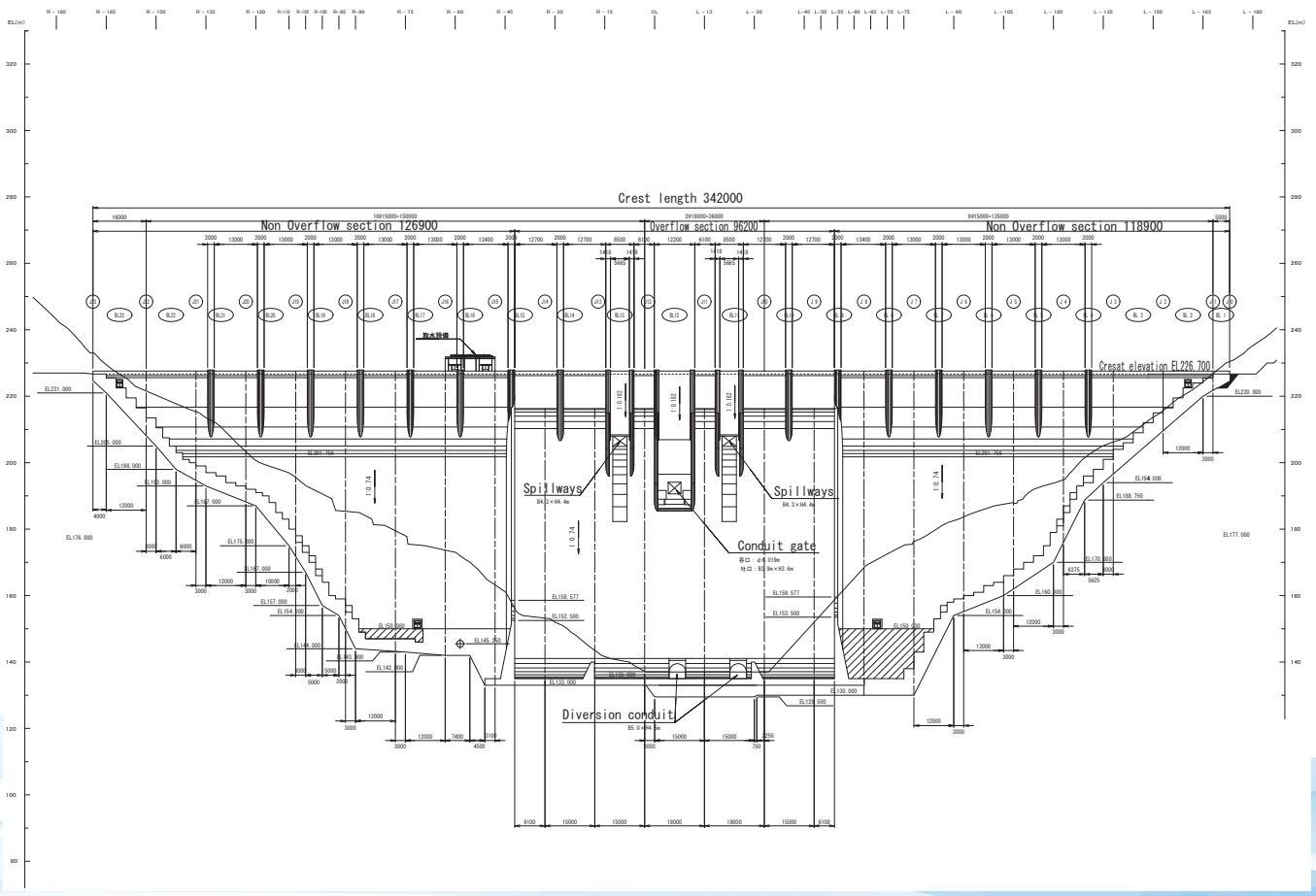



**Figure-3 Downstream elevation**

# Introduction to Dam Technologies in Japan

## Trapezoidal CSG dam

The trapezoidal CSG dam developed in Japan is a new type of dam which combines the characteristics of a trapezoidal Dam and the CSG (Cemented Sand and Gravel) construction method. It rationalizes the construction of dams in three ways: "Rationalization of materials: because the dam body materials require less strength, the required performance of the material is low and there are few restrictions on the selection of materials," "Rationalization of design: The trapezoidal shape improves seismic stability, and so the strength required of the dam body materials is lower," and "Rationalization of construction: Construction work can be executed rapidly by simplified construction facilities."

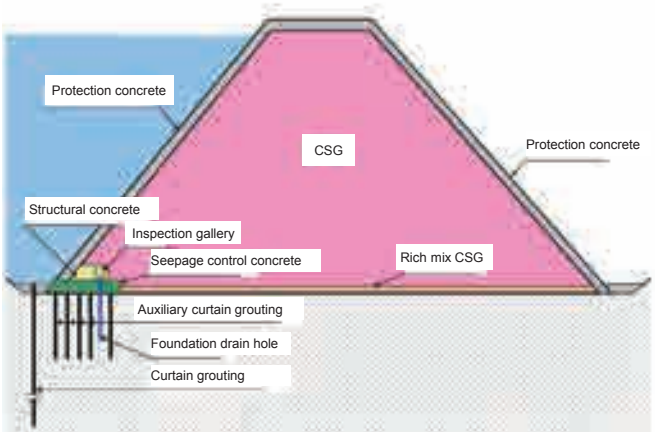



**Figure-1 Concept of Trapezoidal CSG dam**

**Figure-2 Tobetsu Dam**

## Sediment bypass tunnel (SBT)

SBTs are one sustainable and effective strategy against sedimentation. The SBT connects upstream and downstream of a dam and bypasses sediment-laden floods into downstream. They are mainly operated in Japan, Switzerland and Taiwan.
In Japan, SBTs are operated at the oldest concrete dam in Japan, Nunobikigohonmatsu Dam (1900), Tachigahata Dam (1905), Asahi Dam (1998), Miwa Dam (2005). Also, they are currently undergoing trial operation at Koshibu Dam and Matsukawa Dam. The problem of SBTs is countermeasure against invert abrasion and elucidation of sediment hydrological behavior, and research is currently under way.

**Figure-3 Sediment bypass tunnel (SBT)**

**Figure-4 Miwa Dam**

## Preservation measures of dam reservoirs

Water quality issues are closely associated with the size of the dam reservoir, and operation of the dam reservoir.

One of water quality preservation measures for the dam reservoir is conducted by controlling outflow of pollutant and nutrient salts from the catchment area.

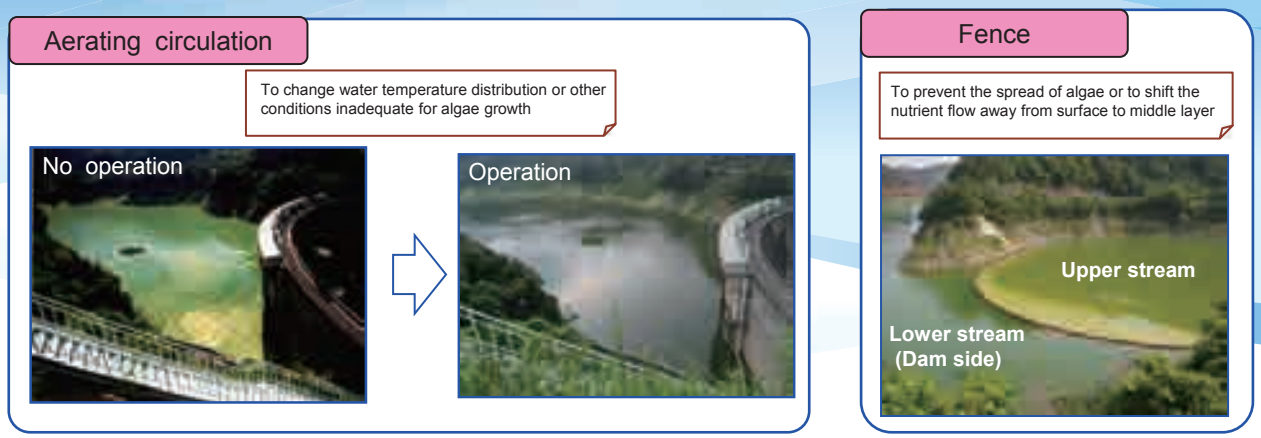



**Figure-5 Reservoir Water quality facilities**

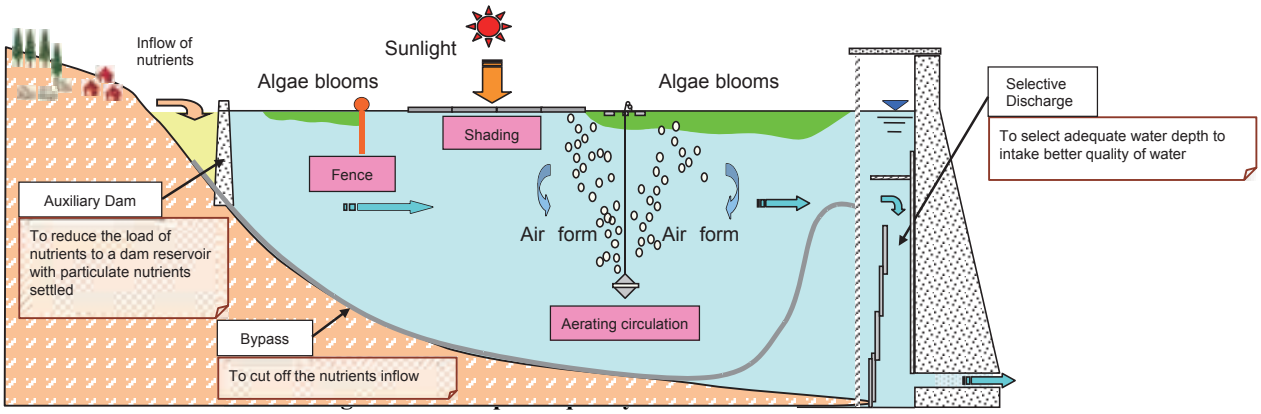
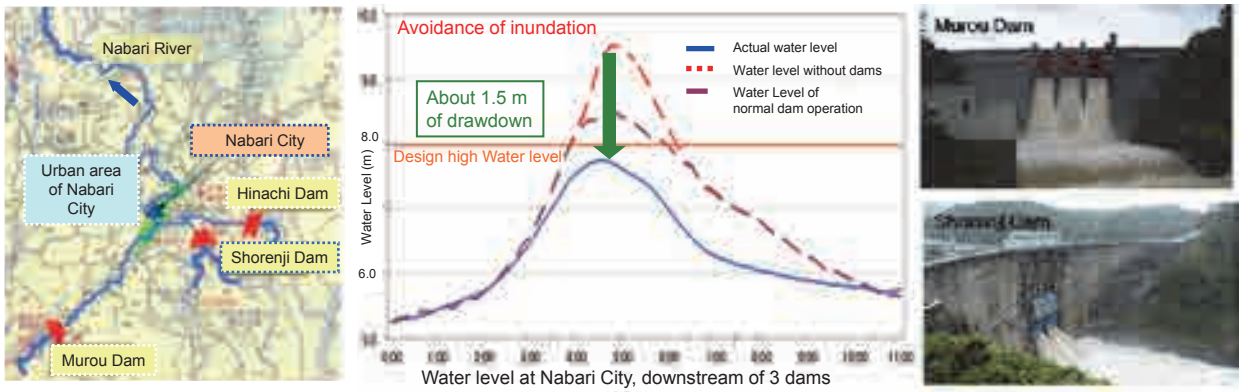



**Figure-6 Example of quality conservation measures**

## Advancement of flood control operation

Recently, flood disasters caused by heavy rains occur frequently in Japan. It is set that the flood control operation of the dam should work most effectively for design flood or hydrograph. However, as the rainfall is a natural phenomenon the rainfall condition varies from time to time. Therefore, the appropriate operation is conducted at all times, making use of the rainfall prediction technologies and flood outflow analysis model and maximizing the flood control capacity of the dam so that the prevention or mitigation of flood damages can be achieved in the downstream areas.




- Heavy rain due to big typhoon threatened to cause inundation in Nabari River on October 8, 2009.
- Japan Water Agency's O&M offices conducted collaborative operations in view of water level, rainfall, and dam capacity of each of the three dams under its integrated control.
- The above figures show that the water level of urban area was kept below the design flood water level at Nabari City.

