May 9-12
Kyoto-Japan
2017

2nd International Workshop on
Sediment Bypass Tunnels

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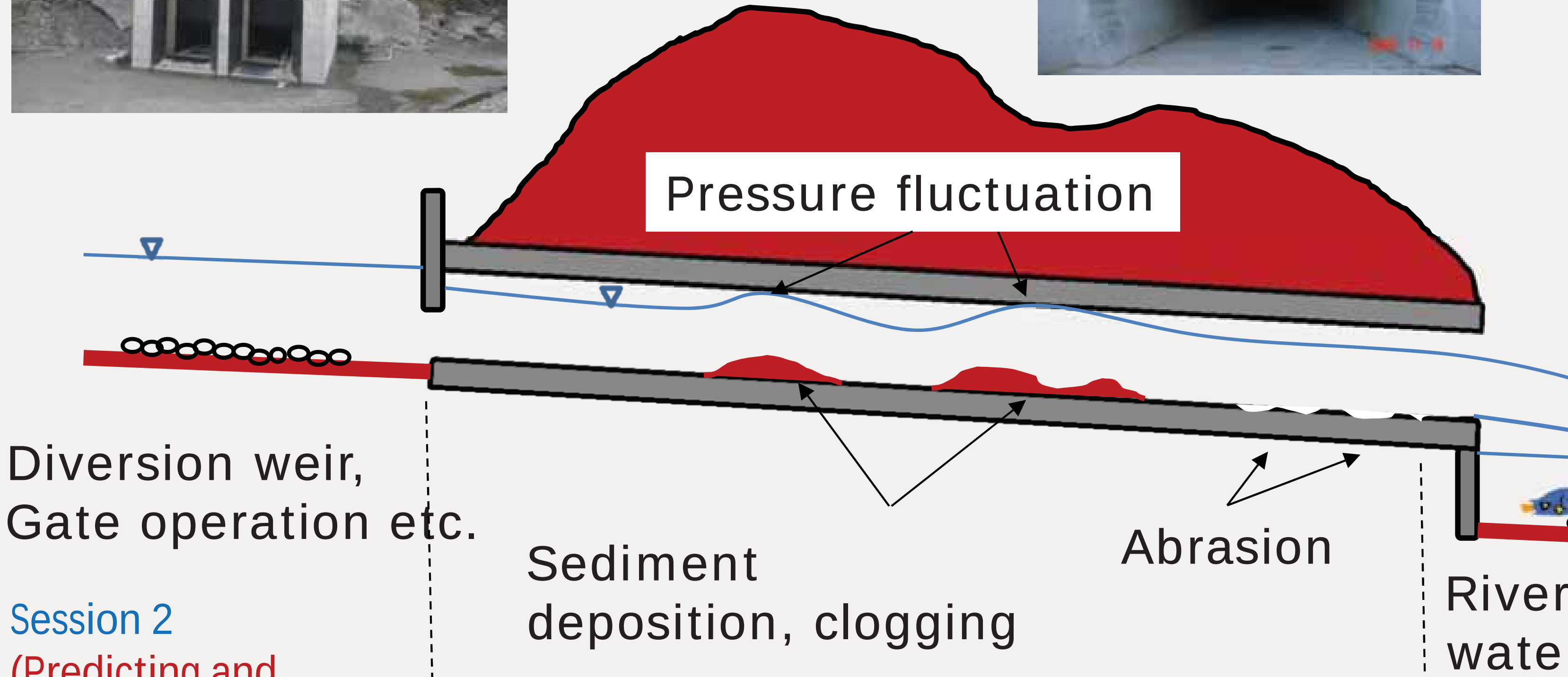
Nagano Prefecture

Closing Remarks

Tetsuya SUMI
Disaster Prevention Research Institute, Kyoto University

Challenging issues on SBTs

Session 1
(SBTs in the world)



Session 2
(Predicting and controlling sediment in upstream river and reservoirs)

Session 3 (Tunnel - hydraulics, invert abrasion)

Session 4 (Bed load monitoring)

Session 5 (Downstream aspects - morphological and ecological effects)

Session 6 (Operation/ EIA)

Upstream | Tunnel | Downstream

WS Key Findings (1)

- Three SBTs have been installed in Kobe more than 100 years ago for sediment passage and clear water storage.
- Sediment bypass system is containing both tunnel and open channel. (Indonesia)
- Suspended high concentration fine sediment can be vented and diverted by sluicing tunnels. (Taiwan)
- Several methodologies to increase the tunnel performance are introduced.
  - Combination with rainfall-runoff prediction (Asahi)
  - Sediment excavation and placing up/downstream SBTs during non-flooding time (Miwa, Shihmen)
- High velocity flow, sediment transport and abrasion models have been updated and calibrated by field data.
- Tunnel curvature and abrasion effects have been discussed by model and field data.

WS Key Findings (2)

- **Several bed load monitoring systems have revealed spatio-temporal sediment transport variation which will be useful to understand the abrasion mechanism and propose countermeasures.**
- **We should discuss which sensor will be suitable based on target grain size, sediment transport rate as well as target velocity.**
- **Positive effects of SBTs can be evaluated by sediment budget, downstream riverbed changes and aquatic lives such as invertebrates.**
- **Various new methodologies are very much welcome such as Metabarcording approach in order to evaluate environmental effects.**
- **New SBTs are now in monitoring stages which will show good performances and the monitoring guidelines should be prepared soon. (Solis, Koshibu, Matsukawa)**

Key questions: How to find suitable existing dams for SBTs?
How to apply SBT for new dams? (Sambor dam in the Mekong River)

(Key message by Prof. G. Annandale)

History of SBT in Japan and Switzerland

Japan

Tachigahata Dam(1905)
Nunobiki Dam(1908)
Muko-no-ike(1916)

Asahi(1998)
Miwa(2005)
Koshibu(2016)
Matsukawa(2016)

Switzerland

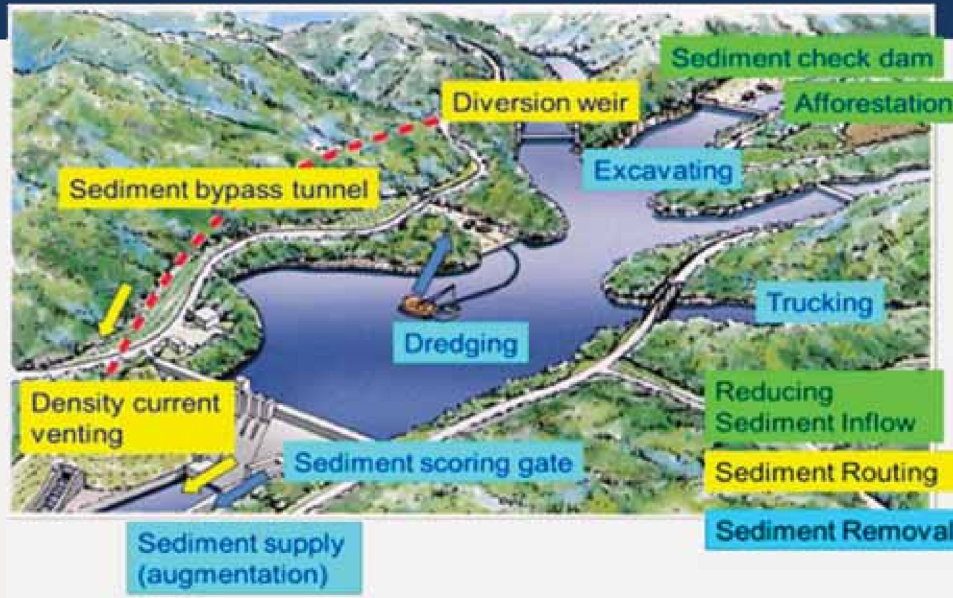
Pfaffensprung(1922)