**Figure-7 Flood control through integrated and collaborative operation of three dams**

## Dam Upgrading Vision

It is important to effectively use existing stocks while controlling total costs. Various technologies will be advanced as the number of cases of the effective use of existing dams grows. On the other hand, more frequent and intense flood damage and more frequent droughts are concerns. Under this context, dam upgrading will be promoted by effectively using existing dams applying both hard and soft measures according to each basin's characteristics and issues. Typical examples are shown in figures. These exhibit that dam upgrading to effectively use existing dams has features and effects such as greatly increasing water storage capacity with the slight raising of dam bodies, or the economic completion of work in a short period of time, to show effects more quickly.

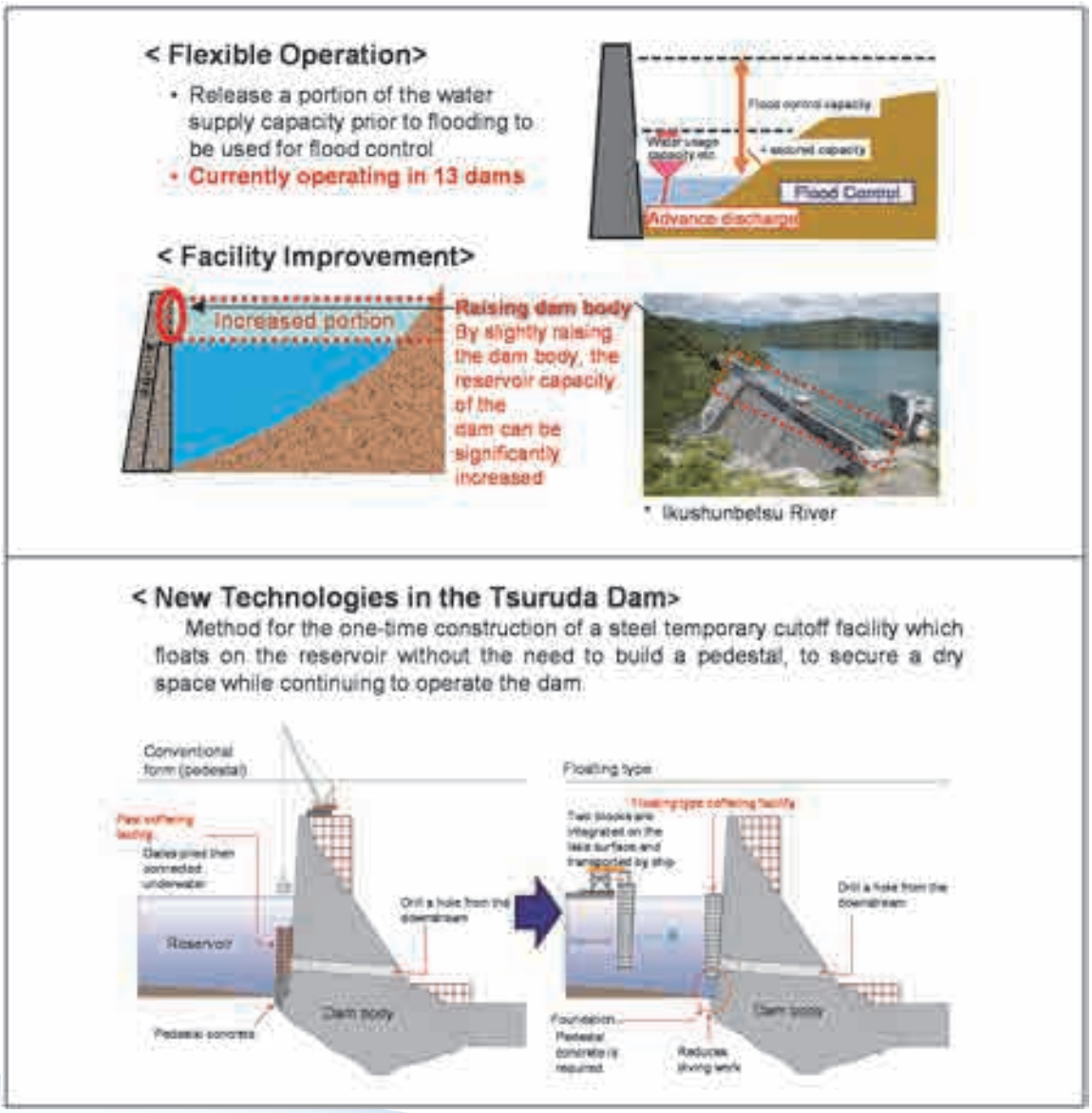



**Figure-8 Projects and Technologies to effectively use dams**

The “Dam Upgrading Vision” which provides a strategy for the further promotion of dam upgrading efforts that effectively utilize existing dams has been formulated in 2017. These strategies for the vision are categorized below.

1) Dam Life Extension
2) Promoting Efficiency and Advancement of Maintenance
3) Flexible and Reliable Operation to Optimally Utilize the Capacity of the Facility
4) Improving Facilities for a more Advanced Functionality
5) Responding to Climate Change
6) Addition of Hydropower
7) Protection and Revitalization of River Environment
8) Regional Development utilizing the Dams
9) Promoting Dam Upgrading Technologies Overseas
10) Development and Implementation of Technologies to Promote Dam Upgrading

## Utilization of ICT in construction of dam

The construction industry in Japan aims at drastically improving productivity of all construction production processes by utilizing ICT, and its approach is called i-Construction.

Even in the construction of dams, the utilization of ICT has been advanced toward improving quality, safe site work, shortening of construction period, and reduction of construction cost.

In addition, using ICT to share information in real time and to utilize and accumulate 3-dimensional data can contribute to a dramatic rationalization of actions throughout the dam life cycle from the design stage, the construction stage to the operation and maintenance stage.

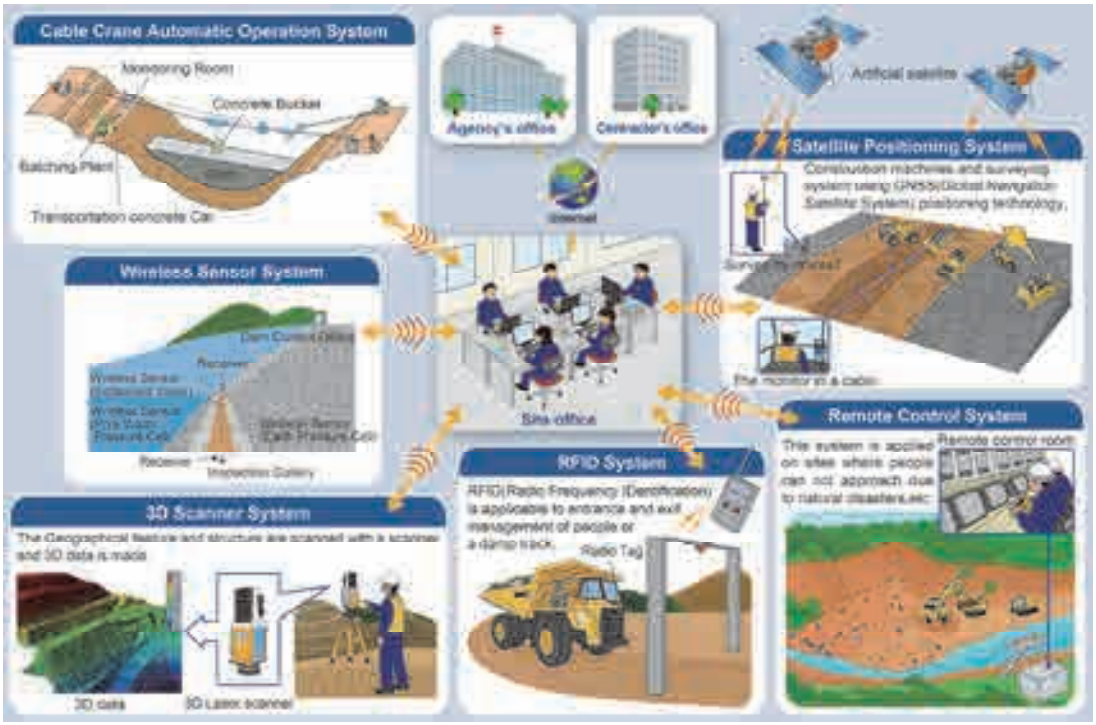



**Figure-9 Application of ICT for Dam Construction**

# Papers in ICOLD & Other Technical Publications

## Theme 1 Safety supervision and rehabilitation of existing dams

### *A. ICOLD 84th Annual Meeting International Symposium in Johannesburg, May 2016*

***Development of emergent monitoring system for leakage from the dam***

*T. Higuchi, T. Sugai, T. Sato, and T. Kayukawa*

In this paper, the development of 24-hour monitoring system for leakage from the dam by using goods on the market will be introduced. From the middle of November in 2013, the IWAYA Dam Management Office had conducted 24-hour alert condition because of unexpected increasing leakage from the dam body and its shallow foundation. The initial monitoring system for leakage volume had some drawbacks in terms of conducting 24-hour alert condition. Some engineers of the IWAYA Dam assembled ad-hoc monitoring and alert system developed by using goods on the market, such as a smartphone.

***Suggestions for dam crisis management learned through The 2011 off the Pacific Coast of Tohoku Earthquake***

*H. Okumura, T. Matsumoto, and K. Koyama*

On 11th of March, 2011, the 2011 off the Pacific coast of Tohoku Earthquake, with a moment magnitude of 9.0, hit on Numappara dam. Immediately, more than 1,000 l/min of leakage increasing which was assumed to run through caused cracks on the asphaltic facing was detected. To avoid a possible serious failure, the water level was drawn down to the safe one. This paper describes the suggestions for dam crisis management learned through these responses taken for the Earthquake and also focuses on the importance of the usual dam monitoring.

***External deformation monitoring of five rockfill dams in the same radar satellites data***

*H. Sato, T. Sasaki1, T. Kobori, Y. Enomura, Y. Yamaguchi, W. Sato, N. Mushiake, K. Honda and N. Shimizu*

It is important to research new methods of conducting effective measurements of the external deformation of embankment dams. External deformations of five rockfill dams in the same SAR data were measured in about four years, and the results of external deformations using SAR data were compared with those by GPS or conventional survey data. We found that the results of external deformations using SAR data agreed well with those by GPS or conventional survey data and the average error of the external deformations between SAR and GPS or conventional survey was about five millimeters.

***Inspection of submerged area with the use of an underwater camera survey vehicle***

*Y. Sakamoto, S. Akimoto and K. Kera*

Japan Water Agency (JWA) has the standard for the dams as river management facilities managed by the JWA. All the daily patrol, inspection, maintenance and repair work, etc. are being implemented based on this standard. But for the areas not exposed, there has been no measure of conducting the visual inspection. JWA therefore came up with an idea of using an underwater-camera to inspect the usually submerged part of the facilities and conducted the test at concrete arch dam and rockfill dam. As a result, it was proved that with both dams there were no damage or degradation.

### *B. 4th Asia Pacific Group Symposium and 9th East Asia Dam Conference, September 2016*

***Dynamic characteristics of dams evaluated using earthquake monitoring data for safety assessment***

*M. Kashiwayanagi, H. Onishi, N. Osada and S. Hayakawa*

Earthquake monitoring is normally conducted in high dams in Japan. Detailed analysis of dam behaviour during an earthquake helps to identify the mechanical properties of the dam which could reflect its current soundness. This paper focuses on the effective utilization of earthquake monitoring data for the safety management of dams. Data on concrete gravity dams, arch dams and rockfill dams are examined so as to elaborate the management criteria in terms of the response characteristics and the predominant frequency. Such dynamic characteristics of concrete dams are formulated with influential factors, which are finally identified as the dam height, dam-reservoir interaction and mechanical properties of the transverse joints. In addition, the applicability of microtremor measurement is verified for another method of identifying the predominant frequency of dams through the in-situ measurement of an arch dam. It is concluded that the dynamic characteristics of the dam examined can be utilized as management indices to reveal an abnormal situation or degradation of the dam by detecting their deviations.

***Study on the deformation mechanism of an ageing dam aiming at future deformation prediction***

*H. Onishi, M. Kashiwayanagi and M. Yoda*

In evaluation of dam behaviour, deformation monitoring is es-

sential. Although most dams show a stable deformation trend, it is highly important to confirm whether these trends will continue in the future assuming that the lifespan of a dam is more than 100 years. If unique deformation behaviours have been encountered in a dam, such as monotonic increase toward the stream direction of the dam and variation in the deformation degree corresponding to reservoir water level or the ambient temperature, the current deformation mechanism, future dam behaviour, and also the necessity of correspondence should be addressed considering dam safety in the future. In this report, we studied the deformation and related data of a 50-year-old concrete gravity dam and interpreted the deformation mechanism with the aid of numerical analysis, and conducted a simulation of dam behaviour in an elastic and steady manner considering the three parameters of reservoir water level, ambient temperature, and sediment depth. The results of the simulation show the consistent dam behaviour against these loads acting on the concrete gravity dam usually.