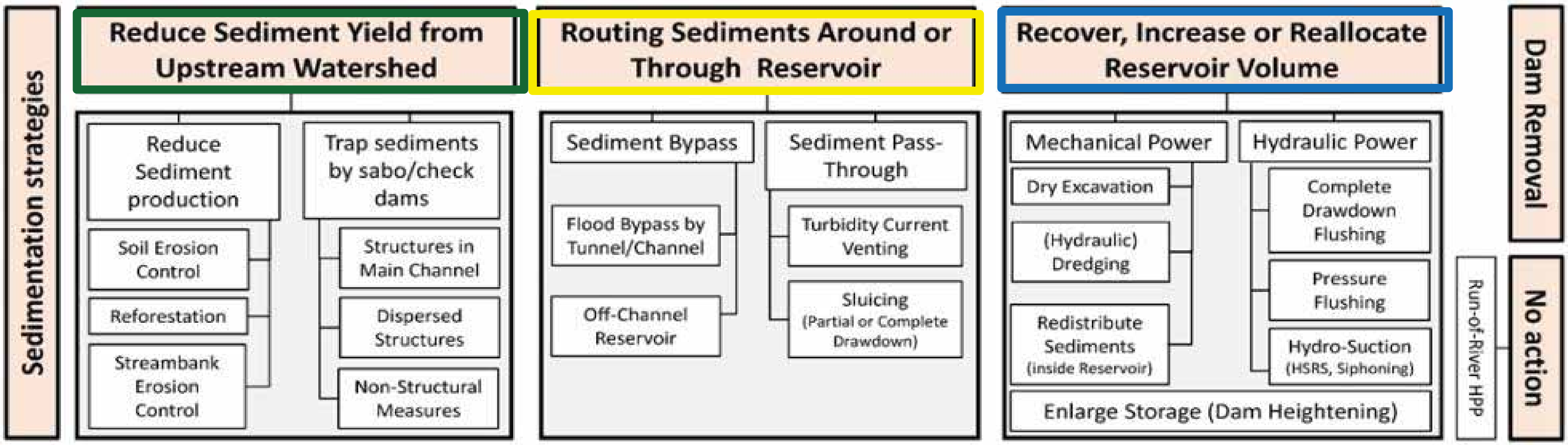
Runcahez(1962)
Egshi(1976)
Palagnedra(1977)

Rempen(1986)
Solis(2012)

Classification of sediment management strategies (ICOLD Technical Committee)

Sediment management to minimize aggradation in reservoirs is achieved with a variety of techniques categorized in three main strategies (ICOLD 1989, 1999, 2009, Morris & Fan 1998, Kantoush & Sumi 2010, Annandale 2011, 2013, Kondolf et al. 2014, Auel et al. 2016).

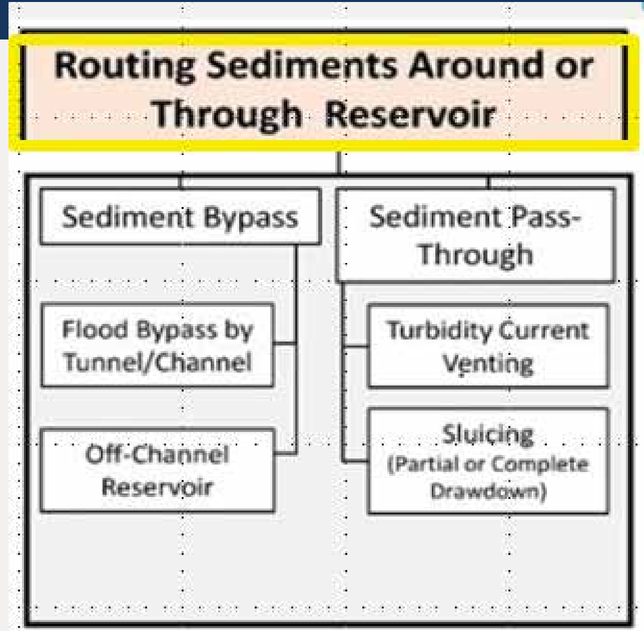


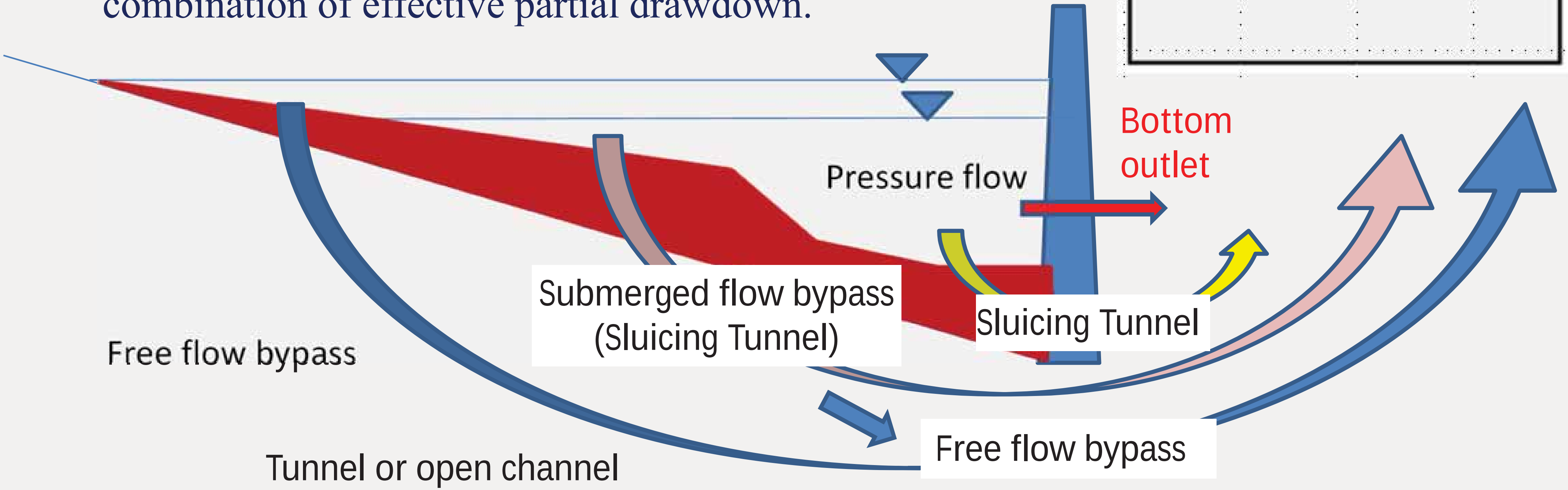


Auel et al. 2016

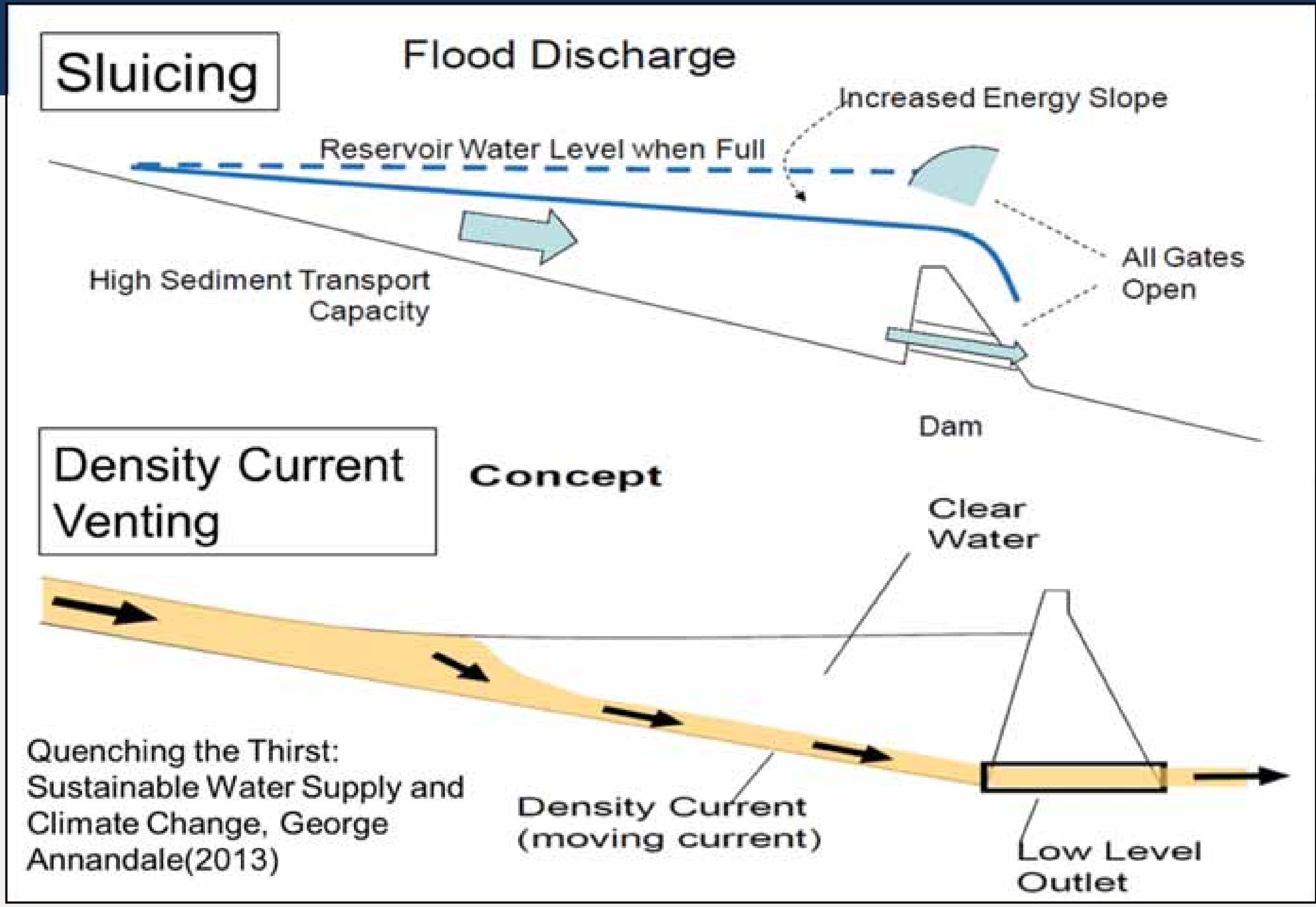
Classification of SBT related upstream reservoir water revel and sediment inflow

- Inflow maximum sediment grain size is critically defined by upstream velocity and tractive force.
- From deep reservoir, only fine sediment will be transported even in case of density current venting.
- From upstream, both coarse and fine sediment can be guided to the SBT.
- From middle reach of reservoirs, normally only fine sediment but coarse sediment can be transported with combination of effective partial drawdown.





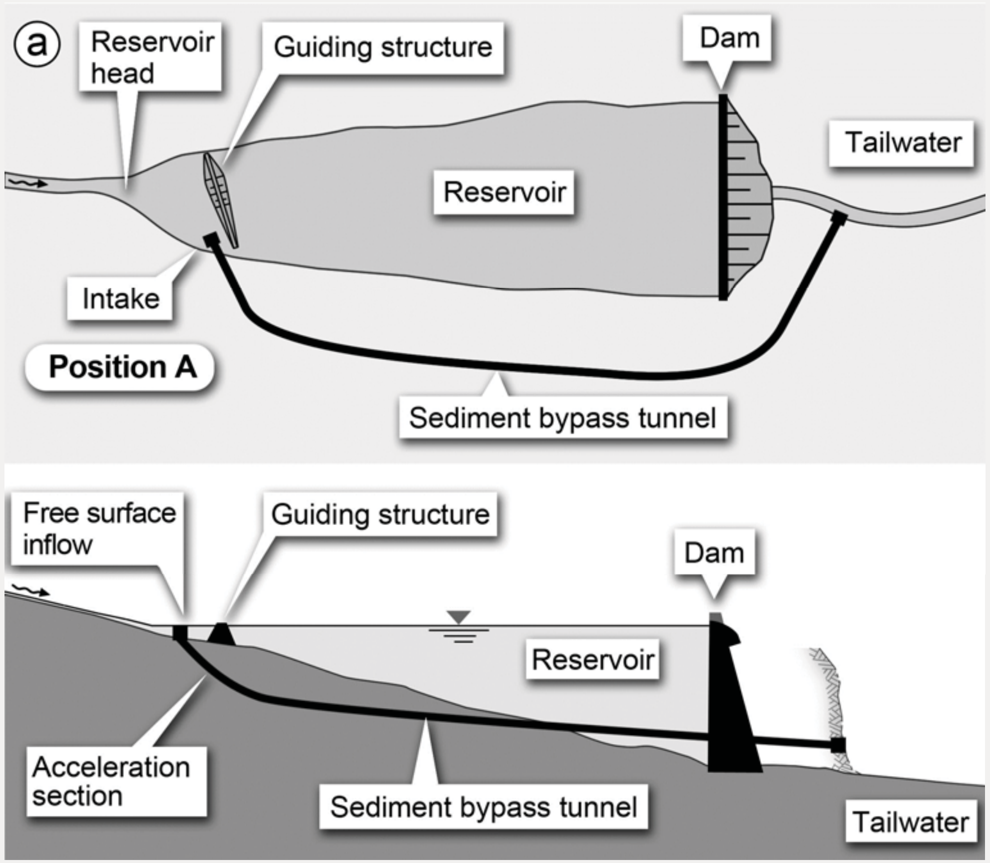
Sluicing and Density Current Venting



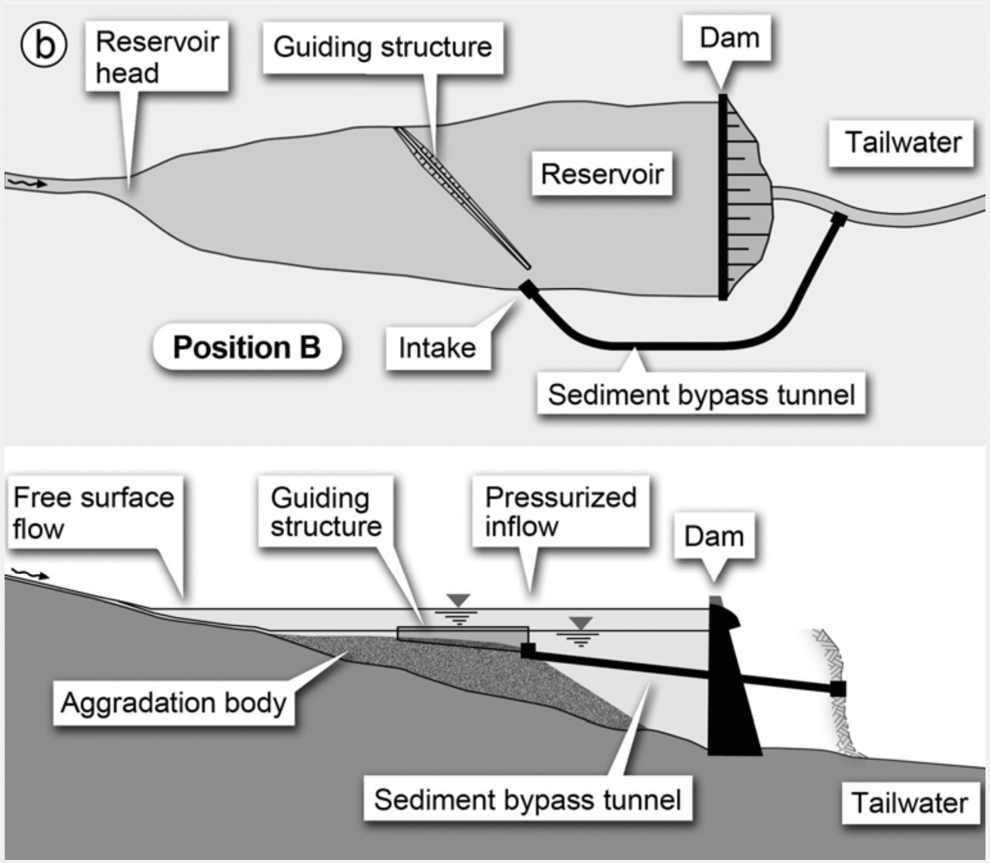
- **Sluicing requires a partial water level drawdown to transport incoming and to some extent accumulated sediments to the dam outlet structure, whereas venting of turbidity density currents can be performed without lowering.**
- **Sluicing includes both bedload and suspended sediment, whereas venting is only possible for the latter.**