***Application of global positioning system for dam deformation monitoring***

*H. Arizono, H. Okumura, H. Onishi and N. Shimizu*

Renovation of safety monitoring system of existing dams has been becoming one of main issues for dam owners. In this regard, Global Positioning System (GPS) has been applied for dam external deformation monitoring in considerable numbers of existing dams in Japan. Electric Power Development Co., Ltd. which is one of the electricity utility companies in Japan, and owns rather old dams for hydropower stations, has started to utilize GPS for dam deformation monitoring for some years, and it has been applied in five dams. Since GPS enables to obtain the data more frequently than those obtained by the conventional manual measurement, it is useful to figure out deformation characteristics and its long-term trends more precisely. In addition, since digital data can be obtained automatically and transmitted online, it is also useful to acquire the status in real time, even if personnel cannot access to dams. On the other hand, the accuracy of GPS data is prone to be affected by some external factors such as climate conditions, surrounding plants growth. This paper shows continuous monitoring data of dam deformation by GPS through case histories in five dams and their effectiveness as well as countermeasures actually provided to improve foresaid matters.

***Investigation and repair on deteriorated transverse joint of Kasabori dam***

*H. Kawasaki and S. Iwasaki*

Kasabori dam is a concrete gravity dam with height of 74.5m completed in 1964 by Niigata prefectural government in a snowy region, for the purposes of flood control and hydropower. It was redeveloped in 1973-79 and again in 2011-17 to upgrade its flood control function. The present work, which started in 2014, includes heightening the dam by 4m, placing concrete on its downstream surface to increase its thickness by 2m, renewing its two gates, and extending its spillway. However, a visual inspection confirmed a serious increase of water leakage around the J2 transverse joint, and the extension of cracks along J2 since the first repair in 1973-79. Thus, before the main work, repair work started in 2014 and, cutting down around J2 by line drilling was performed after lowering the reservoir level. After water-stop installation and steel-bar reinforcement, the concrete was placed, and the J2 repair work was finished by June 2015. Experientially, there were some difficulties coping with the transverse joint trouble (Kawasaki, H., et al. 2014). In this paper, we introduce the investigation process and the repair work on the traverse joint, and try to explain the mechanism of deterioration by earthquakes and heavy freezing-thawing.

***Improvement of deformation prediction of Rock-fill dam with GPS measurement***

*H. Soda, S. Nigo and N. Sato*

Accurate and continuous data accumulation of deformation measurement of dam body is important for proper dam safety management. Regarding the improvement of the accuracy of rock-fill dam deformation survey, there are problems that the measurement frequency is low and the accuracy may be affected by slight differences in measurement techniques and by observer. In recent years, Global Positioning System (GPS) measurement system which enables us to measure the exterior deformation of rock-fill dam bodies continuously, accurately and three-dimensionally have been developed and is experimentally introduced in about 20 dams in Japan. The authors, based on the approximate expressions corresponding to the long-term settlement of the embankment, have proposed approximate expressions of settlement and the horizontal displacement by using the GPS measurement data in Tokuyama Dam. As a result, predicted deformation by using the approximate expressions well matched to the value measured by GPS measurement system. Based on the research results in Tokuyama dam, it is possible to monitor other dams by proposing approximate expressions using the same method that utilizes the features of the GPS of high precision and continuous observation data.

## *C. ICOLD 85th Annual Meeting International Symposium in Prague, July 2017*

***Technical solutions on concrete for Kasabori dam heightening***

*H. Kawasaki, S. Iwasaki, T. Miyano and Y. Hagiwara*

Kasabori dam is a gravity-type concrete dam with height of 74.5m constructed in 1964 by Niigata Prefecture for the purpose of flood control, power generation, etc.. After a serious flood damage in 2011, the redevelopment project started to upgrade the flood control function by heightening the dam by 4 m. On the other hand, this project term was limited to seven years due to disaster restoration grant project, and the workable days of a year are largely restricted because of avoiding heavy snow season and flood season. So, the major challenge is how to complete the construction in a short period. The project includes various works such as concrete placing on the downstream face and crest, renewal of two crest gates, improvement of the spillway and energy dissipater, repair of the transverse joint, and grouting to the dam foundation. In this paper, we focus on the rational designing of dam heightening and

the seismic safety evaluation, the crack control measures and unification of new and old concrete, and the speed up and facilitation of complicated work site by precast forms.

***Inspection of construction joints in the concrete dam body by the impact elastic wave method***

*S. Ichikawa, T. Kamada, T. Sugiura and N. Hayashi*

The deterioration of the horizontal construction joints, which may affect the stability of the dam body is one of the phenomena of the aging concrete dams. The inspection by boring survey has been used to verify the state of the construction joints in the dam body. However, there are some problems in taking boring survey because it is costly, it needs to destroy even a very small portion of the dam body, and it can just check the spots, not the area. Therefore, the study was made on the non-destructive survey method to use the reflective wave of the elastic wave input by the impact, this method was applied for the survey of dam body of which the horizontal construction joints might be deteriorated. The following points were revealed: Estimation of the state of the construction joints by this method coincided with that from the boring survey from a practical standpoint.; This method enabled us to grasp the deteriorated construction joint area in the concrete dam body. Additionally, proper set-up of the strength of sound portion and deteriorated portion of the construction joints enabled us to judge the safety of the dam body.

***Deformation monitoring of rockfill dams in normal times and after earthquakes using satellite SAR data***

*H. Sato, T. Sasaki, M. Kondo, T. Kobori, A. Onodera, Y. Yamaguchi, K. Yoshikawa, D. Sango and Y. Morita*

For development of efficient and advanced deformation monitoring methods for rockfill dams in normal times and after earthquakes, we studied monitoring methods using satellite SAR (Synthetic Aperture Radar) data. Because satellite SAR doesn't need any sensors on dam surfaces and it can observe entire surface of rockfill dams and obtain data regardless of weather conditions, it is expected to contribute in monitoring of deformation of rockfill dams. In this paper, we evaluate external deformation of a rockfill dam using satellite SAR data in about four years. The dam has three targets on the crest for survey and we compared the results of external deformations by satellite SAR and survey at the points. We found the results of external deformations using satellite SAR data agreed well with those by survey and the average error of the external deformations between SAR and survey was about several millimeters. We also investigated tendency of external deformations of dam surface where survey had not been conducted. In addition, we conducted studies of deformation monitoring after earthquakes using satellite SAR data to grasp damage on rockfill dams by 2016 Kumamoto earthquake. We found satellite SAR data could detect small deformation of rockfill dams by the earthquake.

## *D. ICOLD 86th Annual Meeting International Symposium and 26th ICOLD World Congress in Vienna, July 2018*

***External deformation monitoring of nineteen rockfill dams using satellite SAR data***

*H. Sato, M. Kondo, T. Koboir, R. Ishikawa, T. Sasaki, W. Sato, N. Mushiake, T. Sato and K. Honda*

It is important to research new methods of conducting effective measurements of the external deformation of embankment dams. In this paper, based on data collected by Synthetic Aperture Radar (SAR) satellite, a basic examination was carried out regarding the applicability of SAR to the external deformation measurement of rockfill dams. Because no measurement facilities on the dam surfaces are needed for SAR, SAR technique will lead to cost reduction for external deformation measurements of embankment dams. This paper reports the results of satellite SAR based external deformation monitoring of nineteen rockfill dams in Japan in about two years from late 2014 to early 2016. The results of external deformations using satellite SAR data were compared with those by GPS or electro-optical survey data. We found that the results of external deformations using satellite SAR data agreed well with those by existing geodetic data and the average error of the external deformations between SAR and existing geodetic survey was about five millimeters.

***The risk management of thermal cracking for concrete dams subjected to unprecedented temperature fluctuations due to climate change***

*E. Hasegawa, Y. Miyata and T. Kase*

Temperature data used in thermal stress analysis are usually determined on the basis of data accumulated over a period of several tens of years. Because of considerable temperature fluctuations, however, that are thought to be attributable to climate change in recent years, assumed temperature fluctuations have become increasingly greater. Consequently, analytical results tend to deviate from actual concrete conditions so that thermal cracking risk is growing not only in the block under consideration but also at other locations. To address this problem, therefore, a three-dimensional model covering the entire dam structure including the foundation bedrock is constructed to conduct thermal stress analysis and determine the thermal cracking index distribution over the entire dam. On the basis of the results thus obtained, multiple blocks having a relatively high probability of occurrence of thermal cracking are identified, and detailed two-dimensional thermal stress analysis is conducted. At the time of concrete placement, changes in concrete temperature are monitored continuously by use of temperature sensors installed in the dam body, and the measurement results are checked against concrete temperature history simulation results based on past atmospheric temperature data. If the temperature difference is greater than predicted, appropriate control measures such as regulation of temperature and cooling can be taken. In the newly developed system, the relationship between the temperature difference between the exterior and interior of dam concrete and the thermal cracking index is determined so that thermal cracking risk can be managed quantitatively by use of the thermal cracking index calculated from the temperature difference.

***Empirical evaluation of seepage of fill-dams using reservoir level and rainfall***

*H. Soda, J. Ishiguro, K. Otagaki and K. Kishida*

Seepage of fill dams is generally measured by observation equip-

ment installed on the downstream side of the cutoff zone in the dam body and at the toe of the slope. Seepage is an important item measured to evaluate the safety of a dam, but seepage of a dam is impacted by noise such as the rise or fall of the RWL or the rainfall, so safety of a dam is evaluated only during a period when these impacts can be ignored and assuming that seepage has not increased from the past level at the same level. The authors have attempted to evaluate seepage behavior based on the range of past RWLs and seepage quantity at a sampled dam that was constructed 30 years ago. This paper presents the range
of seepage based on past RWLs and rainfall and proposes an evaluation method based on this range.

***History and present state of investigations on landslides caused by reservoir filling: A review***

*Y. Wakizaka*

The internationally most famous landslide caused by reservoir landslide is the landslide at the Vajont Dam in Italy in 1963. Before the occurrence of the landslide at the Vajont Dam, reservoir landslides occurred at many Japanese dams such as the Ishibuchi Dam, Shichikawa Dam, Naruko Dam, Kanogawa Dam and Futase Dam. Since the occurrence of the landslide at the Vajont Dam, reservoir landslides occurred at the Shimokubo Dam, Shingu Dam, Yanase Dam, Odo Dam, Hachisu Dam and Takizawa Dam. In 1995, a manual titled "Investigations and countermeasures for landslides around reservoirs" was published by the Japan Institute of Construction Engineering. This manual was revised in July 2009 as the guideline titled "Technical Guideline for investigations and countermeasures of a landslide around a reservoir" by the Ministry of Land, Infrastructure and Transportation. Uniform and systematic investigations and stability analyses can be performed based on the manual and the guideline. Not one disaster has ever been caused by a reservoir landslide in Japan, because suitable countermeasures are taken based on the results of many kinds investigations of reservoir landslides.

***Application of the transfer function matrix method in a dam engineering***

*M. Kashiwayanagi and Z. Cao*

Transfer function is essential for the seismic design and safety evaluation, etc. of structures. In order to improve the evaluation accuracy of the transfer function, the authors proposed the transfer function matrix method considering mutual interference between vibration directions. In this study, the applicability of the proposed method in the field of dam engineering is investigated. It has been concluded that the proposed method can give out more recognizable dynamic characteristics than the conventional method. It is applicable to the earthquake response prediction of dams at low cost without relying on a numerical model. Furthermore, it shows the possibility for utilizing in the deterioration diagnosis of dams.

## Theme 2 New construction technology

### *A. 4th Asia Pacific Group Symposium and 9th East Asia Dam Conference, September 2016*

***The underwater excavation by the shaft-style underwater excavator T-iROBO UW***

*N. Yachi, H. Miura,and A. Ueyama*

In order to solve the problems caused by deterioration and the inefficiency of the conventional method in redevelopment of existing dams, a shaft-style underwater construction machine (T-iROBO UW) was developed and utilized in the Amagase Dam redevelopment project in Uji city, Kyoto prefecture. The machine is operated remotely to ascend, descend, rotate, to crash and gather the rock using a power shovel that is fixed to a shaft that goes down from the barge to the lake bottom, for underwater works. The underwater excavation is carried out while observing several monitors at the same time. One of the monitors shows landform of the lake bottom in 3D graphics, using the data obtained by investigation of sonar device. On the 3D graphics of landform, the movement of the power shovel is featured in animation, by measuring the angles of the arm of the power shovel. The ultrasonic camera is used to provide the operator a real-time image on the other monitor. It is also possible to replace attachments of the power shovel, and currently the underwater breaker, bucket, and pump are being used. This is a report of the development of T-iROBO UW and its performance.