Two styles of Sediment bypass tunnels

Position A: Reservoir head



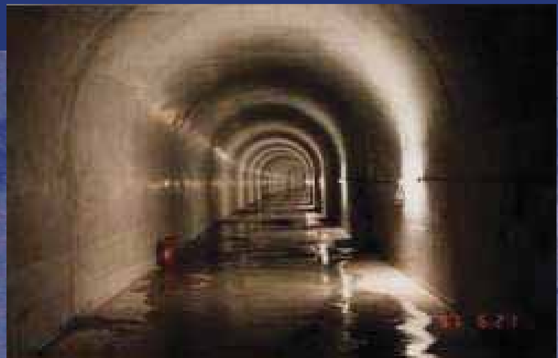
Position B: Downstream of reservoir head



Source: Auel & Boes (2011)

Sediment bypass system at Asahi Dam

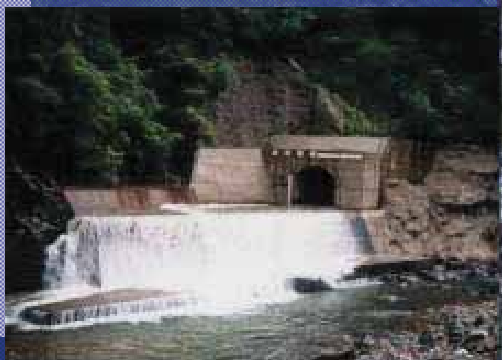
Bypass tunnel
Gradient : 1/34
Height : 3.8m
Width : 3.8m



Weir
Height : 13.5 m
Crest Length : 45 m

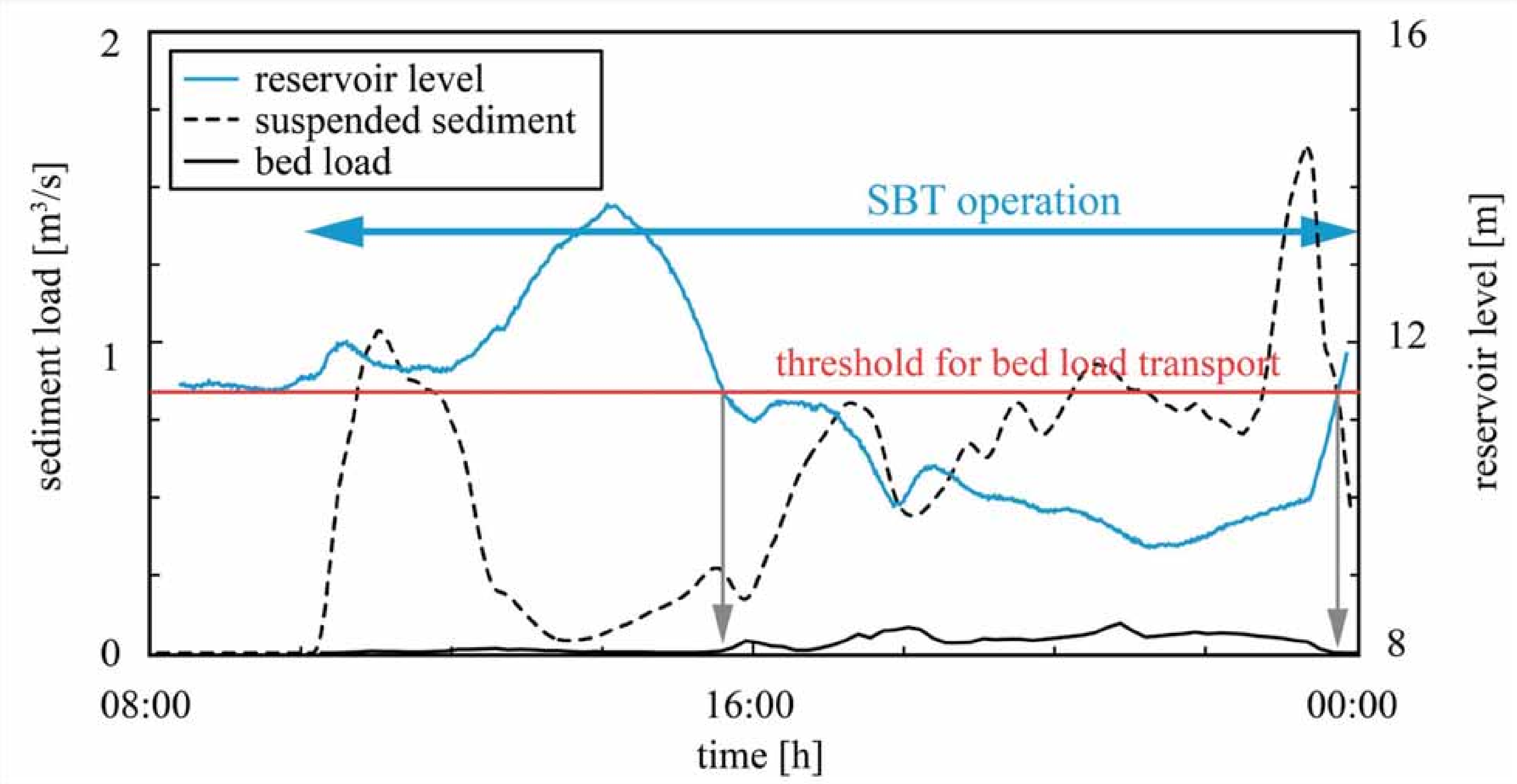
Length : 2,350m
Max. discharge : 140m^3/s

Outlet



SBT Solis: Experiences

Sediment transport is sensitive to reservoir level



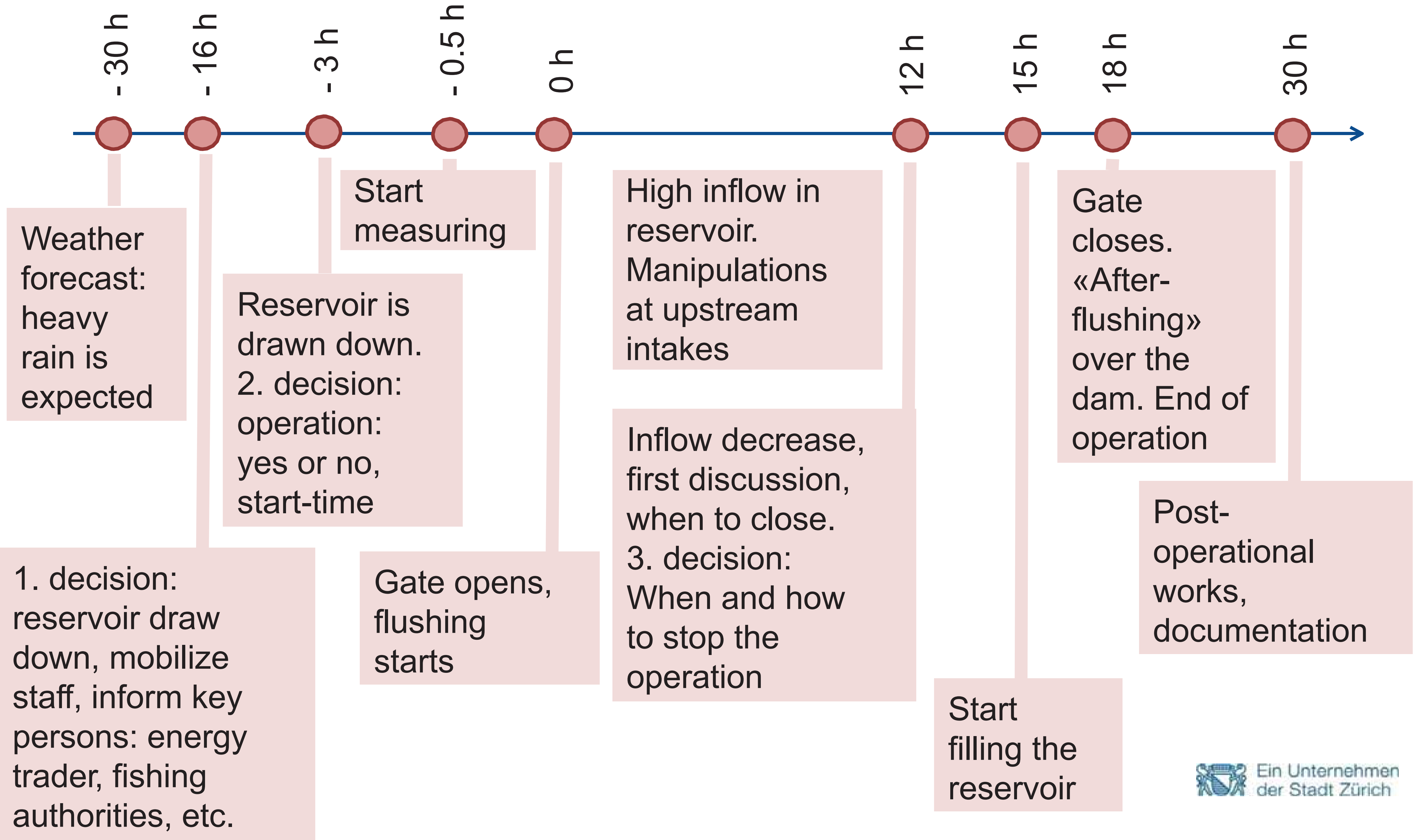
Abrasion model

- **Ishibashi model (full set)**
  - Over estimate of abrasion volume and estimating too much maintenance costs
  - Drawback for SBT
- **Ishibashi model (saltation part only) and Auel model**
  - More data for calibration
  - It is required to optimize project cost and hopefully increase feasibility of SBTs

Future topics

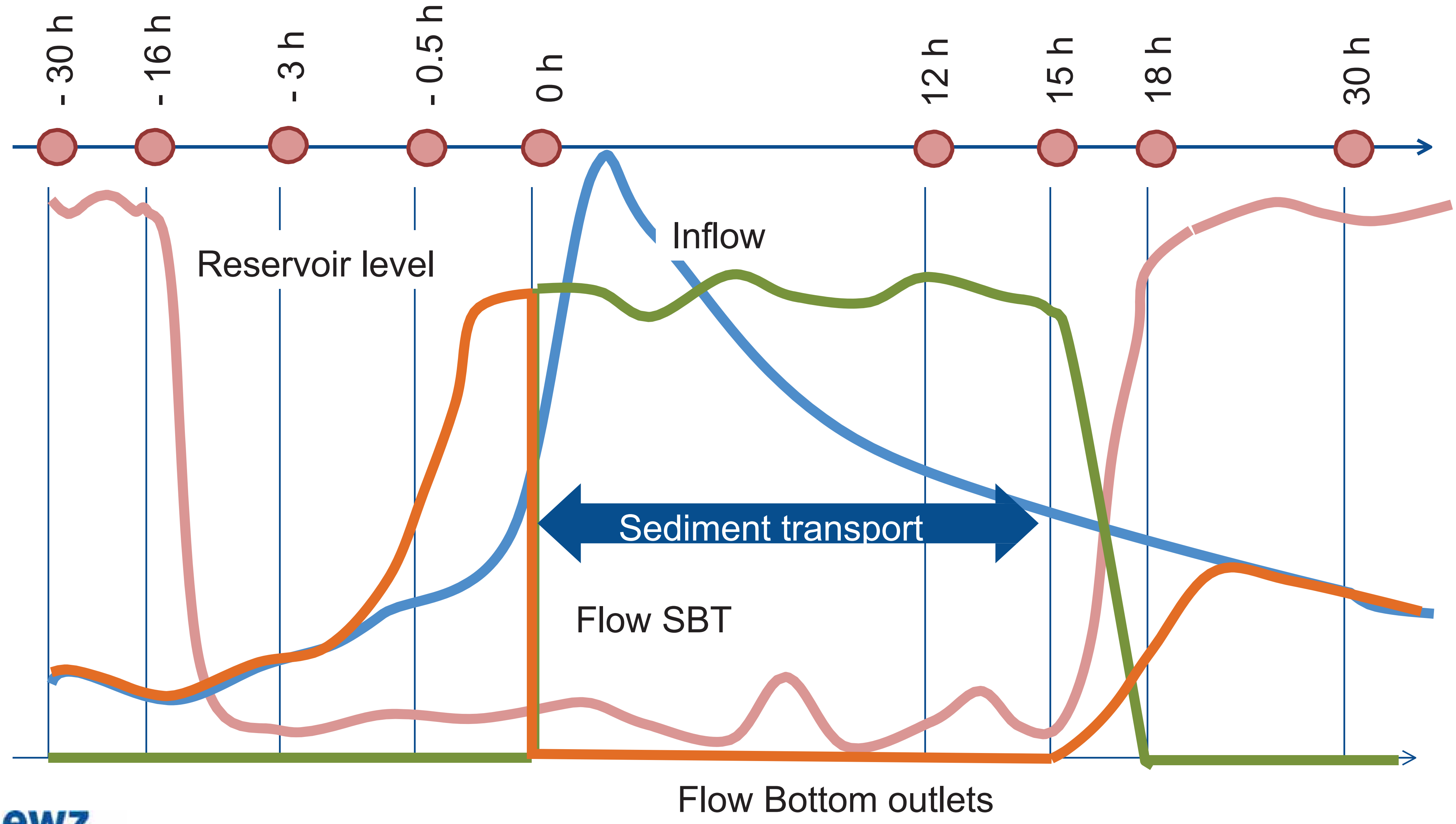
- **Collaboration with hydrological prediction of rainfall-runoff and sediment inflow**
  - **Optimize bypass operation with suitable gate operation**
  - **Solve conflict between water storage recovery for water user's interest and bypassing high sediment-laden flow for minimizing sediment inflow to the main reservoir**
- **Combination with upstream and downstream dams, and other methodologies in order to increase bypass efficiency**
  - **Additional water supply from upstream dams and/or local draw down flushing**
  - **Combination with sediment replenishment upstream/downstream SBT and trucking etc.**
- **Economic evaluation of SBT projects**
  - **How to select suitable long-term discounting rate**
  - **How to estimate value of existing structures and value of extending their lives**