***Construction of a coastal levee at Hamamatsu city coastline using trapezoidal CSG dam technology***

*N. Itoh, T. Suzuki, S. Terada, T. Fujisawa, Y. Kinouchi and N. Yasuda*

In order to mitigate giant tsunami damage predicted to occur on the Hamamatsu city coastline, a coastal levee higher than Level-1 tsunami is being constructed about17.5 km from Lake Hamana to the mouth of the Tenryu river. Here, Level-1 tsunami is a tidal wave which occurs as the result of an earthquake of magnitude (M) 8 with the return period of roughly 100-year to 150-year along Suruga-trough and Nankai-trough. The planned coastal levee is located on a long sandy beach with a seaside protection forest parallel to it on the north side. Considering the conservation of valuable plants and animals, the seriously eroded shoreline, and the scenic appearance of the site, basically the ground level of the seaside protection forest is raised and CSG (Cemented Sand and Gravel) is placed at the center of the levee section and the outer sections are constructed as earth dikes. The planned coastal levee is required to have tenacity enabling it to withstand overflow of Tsunami but, strength equal to that of a concrete structure is not needed, so a CSG structure, which has been developed by dam engineering, is adopted for the internal portion of the levee.

### *Construction of Gokayama Dam by the cruising RCD construction method*

*R. Nishiyama, M. Yugeta, T. Toyomasu, H. Yotsumoto, T. Fujisawa, Y. Kinouchi and N. Yasuda*

RCD (Roller Compacted Dam-Concrete) construction method was developed as a rationalizing dam concrete placing method and has been used to speed up the construction works of concrete gravity dams. The cruising RCD construction method adopted to construct Gokayama Dam has been developed to aim for even more rationalizing dam concrete placing, and which improves construction work efficiency by advancing the placing procedure of the internal RCD, so it enables the continuous placement of dam concrete and enables placement of concrete more speedily. In Gokayama Dam, the slumping concrete is placed in the outer concrete and RCD is place in the inner concrete. Originally, the RCD is not placed unless the placement of slumping concrete is finished in one lift. The cruising RCD construction method is that the placement of RCD starts from one side of the dam site, while the slumping concrete is placed at the other side of the dam site. In that case, the RCD is placed at the next lift. Simultaneously, the RCD and slumping concrete are placed at different two lifts. The placement of RCD antecedent to that of the slumping concrete enables this execution, unlike the conventional RCD construction method in which the slumping concrete is placed antecedent to that of RCD.

### *Construction of Apporo trapezoidal CSG dam*

*S. Yoshimura, S. Takasugi, M. Konno, T. Fujisawa, H. Yoshida and N. Yasuda*

The Apporo Dam is the second trapezoidal CSG dam in Hokkaido, following the Tobetsu Dam. At the Apporo Dam, the shale is used as the CSG material, which is the dam body material, and the dam is constructed on the foundation of the shale and shale-sandstone alternative layer. Shale has the characteristic which causes the slaking phenomenon when it is dried, so various technical studies were conducted to prepare for its use. For the concrete gravity dam, shale or mudstone cannot be used as the aggregates, so the aggregate for the Apporo Dam with original concrete gravity type was planned to purchase from quarry place. Furthermore, the foundation surface of the dam is extremely uneven and bumpy, so the investigation was carried out to select the execution machinery. According to the extent and depth of undulation, the proper spreading and compaction machinery are used in the Apporo Dam. As existing Tobetsu Dam and Kim Dam with trapezoidal CSG type had an even foundation surface, large-size construction machine was chosen. So, this kind of investigation has an important role for the construction of the new Trapezoidal CSG dams.

### *Development of a crawler type soil mixing machine with dryer function*

*S. Yamada, T. Temmyo, T. Koshida, I. Sandanbata, H. Itoh and A. Yamagishi*

This paper describes a newly developed soil mixing machine with dryer function. Regarding the core embankment of rock-fill dams, fine-grained soil and coarse-grained gravel must be mixed uniformly and efficiently in the stockpile. When the fine-grained soil is relatively wet, compared to optimum water content, blended soil becomes difficult to be mixed uniformly because fine-grained soil tends to become what is called “clay lumps”. Therefore reducing water content of fine-grained and wet soils is an important issue for the improvement of core quality. In this background, we developed a machine called “Mantis”, which can blend fine-grained soil and coarse-grained material efficiently even though the mix has a very high content of fines and water. We used a crawler type soil mixing machine, called “Stabilizer” which was improved with a fan for sending hot air produced with engine’s exhausted heat. Finally, we carried out a trial blending test at the stock yard. We found that the processed material was well mixed and its water content was reduced.

### *Large-scale dam body drilling by Tsuruda Dam redevelopment project*

*K.Kaji, K. Oobayashi, K. Miyahara, T. Fujisawa, H. Yoshida and N. Yasuda*

The Ministry of Land, Infrastructure, Transport and Tourism is now redeveloping Tsuruda Dam. The objective of the project is to improve its flood control function by increasing its flood control capacity and installing 3 additional large outlets for flood control. Remarkable features of the project are its large scale: 6m diameter holes and 4.8m diameter outlet. And the height of the dam crest above the holes is more than 60m. This work had to be executed while ensuring Tsuruda Dam’s flood control and water supply functions, requiring the construction of a cofferdam in the reservoir before drilling the dam body. Because underwater work at the large depth was necessary, we developed a new type of floating cofferdam. This report introduces an outline of large-scale dam body drilling at Tsuruda Dam redevelopment project.

### *Proposal of the rationalization of dam construction quality control*

*H. Yoshida and M. Kusumi*

The Dam Construction Technology Research Group of the Japan Society of Dam Engineers studied rationalization of the quality control of the dam construction work. We surveyed many cases of quality control of dam construction executed in recent years and conducted a study based on execution data concerning the possibility of rationalizing quality control. Based on the results of this study, we proposed the rationalization of quality control of future dam construction work.

### *Development of embankment material grading control continuous management system using three-dimensional image processor*

*M. Fujiwara, W. Nakane, I. Miyairi, M. Omata, T. Otake, I. Kobayashi, T. Hashizume and A. Nakamura*

In dam construction, grading control of embankment material is of vital importance in quality control. The conventional practice is to take samples and carry out sieve analyses at regular intervals, which is both labor- and time-consuming. When constructing a trapezoidal dam with cemented sand and gravel, it is standard practice to produce embankment material by mixing locally available earth material such as riverbed deposits and excavated material with cement and water. In order to achieve the required strength of embankment material, therefore, grading control checks need to be made to ensure that its strength is kept within the allowable range. The authors have developed a new continuous grading manage-

ment system using three-dimensional image processing technology. The newly developed system makes real-time monitoring of grading possible by irradiating line laser light onto the material on the conveyor, calculating the volume of particles of each size from the image data continuously acquired with a digital camera and thereby determining particle size distribution. The usefulness of the system has been verified by using it for a countermeasure against landslide in which cemented sand and gravel embankment material was used. This paper introduces the new system and reports the field verification results.

## *B. ICOLD 85th Annual Meeting International Symposium in Prague, July 2017*

### *Dam concrete compaction management system Analyzing concrete vibration to decide when to stop compacting*

*K. Uekoua, H. Furuyab, W. Nakanec and S. Sakazume*

Compaction of concrete is of vital importance in dam construction when trying to attain the required water-tightness, durability and strength of the dam body. Viback concrete vibrator systems are usually used to compact conventional slumpable mixes. Decision as to when to stop compacting, however, is largely dependent on compaction time and empirical judgment based on visual observation, and there are no established quantitative criteria. There is concern, therefore, about problems such as segregation resulting from inadvertent failure to perform compaction, incomplete compaction and excessive compaction. To solve these problems, a new dam concrete compaction management system has been developed. The new system directly measures changing concrete vibration with acceleration sensors and analyzes vibration waveforms so that an objective judgment can be made as to when to stop compacting and numerical data can be recorded. The system makes it possible to make the best decision as to when to stop compacting, regardless of the operator's experience or expertise.

### *Construction of a tunnel spillway at large water depth*

*K. Takahata, R. Yoshioka and A. Konagai*

To increase of the flood control capacity of the dam which has passed through the half century after completion, the large-scale tunnel spillway with a diameter of 11.5m was newly constructed at the abutment of dam under water of 33m. The most important task was a construction of intake shaft of steel pipe sheet pile at the upper end of the tunnel which act as an intake part of new spillway and also serves as a temporary coffering, and measures to stop gush out of water at the joint part with tunnel. For solving these engineering problems, we performed stress analysis and quantitatively grasp the stress distribution of the intake shaft in the constructing stage and joint excavation of tunnel that has been constructed from the downstream. Based on the result of the analysis, we made monitoring plan of shaft displacement and performed countermeasures for reliable water tightness around the intake shaft and tunnel jointing part. As a result of these countermeasures, the construction of the tunnel under the water was safely completed without suffering by large water gush out from the intake shaft.

### *Proposing a fully automatic cementitious mix production system*

*M. Fujiwara, I. Miyairi and S. Sakazume*

The authors have developed a continuous grading management system using a three-dimensional image processor capable of irradiating line laser light to CSG (cemented sand and gravel) materials on a belt conveyor, calculating the volumes of particles of different sizes from continuous image data obtained with a digital camera and determining particle size distribution in real time. By using particle size distribution measurements obtained from the newly developed system in combination with moisture content measurements obtained with radioisotope moisture meters, the quantities of cement and water to be added to produce cemented fill materials can be controlled in real time. This report deals with functions of a fully automatic cementitious mix production system consisting of these components.

### *Construction of a coastal levee in Natsui District, Fukushima Prefecture using trapezoidal CSG dam technology*

*T. Okeda, H. Igari, N. Yasuda, Y. Kobayashi and A. Takei*

The coastal area of Fukushima Prefecture suffered enormous damage from the tsunami caused by the 2011 off the Pacific coast of Tohoku Earthquake, and most of the coastal levees were damaged catastrophically. Completed in October 2013, Natsui District Coast was the first coastal levee to be constructed in Fukushima Prefecture as a restoration and reconstruction project. The length of the coastal levee is 920 m, and the crest height (TP; Tokyo Peil) is 7.2 m. The levee volume is 60,000 m3, and 40,000 m3 of that is made using CSG (Cemented Sand and Gravel), which was made with concrete debris from the earthquake together with cement and water. This is the world's first application of the design and construction method of trapezoidal CSG dams to a coastal levee. By adopting this method, not only does it have a "persistent" structure toward overflows of sea wave, but both material cost and disposal cost were reduced by using concrete debris from the earthquake, which has to be handled as general waste. In addition, we were able to greatly shorten the construction period: it took about seven months to complete the main part of the coastal levee.

### *Trial mix and full-scale trial embankment for RCC dam at Nam Ngiep 1 hydropower project*

*Y. Aosaka, T. Seoka, B. A. Forbes, J. Cockcroft, Y. Murakami and M. Asakawa*

The Nam Ngiep 1 Hydropower Project (290MW) in Lao PDR is presently under construction (2014-2019). A Roller Compacted Concrete (RCC) gravity dam, 167m height is being built in a narrow V-shaped gorge. A total of 2.3 million cubic metres of RCC is planned to be placed in 26 months, as a continuous process through wet and dry seasons using the Slope Layer Method (SLM) for placing RCC. The principal materials are cement and fly ash, imported from Thailand, and locally quarried sandstone/conglomerate aggregate. This Paper discusses the programme of off-site and on-site trial mixes that were conducted between 2008-2015 to obtain a stable, durable and economical RCC mix design, the full-scale trial embankment, and the construction of the left bank wing wall

of the regulating dam and the secondary upstream cofferdam to the main dam, that were carried out from 2015-2016. The full-scale trial embankment confirmed and evaluated the variability of RCC and the Grout Enriched RCC (GE-RCC), the placement characteristics, with respect to the machinery used, the layers thickness, compaction amount, joint treatment, compressive and direct tensile strength, in-situ permeability testing, and finally as observed in full section cuts made through the trial embankment by band sawing cutting.