SBT Solis. Operation 1/2

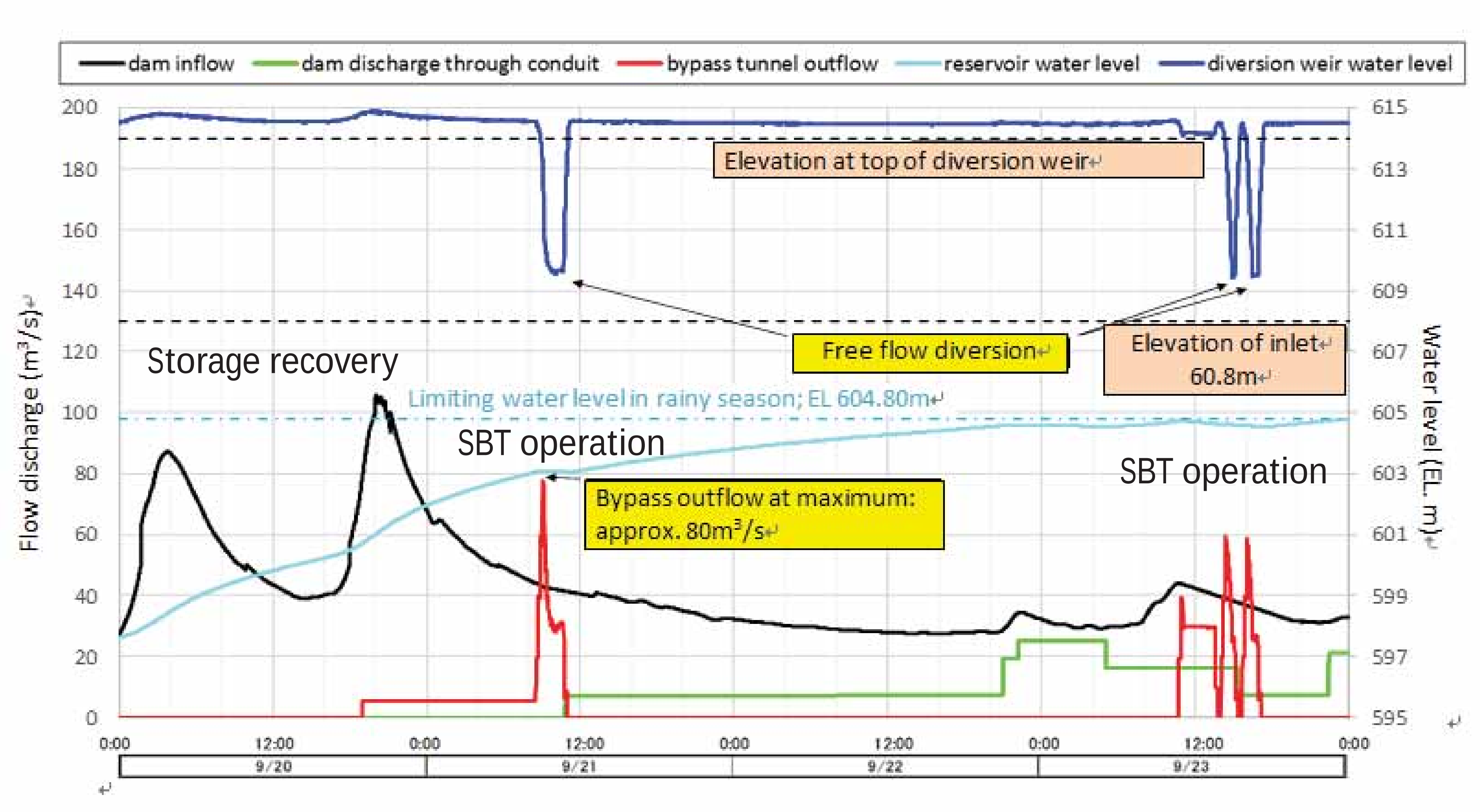


Ein Unternehmen der Stadt Zürich

SBT Solis.
Operation 2/2



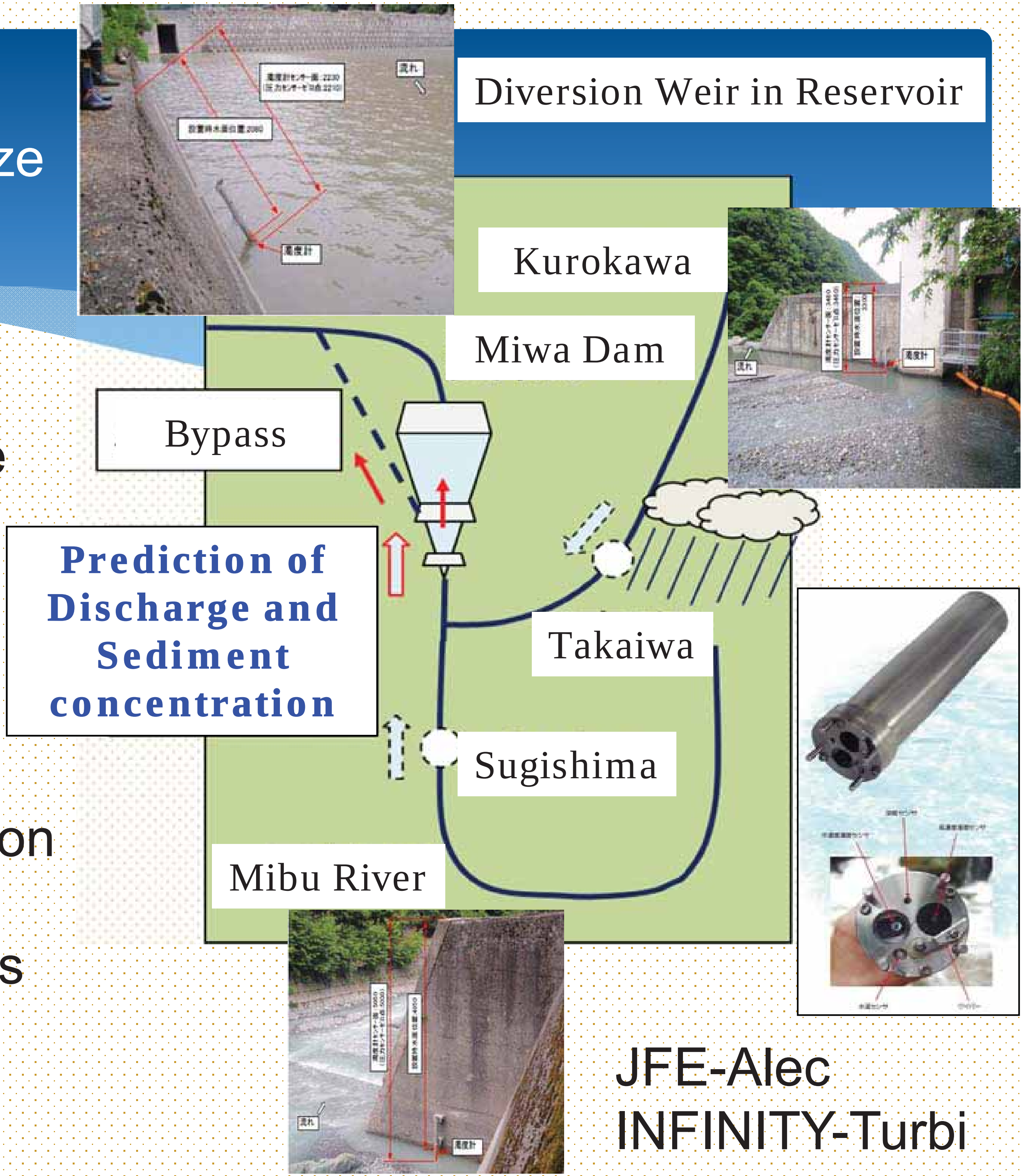
Operation record of Koshibu SBT, Sep.20-23, 2016



How to utilize upstream hydrological data to optimize bypass operation

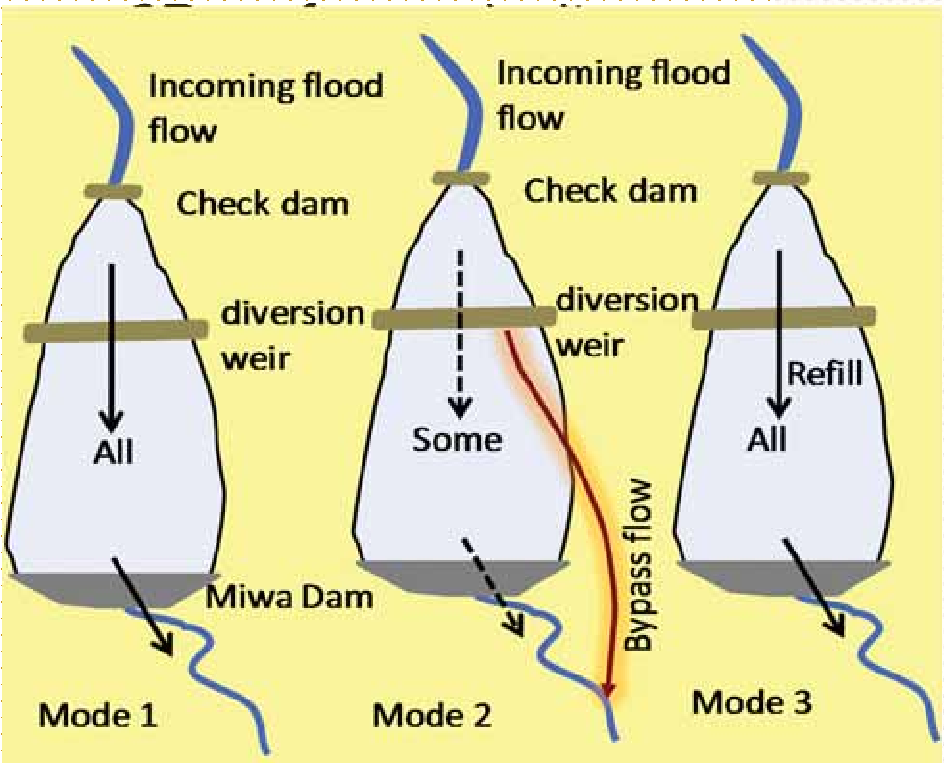
- Rainfall and turbidity are monitored by real-time basis to predict inflow discharge and sediment concentrations

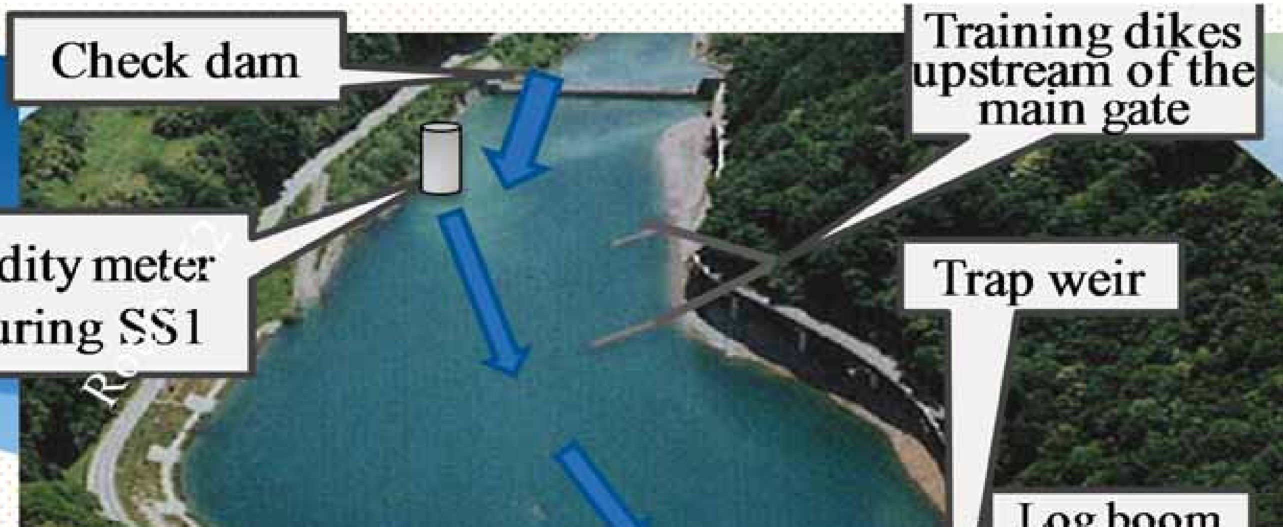
- Effective bypass operation by using sediment concentration predictions

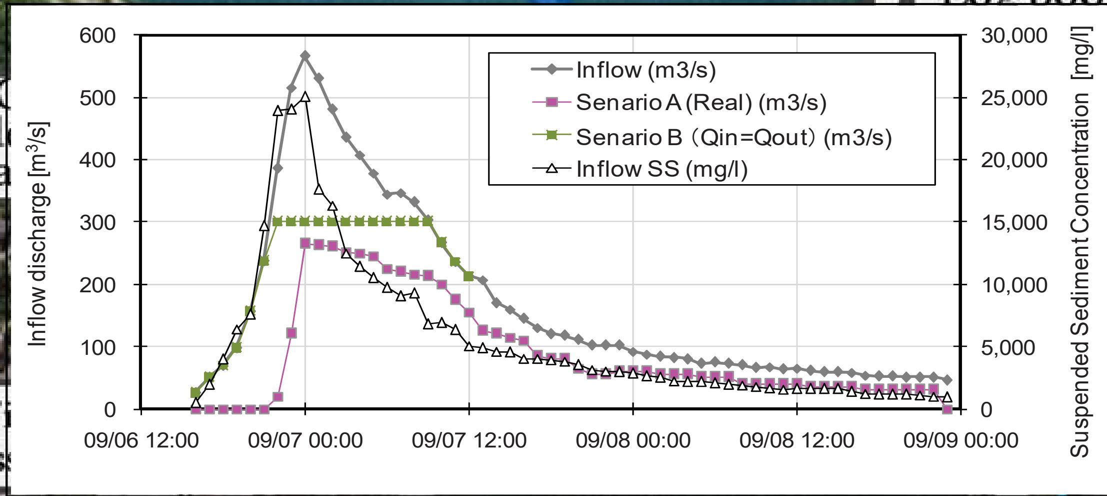


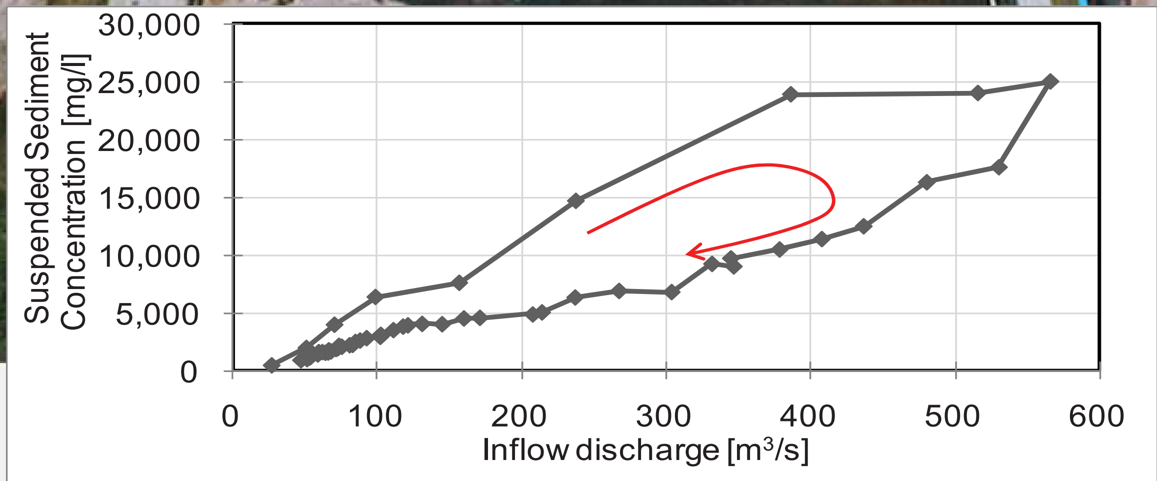
How to effectively divert suspended sediment and high turbid flow through the tunnel