### *C. ICOLD 86th Annual Meeting International Symposium and 26th ICOLD World Congress in Vienna, July 2018*

***Design of a Tsunami coastal levee using trapezoidal CSG technology and quality control during CSG production (Coastal of Hamamatsu city)***

*N. Itoh, T. Takada, S. Terada, N. Yasuda, T. Nakashima and M. Tanaka*

In order to mitigate giant tsunami damage predicted to occur on the Hamamatsu City Coastline, a coastal levee higher than Level-1 Tsunami is being constructed about 17.5 km from Lake Hamana to the mouth of the Tenryu River. Here, Level-1 Tsunami is a tidal wave which occurs as the result of an earthquake of magnitude (M) 8 with the return period of roughly 100 year-150 year cycle along Suruga-trough and Nankai-trough. The planned coastal levee is located on a long sandy beach, parallel to a seaside protection forest on the north side. Its location imposed the design requirements for the conservation of valuable fauna and flora, and scenic appearance, and for the restoration of the seriously eroded shoreline. The levee of CSG (Cemented Sand and Gravel) placed at the center and surrounded with embankment are applied for raising the ground elevation of the seaside protection forest. The planned coastal levee is required to have tenacity enabling it to withstand overflow of Tsunami, but strength equal to that of a concrete structure is not needed, so a CSG structure, which has been developed by dam engineering, is adopted for the internal portion of the levee. Furthermore, the usage of ICT is also attempted to rationalize and advance quality control of CSG material.

## Theme 3 Flood, spillway and outlet works

### *A. ICOLD 84th Annual Meeting International Symposium in Johannesburg, May 2016*

***Planning and design of additional discharge facilities in Japan***

*N. Hakoishi, T. Sakurai and T. Ikeda*

Additional discharge facilities to the existing dam are hardly planned in the design and construction stages of the existing dam. The arrangement of additional discharge facilities is restricted due to the layout of the existing facilities of the dam. In this paper, we explain the considerations in the planning and design of the additional discharge facilities in accordance with purposes and types of a facility. In addition, we describe the design approach of additional discharge facilities which are to be installed by drilling a concrete gravity dam.

### *B. 4th Asia Pacific Group Symposium and 9th East Asia Dam Conference, September 2016*

***Gate operation support table of Ohno flood control dam against excess flood inflow***

*J. Kashiwai, T. Kubozonoand T. Takada*

Flood control operation requires smaller discharge than inflow. This operation raises water level of a reservoir, and cannot be continued until reservoir water level reaches to the dam design flood stage. Flood control operation mode should be changed into overtopping prevention mode in an appropriate way at a certain inflow and water level condition during excess flood inflow. Mode changing timing and the gate operation ways for increasing discharge to prevent overtopping are one of the most serious matters for operation managers. In above situation, MOPO (minimum outflow to prevent overtopping) table, which was developed by Public Works Research Institute Japan, was employed by Ohno dam for supporting the operation judgment. MOPO is obtained through the gate operation simulation in the large inflow condition which reaches to the design inflow. If the outflow at the time in the pair of inflow and water level condition is greater than MOPO, future water level must be controlled under the dam design flood stage without extreme outflow increase. This paper will show the simulation conditions for the Ohno dam's MOPO table. They consist of the inflow condition, gate movement restrictions and outflow increase limitations.

### *C. ICOLD 85th Annual Meeting International Symposium in Prague, July 2017*

***Experimental study of ski jump spillway at the Nam Ngiep1 Hydropower Project in Laos***

*T. Takahashi, Y. Murakami, M. Asakawa, S. Tsutsui and Y. Aosaka*

The Nam Ngiep 1 Hydropower Project in Laos is under construction: two dams and two powerhouses with total installed capacity of 290MW. A 167 m roller compacted (RCC) dam is being constructed in the narrow valley and will be equipped with a ski jump spillway with multiple flip bucket. Hydraulic model tests have been carried out in order to confirm the effect of deflectors and alternative flip bucket geometries which promote increased longitudinal dispersion of the water jets and diving zones downstream in the river course.

***Development of new maintenance program for scouring measures at downstream of dam***

*S. Takagi, M. Sato and Y. Kitamura*

Energy dissipations at downstream of dam have to be sufficient to reduce the stream power and to pass the flood discharge safely. The scouring at downstream foundation of dam and spillway structure is especially a major topic in presence of hydraulic structures for flood control. By utilizing the obtained information, we will further and continuously make our all efforts to securely carry out the existing erosion measures and long-term measures at downstream of dam to stabilize the dam, to thoroughly keep and control the environment including the dam and the river, and to respond to the problems found as the results of the measures. They are including checks and reviews for the maintenance and control standards, plans, and countermeasures. In this paper the new maintenance program was explained and introduced the process of setting up by the experimental study with the field observation, mathematical model tests, and the hydraulic scale model tests. The program was appropriately to be examined through the various observation and tests about the topics of during construction of scouring measures and maintenance for the existing dam.

***Study on scouring phenomena at downstream of dam during flood control***

*Y. Kitamura and S. Takagi*

Funagira Dam was built at the most downstream of the Tenryu River in 1977. The spillway facilities were designed to handle the design discharge of up to 11,130 m3/s under gross head of 10m to 18m. The energy dissipation at downstream of the dam was designed as the hydraulic jump-type on the bed protection blocks. The dam has been experienced several large flood events during the last about 40 years after the completion. The protection blocks were damaged and the scouring downstream foundation of the dam was begun in the early stage, and up to 6,300 measure blocks were continually put on. In recent time, nonetheless, the flood events in 2011, was larger and longer period of flood with maximum flood about 6.396 m3/s, and the scouring increased to the severe condition at the foot and stability of dam. In this paper the experimental study results and knowledge with the field observation, mathematical model tests, and the vertical 2-dimensional and the fully 3-dimensional hydraulic scale model tests were introduced to evaluate the scouring processes and to determine the long-term measures.

***Study on validity of the hydroelectric dam operation adopted GSM and the information about typhoons***

*H. Takakura, T. Matsubara, E. Nakakita and N. Takada*

In recent years, unusual rainfalls and floods have increased, and social demands are increasing that hydroelectric power dams, which have no function for flood-control originally, function as the flood-control dam. The long-term rainfall forecast is needed for the hydroelectric power dam to have the flood-control function by lowering reservoir water level with power generation. In this study, a new proposed weather and flood forecasting method, which combines the efficient formulation of GSM (Japan Meteorological Agency's Global Spectral Model) and the information about typhoons, was applied to Ikehara and Kazeya hydroelectric power dams at Kumano river basin and evaluated. The results showed that the new flood-control method had the applicability to the dam operations in terms of the reductions of the max discharge from the dams.

## Theme 4 Earthquakes and dams

### *A. ICOLD 84th Annual Meeting International Symposium in Johannesburg, May 2016*

***The seismic analysis of an earth-fill dam on thick liquefiable ground and countermeasures against a large earthquake***

*T. Kato, T. Honda and S. Kawato*

This paper introduces the seismic analysis of an earth-fill dam on a thick layer of liquefiable ground and countermeasures that can be taken to counteract the effect of a large earthquake by using effective stress with dynamic analyses using Finite Element Methods (FEM). According to these analyses, the dam's crest subsidence is limited after the earthquake due to the restriction of the liquefaction potential by adopting the counterweight filling method.

## *B. 4th Asia Pacific Group Symposium and 9th East Asia Dam Conference, September 2016*

### *Experimental study on seismic response behavior of fill dams influenced by dam's shapes and input wave's directions*

*Y. Hayashida, S. Masukawa, I. Asano and H. Tagashira*

The characteristics of the seismic behaviour of fill-type dams were examined by shaking table tests, in which three shapes of dam models, namely, symmetric about both a maximum cross section and a dam axis, symmetric about only a dam axis, and asymmetric about both a maximum cross section and a dam axis, were shaken separately in the stream direction and in the dam axis direction, and then the effects of the dam's shape and the direction of the input wave on the seismic response behaviour were verified. From the results of the experiment, the point at which the maximum acceleration values were recorded during the shaking in the stream and the dam axis directions was found to be right above the deepest part of the dam's valley. It was clarified that the response orthogonal to the shaking direction could arise depending on the shapes of the dam, the direction, and the dominant frequencies of the input waves. In particular, in the case of shaking in the dam axis direction, the point at which no response could be incited appeared on the crest of the dam depending on the shape of the dam and the dominant frequencies of input waves.

## *C. ICOLD 85th Annual Meeting International Symposium in Prague, July 2017*

### *Study of seismic performance evaluation method for concrete gravity dams on low stiffness foundation*

*T. Shiono, C. Yamaguchi, Y. Nakano and T. Tsukada*

For evaluation of seismic performance of concrete gravity dams which are constructed on low-stiffness foundation, we should consider the permanent settlement of foundation due to earthquake loading in addition to stress of dam body and foundation. However the Guidelines for Seismic Performance Evaluation of Dams against Large Earthquakes (draft) in Japan don't mention how to estimate the permanent settlement of foundation. So, we studied the evaluation method, which is using FEM dynamic analysis by equivalent linearizing method, modeling the foundation as non-linear material and calculating the settlement by cumulative damage. Then we conducted the centrifugal loading vibration test and numerical analysis to estimate that the method we studied was reliable enough to be used for the first stage evaluation of seismic performance of concrete gravity dams on low-stiffness foundation.

### *An experimental study on permeability of soils under shear deformation using remodeled torsional shear apparatus*

*A. Hisano and M. Takabatake*

We remodeled the apparatus for torsional shear test on hollow cylindrical specimen of soils in order to examine the relationship between the shear deformation and the permeability of the impervious material for rock fill dams. As a fundamental approach concerning the permeability change of impervious materials deformed by the vertical offset, we conducted the permeability test using the apparatus. Firstly, we conducted TEST 1 that was the permeability test method for test material deformed by turning the swivel in steps, while keeping the test pressure constant. We assumed that the coefficient of permeability obtained from TEST 1 was similar to that obtained from JIS A 1218:2009. Secondly, we conducted TEST 2 whose purpose is evaluation of water resistance of deformed test material against high water pressure as severe condition beyond realistic situation. As the result of TEST 1, test material was not measured the increasing characteristics of coefficient of permeability under shear deformed condition. The result of TEST 2 indicates that consolidation pressure has a influence on the increasing characteristic of coefficient of permeability of test material.

### *Efficient repairing and reinforcement method for AFRD damaged by the earthquake*

*T. Tsukada, M. Shimazaki and T. Mizuno*

We developed the effective repairing method for asphalt facing of the Yashio dam, asphalt facing rock fill dam (AFRD) constructed for the upper reservoir of the Shiobara pumped storage power plant of Tokyo Electric Power Company Holdings, where cracks occurred by the 2011 Tohoku earthquake, to complete repairing works in a short period so as to resume power generation immediately. The developed repairing method was consisted of asphalt mastic using asphaltic material developed for the purpose of improving deformation performance under a low temperature, hereinafter we call it "low elastic asphalt", and asphalt impregnated non-woven sheet. We completed the repairing works in about only one month, because we limited the removing area by covering the low elastic asphalt mastic of 10 cm width and 5 cm thickness, as a buffer part absorbing the strain, on the cracks leaving in the layer underneath from the forth layer to the bottom layer of the asphalt facing consisted of seven layers. In addition, it was estimated that the cracks occurred by the strain concentration of the crest concrete block joint connecting the asphalt facing, the facing near the concrete block joints were also reinforced using low elastic asphalt mixtures.

### *Seismic analysis based on results of the laboratory shaking table tests for the dam-model*

*M. Matsuura, H. Ieda, H. Tagashira and S. Sato*

As Japan frequently suffers large earthquakes, a safety collation of performance against earthquake for aged fill-dams is an urgent issue. But an application of technique to maintain high resistance to earthquake based on results of quantitative analysis is limited. First we have taken one step of arranging examples which analyzed conditions and problems about present design techniques for earthquake-resistance. The series of the example of the seismic-stability analysis for the fill-dams is shown in this paper, in which reduction of undrained strength in saturated zone, liquefaction of dam body and foundation and the non-linear property of loose dam body were taken into account. Then we introduce the results for the shaking table tests, which we can demonstrate and inspect the applicability of examination methods for earthquake-resistance. In the tests, six

cases using silica sand were carried out on the 1G field of a small dam with many sensors and centrifugal force field of 60G corresponding to an actual dam height. Three cases of the tests were conducted in the seepage condition. The response acceleration, the settlement and the deformation for the tests were investigated. And we present consideration about diagnosis and its procedure to support a rational and appropriate evaluation.