Turbid flow monitoring









Upgrading dams under operation

Technologies to upgrade dams under operation

1. Technologies to increase reservoir volume (P3)
- 1-1 Raising the dam body
- 1-2 Constructing a new dam just downstream from the operating dam without stream diversion
- 1-3 Under water structural engineering work to construct in deep reservoir

2. Technologies to increase discharge capacity (P5)
- 2-1 Constructing additional crest gates
- 2-2 Drilling the existing dam body from downstream
- 2-3 Constructing new spillways
- 2-4 Upgrading existing spillways

3. Technologies to improve structural stability (P7)
- 3-1 Improving an existing dam's structural stability to resist earthquakes damage
- 3-2 Controlling seepage through dam bodies and/or their foundations
- 3-3 Improving structural stability of downstream
- 3-4 Inspecting structural stability to resist catastrophic earthquakes

4. Technologies to improve operation (P9)
- 4-1 Maximizing its functions through coordination with several other dams
- 4-2 Implementing flexible operation well timed with the flood discharge
- 4-3 Converting to a new system while continuing operation
- 4-4 Constructing or upgrading power plants

5. Technologies to control sediment (P11)
- 5-1 Controlling sediment by bypass tunnels
- 5-2 Excavating and transporting sediment
- 5-3 Constructing a check dam to control sediment
- 5-4 Combining several sediment removal methods

6. Technologies to improve environments (P13)
- 6-1 Adopting selective water intake facilities
- 6-2 Bypassing fresh water directly from the upstream to the downstream river
- 6-3 Adding new aerators
- 6-4 Adding facilities such as fish ways to conserve the ecosystem

Source: MLIT

Other SBTs : Sediment Coveying Tunnels

Amahata Dam
(Conveying tunnel)

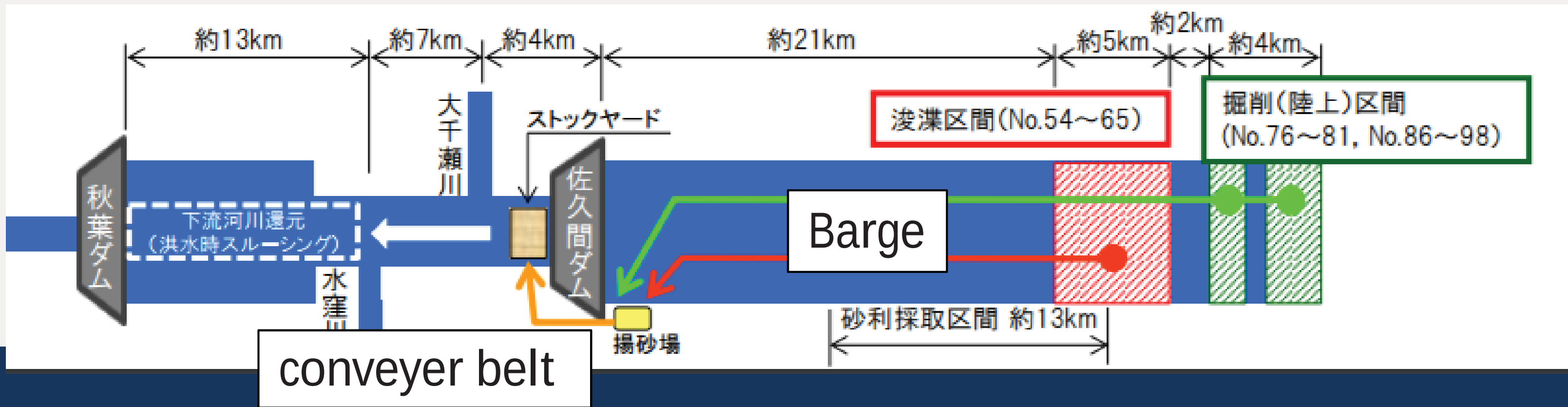
Nagayasuguchi dam (MLIT)

(Two conveyer belts will transport excavated sediment from one tributary to downstream)

Sediment Replenishment

Sakuma dam (J-Power/MLIT)

(Barge and conveyer belt will transport excavated/dredged sediment from reservoir to downstream)



RESERVOIR SEDIMENTATION AND SUSTAINABLE DEVELOPMENT (堆砂対策と持続可能な開発)

26th Congress & 86th Annual Meeting, 1-7 July 2018, Vienna (Austria)
Question 100 is now call for papers.

1. **Best practice of storage design including sediment release structures, reservoir operation and sedimentation management techniques including dredging, sediment removal and debris removal.**
   堆砂を下流に流す設備、貯水池操作、及び、浚渫、堆砂並びに残滓除去を含む堆砂管理技術等の最適な貯水池運用手法
2. **Sediment replenishment techniques downstream of dams for river regime and morphology restoration.**
   河川の流況及び生態系保全のためのダム下流への土砂供給技術
3. **Experiences with turbidity current discharge by bottom outlets and the performance of sediment bypass tunnels.**
   底部放流管からの濁水の放流経験と排砂バイパスの実績
4. **Effect of climate change on reservoir sedimentation and consequences on sustainable storage use.**
   気候変動が堆砂と持続可能な貯水池使用に与える影響

ICOLD New TC on Reservoir Sedimentation

- **Suitable application environment (necessary inflow yield, reservoir size, CAP/MAR-CAP/MAS ratio)**
  - **CAP: Reservoir capacity, MAR: Mean annual runoff volume, MAS: Mean annual sediment inflow**
- **Typical SBT dimensions and hydraulic conditions**
- **Sediment grain target size**
- **SBT construction (incl. guiding structure, intake, tunnel, outlet)**
- **Invert lining (abrasion-resistant materials: high-performance concrete, steel, cast basalt, granite, Epoxy resin mortar)**
- **Invert abrasion estimation and periodical maintenance works**
- **Ecological impacts (sediment connectivity, downstream morphological and ecological effects)**
- **Case studies (Switzerland, Japan, Taiwan, ...)**

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Dr. George W. Annandale

Principal, George W. Annandale, Inc.

Dr. Annandale is a civil engineer with 42 years of experience specializing in water resources engineering. He is an expert in reservoir sedimentation management and is known for his expertise in scour of rock.

Title of keynote lecture: *Raising a Child and the Zen of Sediment Management*

Dr. Chien-Hsin Lai

Director-General, Water Resources Agency, Director of Water Resources Agency, Ministry of Economic Affair, Taiwan (R.O.C.)

Dr. Chien-Hsin Lai was appointed as the Director-General of Water Resources Agency (WRA), Ministry of Economic Affairs since November 2016. Prior to that, he was the Deputy Director-General and the Chief Secretary of WRA, and the Director of Southern Region Water Resources Office. He was in charge of many important projects, including the emergency response plan for Cao Ling landslide dammed lake during Chi-Chi Earthquake, the trans-watershed diversion project of and sediment sluicing tunnel project of Tseng Wen Reservoir. WRA awarded him the Outstanding Senior Award in 2006, and the Executive Yuan awarded him the Model Civil Servant Award in 2007.

Title of keynote lecture: *Hydraulic Desilting of Reservoir in Taiwan*

George W. Annandale

Chien-Hsin Lai

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  - Dr. Sohei Kobayashi, Proceedings
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  - Mrs. Junko Ibaraki, Finance & Accommodation

  - Water Resources Environment Center , Proceedings
  - Chubu Regional Management Bureau, MLIT, Study tour
  - Nagano Pref. Government, Study tour
  - Kansai Electric Power Company, Welcome Reception

  - Mrs. Chizuko Muranaka, Interpretor

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