## *D. ICOLD 86th Annual Meeting International Symposium and 26th ICOLD World Congress in Vienna, July 2018*

### *Three-dimensional behavior properties and reproduction analysis of an arch dam during large-scale earthquakes*

*H. Sakamoto, N. Sato and N. Tomida*

This study analyzed the following earthquake records at the Yagisawa Dam, which is managed by the Japan Water Agency, in order to clarify the three dimensional behavior of arch dams during large-scale earthquakes: (a) microtremor records measured simultaneously at 14 points, (b) small earthquake measurement records obtained simultaneously by seismographs installed at 6 points, and (c) maximum earthquake records (6.56m/s2 at center of dam crest). The behavior at the Yagisawa Dam found in (c) during a 6.56m/s2 earthquake record was difficult to reproduce based on three-dimensional FEM analysis, which is generally used in Japan, but were reproduced with high precision by analysis using revised foundation ground – dam body – reservoir coupling conditions.

### *Studies on extensibility of asphalt face and effective reinforcement based on AFRD damaged by the earthquake*

*T. Tsukada, M. Shimazaki, T. Mizuno and Y. Matsumoto*

The 2011 Tohoku Earthquake triggered cracking in the asphalt face of Yashio Dam, which extended for 70-80 m from the crest almost running parallel to the abutment on both sides. This asphalt-face rock-fill dam was located about 300 km from the epicenter. The maximum observed acceleration was around 0.05 m/s$^2$ at the foundation and around 0.25 m/s$^2$ at the crest, not necessarily intensecompared to the levels envisaged in the design (0.266 m/s$^2$ at the foundation and 1.0 m/s$^2$ at the crest). Nevertheless, the dam was damaged. Therefore, the conditions of cracking were studied in detail on site in combination with indoor testing and dynamic response analysis to reproduce and compute the behavior of the dam during the earthquake. As a result, the cracking was presumed to have appeared when strains concentrated on a block joint of the crest concrete. The further downward propagation along the slope was probably caused by strains from displacement by the earthquake and thermal contraction from the drop in the water level, which concentrated at the tips of the cracks. Indoor tests and simulations by dynamic analysis were conducted to validate the presumed causes of crack propagation. A method was devised to repair the cracks while ensuring adequate performance of the asphalt face consisting of a total of seven layers. In this method, only three layers were cut out and replaced with a material resembling a joint sealant that contained polymer-modified asphalt with great deformation following performance even in cold temperatures. The material's composition was also determined by taking the workability into account. Before the repair work, a simulation test was conducted with a sample to make sure that the method not involving cutting and replacement down to the bottom layer would provide comparable or greater deformation following performance than the existing asphalt face. The same material from the repair work was used at the crest area that experienced the strain concentration. A structure was devised and constructed to follow even a large strain after a simulation by numerical analysis.

### *Study on the mechanism of the peculiar behaviors of Aratozawa Dam in The 2008 Earthquake*

*N. Yasuda, N. Matsumoto, M. Naruoka and , Z. Cao*

During the 2008 Iwate-Miyagi Earthquake (M7.2) of June 14, 2008, seismic motions with the maximum acceleration of 10.24 cm/s2 in the stream direction were recorded at the foundation bedrock of Aratozawa dam, a rockfill dam located approximately 16km from the epicenter. However, the maximum response acceleration in the same direction near the center of the dam crest was 5.25 m/s2, and the acceleration amplification ratio of the dam body was far lower than that normally considered for a rockfill dam. Furthermore, it was measured that the crest settled down 19.8 cm after the earthquake. In this study the dynamical properties of the embankment materials have been identified with the reproduction analysis of the past earthquakes, and the recorded behaviors of the dam body during the mentioned strong earthquake have been simulated. The generating mechanism of the peculiar earthquake behavior has been investigated based on the results of earthquake response analysis. Furthermore, in order to understand the deformation mechanism, sliding stability analysis and cumulative damage analysis are performed. According to the results, the residual deformation of the dam body after the strong earthquake is inferred to be caused by the shaking settlement of the embankment materials.

### *Centrifugal model test for destruction of dam body induced by the liquefaction of its foundation*

*Y. Hayashida, H. Tagashira and S. Masukawa*

Huge earthquakes have been occurred frequently in Japan and there are about 1200 irrigation fill dams which have passed over 50 years after construction. Some of such irrigation fill dams (especially, earth dams) have the problem about leakage and loss of cross section by aging. In these dams, countermeasures to constructing impervious zone on the upper slope of dam body as countermeasure against leakage and reinforcement are adopted frequently. Purpose of this study is to acquire the fundamental scientific knowledge about deformation and destruction behaviors of dam body with inclined core zoning, especially, in sight of the liquefaction of its foundation which is one of principal factor to induce large deformation during earthquake. Destruction mechanism of dam body developed by interactions among liquefiable foundation, dam body and reserved water are verified by the centrifugal liquefaction experiment. From results, it is clarified that dam body effects to the behavior of pore water pressure in the liquefiable layer. Increased value of pore water pressure under shaking become several times when dam body exists. However, retrofitting at the toe of downstream slope of dam body can inhibit the typical increasing of pore water pressure. And it is supposed that behavior of pore water pressure in liquefiable layer closely related to the deformation behavior of dam body. Fracture of dam body with inclined core develop progressively according to the interactions among liquefiable foundation and dam body. And it is supposed that deformation of upstream slope of dam body is dominant factor to induce catastrophic

destruction of dam body. Retrofit at the toe of downstream can restrain such deformation and, even though dam body damage severally, catastrophic destruction inducing over topping is prevented.

***Discussion on the mechanism of the destruction of a small-scale dam by The 2011 Great East Japan Earthquake and reconstruction and reinforcement***

*T. Miura, M. Matsuura, T. Tanaka, F. Tatsuoka and Y. Mohri*

In Japan, where rice farming is the main agricultural activity, the advancement of civil engineering technology has facilitated the development of new paddy fields and new agricultural facilities and there are approximately 210,000 small-scale dams that irrigate farmland in areas where there are no large rivers. Many of these small-scale dams are earthfill dams. Because of the shortage of suitable embankment materials, the embankments of many of these small-scale dams have an insufficient degree of compaction. The reconstruction of the Fujinuma Dam, a small-scale dam in Fukushima Prefecture, which was destroyed by the Great East Japan Earthquake, incurring loss of human lives, is described in this paper. The safety standard for the reconstruction of the Fujinuma Dam was defined as "constructing a safe and reliable dam that is overwhelmingly more seismic resistant than the failed old dam," based on the results of analysis of the causes of the failure of the old dam. The technical goal for the reconstruction was defined as "ensuring the safety of the dam against the largest possible ground motion expected in future." As the new dam had to be constructed as a high-quality dam with a larger degree of compaction than the old one to satisfy the standard and achieve the goal, a standard for the degree of saturation, which had not been used in the conventional dam construction, was defined for the reconstruction of the Fujinuma Dam. The design and the results of the execution control tests are discussed in this paper.

## Theme 5 Reservoir sedimentation and sustainable development

### *A. ICOLD 84th Annual Meeting International Symposium in Johannesburg, May 2016*

***Positive effects of reservoir sedimentation management on reservoir life: Examples from Japan***

*C Auel, SA Kantoush and T Sumi*

The effectiveness of different strategies against reservoir sedimentation is demonstrated herein using data sets of Asahi, Nunobiki and Dashidaira reservoirs in Japan. The applied strategies encompass sediment routing with a bypass tunnel, drawdown flushing during floods and sabo dam construction in the catchment. It is shown that bypassing and flushing are very efficient strategies enlarging reservoir life by 3 to 21 times up to many hundreds of years. Furthermore, it is revealed that also efforts in the catchment, e.g. sabo dam construction, is effective enlarging reservoir life by 2.4 times.

***2D reproduction analysis of reservoir sedimentation caused by flood***

*N Sorimachi, K Hashimoto and T Sato*

Reservoir sedimentation of an existing hydroelectric dam was reproduced by two-dimensional numerical analysis. To make the calculation simple, numerical analysis was based on parametric studies. As a result, reservoir sedimentation was reproduced by two-dimensional analysis, in terms of sediment's volume. In addition, relation between reservoir level and inflow, for the effective dredging of sediments, were estimated to some extent. We will conduct additional experimental operation and numerical analysis to obtain more information about moving sediments into the dead storage effectively.

***Development of a bedload transport measuring system for sediment bypass tunnels in Japan***

*T. Koshiba, T. Sumi, D. Tsutsumi, S. Kantoush and C. Auel*

Sediment Bypass Tunnels are operated to divert sediment around reservoirs reducing reservoir sedimentation. A major drawback of these tunnels is severe invert abrasion due to high velocity and sediment flows. There is an urgent need to establish innovative measurement systems of sediment transport rates in SBTs. In this paper, three bedload measuring systems, namely hydrophones, geophones, and newly developed plate microphones are introduced and compared. The Koshibu SBT is planned to operate from 2016. Plate microphones combined with geophones and other planned systems are installed in the tunnel. Results of preliminary tests and installation plans of bedload measurement are presented.

***A practical example change of river bed environment downstream from dam reservoir by sediment replenishment***

*Y. Musashi, Y. Nakata, T. Suzuki, M. Oshima and S. Demizu*

We reviewed the case of the Nakagawa River, which had one of the largest scales of sediment replenishment. Its monitoring results are composed of river survey, river bed material survey, biological research and so on. The results show the changes of river bed condition such as restoration of river bed materials, the increase in the ratio of fine sediment on the armored river bed and the expansion of riffle. We estimated the amount of transported sediment by one dimensional analysis of river bed variation. We also examined the effects of sediment replenishment on amount of sediment yield by grain size.

## B. 4th Asia Pacific Group Symposium and 9th East Asia Dam Conference, September 2016

### *Vertical Multi-Holed Double-Pipe system: A new sediment suction method utilizing a natural head*

*A. Hisano, S. Oota and K. Maeda*

At present, the sediment removal method using a suction pipe is the subject of research as an effective method for discharge of accumulated sediment in dam reservoirs. Vertical Multi-Holed Double-Pipe system is one of these methods and has been researched by the authors for the application to an actual reservoir. This system is expected to reduce the cost of removing sediment accumulated repeatedly around a local place such as the neighborhood of the intake. This paper explores the following topics: methods and results of the laboratory tests of the system; the hydraulic design method based on the laboratory tests; and the estimation of sediment concentration in the discharge flow.

### *Abrasion and corrective measures of a sediment bypass system at Asahi Dam*

*T. Nishikawa, Y. Yamane and Y. Omoto*

At the Asahi Dam of Kansai Electric Power Co., Inc., a sediment bypass system was built and in operation in 1998 to take a fundamental measure to mitigate impacts by prolonged water turbidity and sedimentation ascribable to collapse of mountain slopes in the upstream caused by a great flood in 1990. The effectiveness of the bypass system has been verified and reported in the past. In the meantime, the tunnel invert has been worn notably by a significant sediment transport at high velocity and how to improve the efficiency of periodical maintenance is an issue. This paper describes the abrasion of the tunnel invert of the sediment bypass system at the Asahi Dam that has been in operation for approximately 15 years, and evaluates possible tunnel maintenance methods using the life-cycle cost based on monitored data of abrasion.

## C. ICOLD 85th Annual Meeting International Symposium in Prague, July 2017

### *An examination of efficient turbid water coagulation method using natural coagulant*

*M. Miyakawa, M. Kusumi, T. Ishigami and K. Motoyama*

Long term persistent turbidity is a major problem in reservoirs of Japan and other countries. We are examining the practical methods using natural coagulants, such as allophane (clay), which can be deposited in the reservoirs, to prove experimentally the effectiveness of allophanes coagulation performance, and to develop a useful and environmental friendly coagulation method for turbid water. The experiments conducted in this study provided two important findings. The first is that, through the laboratory experiments, we proved that the new practical dispersers, which are a cavitation mixer and a high pressure water sprayer, can be used effectively to disperse allophane. And we confirmed the usage of these dispersers raises the zeta potential of allophane. This effect is presumed to promote coagulation. The second is that the coagulation effect at the depth of more than 10 m was confirmed through the field experiment, where the new dispersers were used. As mentioned above, we can propose more practical, useful, and environmental friendly treatment method for turbid water using allophane at dam reservoirs.

### *Grouting method for dam reservoir foundation by effective use of ground water flow*

*F. Kawashima, T. Tsukada and S. Tsuruta*

In the bedrock of the Yashio dam reservoir foundation, the upper reservoir of the Shiobara Pumped Storage Power Plant of Tokyo Electric Power Company Holdings, the high dip angle open fissures are distributed to the deep area, there was relatively large amount of leakage due to these fissures and we needed to reduce leakage. As the leakage reduction measure, we selected the cement grouting at the bottom of the reservoir filled with water, with relatively wide borehole spacing by effective use of ground water flow. We confirmed its applicability by the field tests, research and laboratory tests by parallel plates which simulating the open fissure in the bedrock, and applied it to leakage reduction works. We completed the leakage reduction works and we were able to reduce the leakage to our target level.

### *Measures against the predicted degradations of water quality of Makio dam by the volcanic eruption*

*K. Onoshima, H. Imamoto, T. Miyashita and Y. Ishiguro*

Mt. Ontake erupted on September 27, 2014 and it was the second time in recorded history. The distribution and volume of products by the volcanic eruption were almost similar to those of the previous eruption in 1979. The catchment of Makio Dam is located at the foot of Mt. Ontake, therefore the influence of the eruption on the water quality of the dam reservoir was predicted to be continuing over a long period. In response to this situation, Japan Water Agency (JWA), the management body for Makio Dam, has collaborated with local governments/municipalities concerned and water users/stakeholders to implement not only efficient water quality monitoring but also appropriate measures for water quality conservation while making accurate forecast of discharged turbidity. As a result, the dam has kept supplying water to the downstream continuously without any particular trouble in water use at the moment.

### *Sediments discharging using siphon system demonstration test at the Republic of Indonesia Wonogiri multipurpose dam*

*T. Sumi, H. Itoh, T. Sase, T. Satoh and S. Kantoush*

The countermeasures by machines for excavation and dredging reservoir sediments have been often used in the past but in the future the total cost, including operation and maintenance costs as well as construction costs and the inhibitory effect of shoreline retreat of the coastal region have come to be required in the sediments countermeasure. In this paper, we report the results of demon-

stration tests of sediments countermeasure in Indonesia Wonogiri dam including sediments reduction of the reservoir sediments to downstream river by the siphon system using water level difference between reservoir and downstream river water level, not only construction costs but also aims to reduce energy consumption for operation and maintenance costs by the siphon system in Indonesia Wonogiri dam. A sufficient water level difference for the drought in the test cannot be reserved by using sediments discharge pipe with a diameter of 400mm, the system can transport sediments with a maximum particle size of about 130mm, with an average transport capacity of 30m3/h in the transport distance of 250m and with sediments discharge per unit power of about 8.1m3/kwh. Siphon system has 27 times processing capacity compared the dredging system with small pump with a capacity of 0.3m3/kwh.

***Density current flux due to bubble plume using a new air energy system***

*E. Furusao, H. Kawasaki, S. Takasu and S. Uchizato*

The Dam Air-energy System (DAS) is a new energy system using compressed air with high efficiency in dams. Several countermeasure facilities were installed in the Haneji Dam for water quality improvement as the first full-scale system using DAS. DAS facilitates artificial circulation of water by using a bubble plume caused by the production of compressed air by the DAS. Due to the efficiency of DAS, a large amount of compressed air (9.7 m3/min) can create a bubble plume. Field experiments were conducted to elucidate the flux in the horizontal density currents caused by the bubble plume. Based on temporal changes in the vertical profiles of water temperatures, flow rates of surface currents and intrusion as the middle layer flow were estimated. This method is applicable to the Haneji Dam due to the long residence time of water as hydrologic characteristics of the Haneji Dam reservoir. It was observed that a large amount of current flux was produced by the DAS-bubble plume system. By comparison of the experimental results with many previous studies, empirical equations for estimating the flux in current due to the bubble plume are proposed.

***Control method of water bloom using characteristics of reservoir ecosystem***

*Y. Iseri, M. Mori, K. Kudo and S. Yamamoto*

In the management of the dam reservoir, water bloom is often produced by an abundance of nutrient salts and causes significant damage on water supply including poor scenery, unfavorable water taste and production of toxic substance. Cyanobacteria belongs to bloom forming Microcystis and most frequently occurs in the reservoirs. They are also known to grow rapidly in high temperature environment and are, in fact, in increasing trend in the world because of the green house effect. This paper introduces the control method of the bloom, including Jet-Shock System for dispersing colony cells into the isolated cells, UV radiation Ship for stopping cell division and cooperation system to improve ecological purification function.

***Field experiment of bedload transport rate measurement at sediment bypass tunnel***

*T. Koshiba, S. Kantoush and T. Sumi*

For advanced maintenance of sediment bypass tunnels (SBTs), particularly concerning on the abrasion of the tunnel invert, a monitoring of sediment through tunnel is essential. We developed new bedload measurement systems, namely a plate microphone and a plate vibration sensor. After confirming the high sensitivity and robustness of these systems by flume experiments, these systems were installed at the outlet of Koshibu SBT, which started operation in 2016, in Japan. Prior to its commencement of the SBT, on-site calibration experiment was conducted. In the experiment, sediment is input in the SBT artificially by truck beforehand and flushed them out with clear water from the upstream. The experiment is repeated for 10 times with different grain size (5, 10 and 50 mm), volume (1, 3, 5 and 9 m3) and water discharge (5, 10 and 50 m3). Seven sensors of the measurement systems, which installed evenly along the width, successfully recorded the signals of passing sediment. In this paper, practical calibration formula of predicting sediment transport rate by recorded data are developed by analyzing the pattern of the 10 experiment cases. Finally, a method to quantify sediment transport rate and a desirable operation of those measurement systems on-site are discussed.

## *D. ICOLD 86th Annual Meeting International Symposium and 26th ICOLD World Congress in Vienna, July 2018*

***Observation and Estimation Method of Sediment Production in Kamanashigawa Basin, Fujikawa River System (Toward an Accurate Estimation of Dam Sediment Volume)***

*K. Tomita, Z. Ye, T. Hikita and T. Sumi*

The sediment storage in a dam is usually designed based on the cases which have similar watershed condition or sediment discharge in the nearby area, but not calculated directly from the sediment observation data in the watershed. Furthermore, the inflow of sediment due to flood events after dam construction is only accounted by total sediment volume. Besides, the sediment that flow into dam reservoir during a flood and the unstable sediments reserved in upstream that will become the supply resource in the future, are not under observation yet. In this paper, some consideration to improve the estimation method for sediment discharge in a watershed were conducted for sediment management in dam operation, by combining observation data of the sediment transport obtained by various equipment such as hydrophone, turbidimeter, and that predicted by satellite SAR image interference analysis, in Omukawa River, a right branch of Kamanashigawa, Fujikawa river system, Japan. Using the middle to downstream section of Omukawa River (extension L = 8.3 km, gradient 1/58) as a study site, a comparison between the volume of sediment transport obtained by SAR image interference analysis using 9 SAR images acquired by the ALOS-2 satellite passing over JAPAN, and the sediment discharge observed by hydrophone, turmidimeter and sediment trap pit during 2014-2016 period, is conducted. Some considerations were made for the results. The result shows that, although the data show relatively large scattering, an approximate linear correlation was recognized. The reason of the difference between two data is

assumed that sediment discharge is measured in only 2.0m wide area with respect to the river width of 72 m, which is not adequate for representing the entire river cross section.

### *Case analysis of sediment bypass tunnels (Switzerland, Taiwan, Japan)*

*H. Ohori, M. Ono, Y. Takata, G. Nagatani and T. Sumi*

Until now, the planning and design of SBT has been performed individually, in accordance with the circumstances of a particular dam. In order to systematize design methods for SBT, with this research we created a database of the purpose and specifications of SBT. We then applied classifications by structural types, and analyzed related characteristics. The target was a set of 15 SBT in Switzerland, Taiwan and Japan. Classification of structures was performed based on the sediment discharge form, the purpose of the dam, and the main purpose of the SBT. Here, the sediment discharge form refers to whether or not sediment entering upstream of the reservoir is passed through the reservoir. For the analysis of SBT characteristics, we analyzed the tunnel design discharge, the tunnel structure, and the target grain size of sedimentation, based on the prior structural classifications. We then organized considerations to be taken into account with future SBT planning and design.

### *Research on sediment sluicing operations through dam discharge operations in consideration of upstream/ downstream riverbed characteristics*

*Y. Kitamura and S. Takagi*

Sediment environment changes due to sedimentation in a dam reservoir not only cause changes within the reservoir but also affect a wide range of the dam's upstream/downstream. Sedimentation in a dam reservoir greatly changes the upstream/downstream riverbed environment, with effects such as increasing the flood level in the upstream area, armor coating and degradation of riverbed of the downstream riverbed, and even coastal retreat. Due to this, the importance of comprehensive sedimentation management, which includes not only sedimentation measures targeting the environments within the dam reservoir but also sediment flushing and sediment sluicing (hereinafter referred to as "sluicing") measures comprehensive sediment management, has been increasing. Sedimentation sluicing measures, which are comprehensive sediment management, have often been implemented. In this paper, the authors analyze data obtained from hydraulic model experiments and results of numerical analyses regarding measures against riverbed erosion in areas downstream the Funagira Dam, and discuss sediment flushing and sluicing techniques based on dam discharge operations taking the riverbed characteristics upstream and downstream the dam into account. The results obtained indicate that it is possible to estimate the amount of sediment outflow from the average riverbed level upstream the dam reservoir and the flood volume; to forecast changes in the flow downstream the dam from the estimated amount of sediment outflow and the average riverbed level downstream the dam; and to maintain and control the flow. On the basis of the numerical analysis results, the authors also propose adequate gate operations and discharge level operations to control dam sedimentation and sluicing as well as the flow downstream the dam.

### *Analysis of sedimentation countermeasures in hydropower dams considering properties of reservoir sedimentation*

*C. Onda, H. Okumura and T. Asahi*

Sedimentation in hydropower reservoir is one of the most important problems for sustainable power generation. Many our company's dam and reservoirs were installed in post war reconstruction period, then for decades reservoirs have stored much sedimentation inside up to sedimentation ratio about 10% because of high degree of sediment production and river flow regime. We have trying to excavate sedimentation out of reservoirs to avoid aggradations of upstream riverbed and obstacle for intake and outlet functions. Reprehensive five different type reservoir sediment managements considering sediment properties have been really carried out. In comparatively large Sakuma dam, provisional transporting inside reservoir is main countermeasure, in near future radical management will be required. In comparatively small Futatsuno and Taki dam, current excavating sedimentation volume is enough for maintaining reservoir size for flow sedimentation. So that sediment routing methods as bypassing will be planned in a hurry. In smaller Setoishi and Yambara dam, sediment sluicing or hydro-suction sediment removal systems have been already started as test. In spite of no quick remedy to countermeasure reservoir sedimentation dramatically, some methods exist that select suitable options for each reservoir considering with reservoir size, life and basin. Not only the technical feasibility, but also the economic advantages and ecological acceptability should be considered. For sustaining reservoir and hydropower, reservoir sedimentation management will be active and adaptive more and more.

### *Prediction of environmental effect due to sediment sluicing at a series of three dams*

*T. Yoshimura, H. Shinya, T. Sumi and N. Onikura*

With the flood disaster experienced in the Mimikawa River system due to Typhoon Nabi in 2005, various problems caused by sediment in the river basin became clear, including increased risk of flooding with rising riverbed levels in damregulating reservoirs, grain coarsening in the downstream river channel with the entrapment of sediment in dams, and the destabilization of bridge piers in the downstream river channel. As part of an effort to resolve all these problems simultaneously, from sediment sluicing at a series of dams was implemented. Sluicing is an operation carried out when there is river flooding due to typhoons. Dam-regulating reservoir drawdown is carried out, and sediment flowing into these reservoirs from the upstream is allowed to flow downstream of dams. This paper principally covers 1) an overview of sediment sluicing at dams in the Mimikawa River system, 2) understanding and analysis of the river environment prior to sluicing, 3) predictions of the effect on the river environment due to sluicing, and 4) testing of these predictions.

### *New development of technology for countermeasures against barren ground by dam reservoir sediments (Super fulvic acid iron)*

*T. Toyoda, J. Takimoto, T. Sumi, S. Horiya, Y. Sakai and M. Sueyoshi*

This time, our research group focused on the effect of high concentrations of fulvic acid produced at the bottom of the dam, using a high concentration fulvic acid iron elution unit, in a real sea area

where barren ground is progressing. By conducting demonstration experiments on the algae field recovery of the dam reservoir, it is going to develop for the practical application of technological development for effective utilization of lake bottom deposits. We have used steelmaking slag made from blast furnace as a material to promote dissolution of divalent iron ions in the past development process, but from this time we have found more effective materials, we have manufactured from electric furnace converter A material containing high concentration divalent iron ions was adopted. This is a material containing high concentrations of divalent iron ions which is 100 times higher than the steelmaking slag that has been adopted so far. Regarding the commercialization of this research and development overseas, it is scheduled to apply in Korea the first time in East Asia. In addition, we propose a new calculation formula for CO2 absorption (carbon conversion) by seaweed bed construction, and the annual fixing by the algae of Japan is estimated to be about 3 million tons. It is expected that future development of research and development utilizing this technology will be commercialized in areas such as tidal banks as a port conservation technology and construction for forming seaweed bed and seawall maintenance etc. Research and development in this area has attracted attention as a technique for improving the quality of cultured laver as application technology in recent years, technology for restoring seaweed beds and improving the production of agricultural products in recent years.

### *Plan and operation results of Koshibu Dam sediment bypass tunnel*

*T. Sakurai, T. Tsujimoto, I. Kunimura, H. Takeuchi and K. Ishida*

In order to prevent sedimentation in the reservoir and ensure the continuity of sediment transport at the river, the Koshibu dam sediment bypass tunnel was planned and completed in September 2016. From the viewpoint of structure, environment and sediment budget, monitoring plan was examined by the monitoring committee and several trial operations have been carried out. Since the purposes of the Koshibu dam is including flood control, irrigation and power generation, the sediment bypass tunnel is planned to operate during the flood control. In order to adapt to the flood control rule, two crests placed on the two orifices is designed for the inlet structure. The target bypassing sediments are gravel having a grain size of about 100 mm or less, sand and silt (clay). As a countermeasure against abrasion damage caused by the sediment transport, around the gate with a relatively low flow velocity was protected with “rubber steel” and the downstream section with high flow velocity was protected with steel lining. In the monitoring plan, the objectives of monitoring at each viewpoint were arranged by selecting suitable methods. In sediment budget monitoring, as the first case of the sediment bypass tunnel in Japan, sediment observation devices were installed on the bottom of the tunnel outlet part. After completion of the bypass facility, several trial discharge operations were carried out. Even though the trial discharge was a small scale compared with the planned maximum bypass discharge and comparatively short time, as a result of monitoring, it was confirmed that there was no problem in gate operation, and no significant abrasion damage and environmental changes in the downstream river. Moreover, it was able to estimate the sediment budget and sediment transport characteristics during bypass operations. Regarding abrasion damages, long-term monitoring is needed since the flow rate and operation time in the trial discharge was limited.

### *Sediment derivation by bypass tunnel restores downstream environment*

*S. Kobayashi, H. Fukuroi, T. Sumi and Y. Takemon*

We reviewed studies of the effect of SBT on the downstream environment to clarify whether SBT has a positive effect on downstream, and to understand the key features of SBT that promote the environmental recovery of the degraded reaches. Major results of the studies are listed as follows.
1. Below-SBT site in the downstream of dam was more like upstream of dam than above-SBT site in the downstream of dam, in terms of bed grain size, microhabitat composition, and invertebrate community.
2. Environmental recovery of downstream reaches, evaluated by upstream-downstream similarity in microhabitat composition and invertebrate community, corresponded with the years of SBT among the 4 dams. 3. Comparison of among-sites dissimilarity in invertebrate community among 3 types of rivers (non-dam, dam without SBT, dam with SBT) suggested a positive effect of SBT on habitat fragmentation.
4. Turbidity of downstream during and after floods and red tide occurrence in the reservoir decreased after the start of SBT.
5. Although bed level didn’t increase constantly, grain size, pool-riffle structure, gravel-bar changed as expected within a several years after the start of SBT.
6. Invertebrate community of downstream became more like that of upstream of dam within 2-3 years after the SBT in terms of both taxon richness and taxonomic composition.
7. Sediment releases by SBT acted as natural pulse disturbances that lower invertebrates and ecosystem functions, followed by their rapid recovery.
8. Numerical and field studies showed that the downstream channel becomes steeper and the riverbed becomes unarmored conditions by SBT. Surface grain
size distribution can change quickly even by one SBT release.
9. Turbidity decreased after the SBT operation. Algae, invertebrates, and fish decreased after each event but they recovered to a pre-event level soon.
10. Although test-run of SBT had been done for several years, there was no evidence of the recovery in the invertebrate community of downstream reaches towards an upstream state.
Downstream environment is expected to recover to a pre-dam state within a few to several years after the start of SBT if surface bed materials are reworked and exchanged. The downstream recovery by SBT that release mainly fine sediment will be examined by ongoing monitoring in multiple Japanese dams.

### *Challenges of Dam Reservoirs for the Coming Japanese Society and Several Proposals*

*T. Hamaguchi, H. Mori and H. Ishii*

This communication is to introduce the core contents of the report compiled by the special committee of Japan Society of Dam Engineers (JSDE) in 2016, which aims to clarify important targets in planning, operation and maintenance of dam reservoirs, with full and adaptive utilization of dam stock for the coming Japanese society in mind. Approx. 2,700 existing dam reservoirs play indispensable role in supply of water, energy, mitigation of flood damage, maintenance of normal function of the river flow, and recreational function. With increase of aged dams, there is an increasing number of re-development project of dams, whose major purpose is enhancement of flood control capability and recovery from excessive sedimentation. Importance of “backup” capacity is pointed out here.

After examining three influencing factors, namely decline in population, climate change, and rare but devastating disasters, major issues will be mitigation of flood damages, maintenance of normal function of the river flow, hydropower, and sediment management. Necessity of flood control capacity for long-term river improvement plan is confirmed. Hydropower's stabilizing function for solar and wind power is also focused. A basic framework consisting of four phases is presented, to make the stock of dam reservoirs function fully, with proper maintenance and adaptive operation to changes. They are 1) Long service life, 2) Wise use, 3) Capacity increase, and 4) Network use.
Finally, nine proposals of high priority are shown as follows.

1. Enhancement of flood control capacity
2. Securing water supply in a crisis situation
3. Promotion of hydropower
4. Networking of dam reservoirs at a basin level and efforts for consensus building
5. A method to concretize backup capacity
6. Improvement in reservoir operation
7. Securing dam safety
8. Technology development for longer service life of dams
9. Better understanding of dams and fostering engineers of next generation

## Theme 6. Geology and rock foundation

### *A. 4th Asia Pacific Group Symposium and 9th East Asia Dam Conference, September 2016*

***Reduction of ground water flow by promoting clogging effect of soil particles***

*T. Tamai, T. Shiono, N. Sorimachi, T. Tsukada and F. Kawashima*

Grouting was conducted to reduce groundwater flow in the bedrock of a reservoir of a pumped storage power plant, located in the site where the ground water level is low. We conducted grouting around the bottom of the reservoir, due to difficulty of forming the grout curtain reaching the low permeable layer of the bedrock. To reduce the permeability of bed rock with the smaller volume of grout, we invented a method to promote clogging effect artificially by spreading soil particles into reservoir water. The soil particles were obtained from the residual horticultural soil after being screened, collected near the reservoir, in order to reduce the cost. This paper summarizes the results and evaluation of laboratory tests, field tests and application of the invented method.

### *B. ICOLD 85th Annual Meeting International Symposium in Prague, July 2017*

***Dam foundation design for the main dam at Nam Ngiep1 hydropower project in Laos***

*T. Tabuchi, Y. Murakami, M. Asakawa, T. Seoka and K. Ueda*

A roller compacted concrete (RCC) gravity dam of 167 m height is under construction in Laos. Due to a folded zone in the geology of the right abutment, several weak horizontal layers are distributed below the river bed and these were considered to have potential to seriously impact the dam stability. In order to evaluate the mechanical properties and the distribution and formation of these weak layers, detailed geological investigations were instigated by conducting core drilling, rock property tests, X-ray diffraction (XRD) analysis and computed tomography (CT) scanning. Through a multiple-wedge stability analysis and finite element analysis (FEA), a shear key was designed to penetrate part of the weak layers and be incorporated into the dam body to improve the dam stability against sliding.

### *C. ICOLD 86th Annual Meeting International Symposium and 26th ICOLD World Congress in Vienna, July 2018*

***Evaluation of the dam geology and geological risk at the Namngiep 1 hydropower plant***

*T. Seoka, Y. Aosaka, Y. Yoshizu and T. Tabuchi*

The surface of the mountain at the dam site is covered by talus and a stratified structure below has alternating layers of sandstone and mudstone having rock class of CM to CH. On this has been developed the dam site. As general the bedding planes on the both abutment are moderately dipping with 8° in downstream direction and 8° in riverbed direction. And around the middle of the dam axis the dip angle of the bedding plane is 15° to 25° in the same direction. On the right abutment the fold axis is continuous in the upstream and downstream directions and geological formation shows a steep profile, but it becomes moderate again at the higher elevation. No outstanding fault has been observed and a box fold has been formed at the steep slope area. Flexural-slip associated with fold formation has developed around the fold axis. It is extrapolated that flexural-slip occurred before solidification based on the observation that blocks formed by joint sets intersecting with the bedding planes are observed in the sandstone layer and ductile deformation are frequently observed in the mudstone layer. Simultaneously definite striation of reverse-fault sense harmonized well with flexural-slip observed in some fine sandstone indicates that coarse sandstone and fine mudstone had flexural-slip developed in semi-brittle and ductile condition in geological time respectively. The weak layers are 8 in number and are confirmed on the bottom of the dam and both the abutments, and they are issues to consider specific strength and continuity of weak layers. Physical properties of the rock were determined based on observation of outcrops and drilling cores, in-situ block shear tests and laboratory tests. Physi-

cal properties of rock mass were evaluated based on Hoek-Brown failure criterion for each part of the foundation rock. Physical properties of weak layers were determined based on the shear box tests of the disturbed samples, liquid limit tests and plastic limit tests. The total strength of the weak layer can be estimated from the component of weak layers. In addition, X-ray diffraction analysis was conducted in order to verify that these fine particle fractions in the weak layers do not include any swelling clay (for example, Smectite) which might significantly degrade physical properties. Besides detailed observation by means of CT scanning was conducted in order to examine the continuity of a fractured part. Geological risk should be evaluated adequately for the dam construction in the BOT scheme project. The risk to a hydropower project is high compared with other infrastructure projects because large amount of project cost depends on geological condition. Therefore, adequate evaluation of geological risk and diversification of geological risk are very important factors. In addition, highly accurate geological data helps adequate evaluation of geological risk. Drilling technology especially is one of the most important factors to support geological evaluation. In this paper, the methods to evaluate the dam foundation rocks are discussed in the feasible study phase to the execution phase. Evaluation of the geological risk and the method to reduce the geological risk are discussed based on actual geological data.

### *Slaking countermeasures related to rock contact execution at the soft rocks foundation*

*S. Yoshimura, S. Takasgi, N. Yasuda, H. Satoh*

Apporo dam is a multi-purpose dam now under construction at the Azuma river in Horonai frontage of Atsuma town, Yufutsu district of Hokkaido prefecture as part of comprehensive development of the Azuma river. The dam is a trapezoidal CSG dam with of 47.2m in height, 47,400,000m$^3$ in total reservoir capacity, and 43,100,000m$^3$ in effective reservoir capacity. Apporo dam uses soft rock as the CSG material of dam body, and its dam foundation is also soft rock. Properties of the soft rock surrounding Apporo dam include slaking caused by cyclic wetting and drying, so various technical studies were conducted in order to use soft rock as the foundation bedrock. The dam foundation is extremely uneven so the excavation procedure was also studied. Slaking tests during the survey and slaking confirmation tests before construction works showed clearly the slaking characteristic of this bedrock and leads to the effective countermeasures. The construction works were completed and the first impoundment started in October.

### *Behavior analysis of the underground powerhouse based on precise displacement measurement*

*M. Kashiwayanagi, K. Maeda, N. Shimizu*

A few damaged pre-stressed anchors were identified in the 40-year aged underground powerhouse, while no other deterioration in the cavern was found. The underground powerhouse includes output of 220 MW and two generator units. The cavern located 100 m beneath the reservoir has the dimension of 23 m wide, 42.25 m high and 70.2 m long. The monitoring of the convergence has been conducted at two generator sections of the cavern to clarify its long-term performance using a newly developed laser range finder since then. The monitored convergences have behaved stably reproducible and been clearly consistent with the yearly and/or the seasonal fluctuations of the reservoir water depth and the ambient temperature in the cavern. These are less than the unusual convergence which is designated under the assumption of the entire loss of the support effect as the risk scenario. No concerns are found in the current situation of the cavern so far.